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The Science ELF: Assessing the enquiry levels framework as a heuristic for professional development

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This study utilized an explanatory sequential mixed methods approach to explore randomly assigned treatment and control participants' frequency of inquiry instruction in secondary science classrooms. Eleven treatment participants received professional development (PD) that emphasized a structured approach to inquiry instruction, while 10 control participants received no PD. Two representative treatment participants were interviewed and observed to provide an in-depth understanding of inquiry instruction and factors affecting implementation. Paired *t*-tests were used to analyze quantitative data from observation forms, and a constant comparative approach was used to analyze qualitative data from surveys, interviews, purposeful observations and artifacts. Results indicated that treatment participants implemented inquiry significantly more frequently than control participants ($p < .01$). Two treatment participants' instruction revealed that both used a similar structure of inquiry but employed different types of interactions and emphasized different scientific practices. These differences may be explained by the participants' understandings of and beliefs about inquiry and structuring inquiry. The present study has the potential to inform how methods of structuring inquiry instruction and teaching scientific practices are addressed in teacher preparation.

Keywords: *Professional development; Mixed methods; Inquiry-based teaching; Secondary school*

Since the development of the 1996 National Science Education Standards, research on inquiry has drastically increased (Yeh, Jen, & Hsu, 2012). Literature reviews on

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the topic of inquiry indicate varied student outcomes in science classrooms (e.g. Minner, Levy, & Century, 2010), and the teacher is one factor that may explain the diverse results in inquiry-based instruction. Barriers can limit inquiry implementation (e.g. Anderson, 2002), and inquiry can also seem confusing and overwhelming for new teachers which can impede their use of inquiry in the classroom (e.g. Wee, Shepardson, Fast, & Harbor, 2007). Inquiry-based professional development (PD) programs have been developed to help support secondary teachers' implementation of inquiry in the science classroom (e.g. Luft, 2001). The present study explores a PD program for first- and second-year secondary science teachers which focused on one method of structuring inquiry, called the Enquiry Levels Framework (ELF).

Inquiry and Scientific Practices

According to Schwab (1962), 'enquiry' is the 'construction of scientific knowledge by the interpretation of data through the use of conceptual principles' (p. 29). Scientific knowledge gained through the process of inquiry is constructed from the interpretation of observations, and these interpretations are based on prior knowledge. Furthermore, scientific knowledge is continually revised based upon new technologies and interpretations. However, Schwab argues that traditional K-12 science curricula fail to align with the enquiry process, leaving students with 'a nearly unmitigated *rhetoric of conclusions* in which the current and temporary constructions of scientific knowledge are conveyed as empirical, literal, and irrevocable truths' (Schwab, 1962, p. 24). Schwab (1962) suggests students learn *how* scientific knowledge is constructed and the difficulty of gathering and interpreting data by experiencing the enquiry process within the laboratory setting.

This conceptual understanding of enquiry in science education has been further elaborated on by the National Research Council (NRC) (2000), which characterizes inquiry according to five characteristics: learners are engaged in scientifically oriented questions, learners give priority to evidence, learners formulate explanations from evidence, learners evaluate their explanations, and learners communicate and justify their personal explanations (p. 26). The majority of inquiry-based studies utilize these features to define inquiry (e.g. Lotter, Harwood, & Bonner, 2006). However, it is unclear whether an inquiry-based activity must include all or some of these classroom characteristics. In an attempt to simplify inquiry for teachers, Bell, Smetana, & Binns (2005) argued that the essence of inquiry involves answering a scientific question through the analysis of data. To better align with the National Research Council's *Framework for K-12 Science Education* (NRC, 2012), the PD in this study defined inquiry as 'asking questions, collecting and analyzing data, and using evidence to solve problems' (Bell, Maeng, Binns, 2013; Maeng & Bell, 2012, p. 3). This streamlined definition provides students the opportunity to experience 'enquiry' (e.g. the construction of scientific knowledge by the interpretation of data), while providing a straightforward way for teachers to assess whether they are including inquiry in their own instruction.

The present investigation used scientific practices as an overarching framework to characterize teachers' inquiry-based practice in the present investigation (NRC, 2012). Scientific practices, a common set of characteristics incorporating students' use of both knowledge and skills in scientific investigations, may be incorporated into inquiry-based activities or non-inquiry-based activities. They are described in the Next Generation Science Standards (NGSS) as students engaging in (1) asking questions, (2) developing and using models, (3) planning and carrying out investigations, (4) analyzing and interpreting data, (5) using mathematics and computational thinking, (6) constructing explanations, (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating results (NRC, 2012, p. 42).

The purpose of emphasizing scientific practices in instruction is for students to emulate what scientists do in practice. The five features of inquiry and the simplified definition of inquiry align with the majority of the scientific practices (Table 1). All three indicate that students should engage in answering scientific questions through the use of evidence. The 'analysis of data' emphasized in the simplified definition of inquiry encompasses multiple scientific practices including mathematical and computational thinking and constructing explanations. Additional scientific practices include developing and using models, and obtaining, evaluating, and communicating results. Essentially, the simplified definition of inquiry provides the foundation on which scaffolding of more sophisticated scientific practices can be built. Using scientific practices to characterize and understand teachers' implementation of inquiry may help provide insight into scientific practices teachers already incorporate into inquiry-

Table 1. Comparison of scientific practices to enquiry characteristics

NGSS scientific practices[a]	NSGS features of enquiry[b]	Simplified definition of enquiry[c]
Asking questions	Engaged in scientifically oriented questions	Asking questions
Developing and using models		
Planning and carrying out investigations		Collecting data
Analyzing and interpreting data		Analyzing data
Using mathematics and computational thinking		Analyzing data
Constructing explanations	Formulate explanations from evidence	Analyzing data
Engaging in argument from evidence	Give priority to evidence	Using evidence to solve problems
Obtaining, evaluating, and communicating results	Evaluate explanations Communicate and justify their personal explanations	

[a]NRC (2012).

[b]NRC (2000).

[c]Bell et al. (2013), Maeng & Bell (2012).

based instruction. Furthermore, using scientific practices to analyze inquiry instruction may reveal practices that should be further emphasized in PD for inquiry instruction.

Factors Affecting Inquiry Implementation

A substantial body of research explores the teacher's essential role in helping students engage in scientific practices during inquiry-based activities. One of the most important factors influencing practice is teachers' conceptions about inquiry (e.g. Wallace & Kang, 2004). According to Mansour (2009), conceptions encompass both teacher beliefs and teacher understandings, which cannot be assessed independently of each other. Teachers' understanding of inquiry constitutes their operational definition of inquiry and their perception of what inquiry looks like in the classroom, while teachers' beliefs can be defined as 'their epistemological commitments to how a content domain should be taught' (Harwood, Hansen, & Lotter, 2006, p. 70). Thus, their beliefs about inquiry would be their epistemological commitments about how inquiry should be used to teach a content domain. As an example, a teacher may discuss inquiry as having students collect data in a laboratory and having a whole-group discussion about analyzing the data to draw conclusions, which would be their *understanding* of inquiry. Further probing the teacher's decision for why they used a whole-group discussion may reveal the teacher's *beliefs* about structuring students' inquiry experiences. Together, teacher beliefs and understandings constitute their conceptions of inquiry, which is the construct addressed in this study.

In addition to defining and characterizing inquiry, there are also many ways teachers can structure inquiry-based activities in the science classroom. As a result, researchers debate what approach is the most effective for implementing inquiry in the classroom (e.g. Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006). The lack of a consensus of what constitutes inquiry and how to structure inquiry in the classroom results in ambiguity about inquiry (Anderson, 2002).

One method to help support teachers' implementation of inquiry in the secondary science classroom is PD. A large number of PD studies provide secondary science teachers an approach to structure inquiry in their classroom such as a six-step model of inquiry (Blanchard, Southerland, & Granger, 2008), an extended inquiry cycle (Luft, 2001), the 5E model (Van Hook, Huziak-Clark, Nurnberger-Haag, & Ballone-Duran, 2009), the continuum of inquiry (Wee et al., 2007), and a predict, observe, and explain model (Rushton, Lotter, & Singer, 2011). Overall, these studies indicate that inquiry-based PD can support teachers' effective implementation of inquiry in the secondary science classroom. However, a variety of factors influence the frequency and quality of inquiry instruction including teacher understanding, teacher beliefs, and external support. Teachers appear to also need a practical and straightforward approach to structure inquiry.

Enquiry Levels Framework

One method of structuring inquiry that has not been investigated in-depth is inquiry levels. These levels were originally developed as a conceptual model for supporting students in practices similar to that of scientists (Herron, 1971; Schwab, 1962). According to Schwab (1962), enquiry investigations should always precede instruction on a given topic. At level 1, students are provided the research question and the methods, but they do not know the answer or principle ahead of time. A level 2 enquiry activity is characterized by providing the research question but no methods for answering the question. Level 3 is the least structured, in which students are 'confronted with the raw phenomenon' and develop both the question and the method (Schwab, 1962, p. 55). Herron (1971) further developed these levels of enquiry into a tool for evaluating activities. He also added a level 0 to describe a non-enquiry activity in which students are provided the question, methods, and one clear solution (Herron, 1971).

A more recent modification to these levels relies on Schwab's original conceptual framework of classroom enquiry as a practical tool for teachers to structure inquiry activities (Cothran, Geiss, & Rezba, 2000; Bell et al., 2005). In this version of inquiry levels, a level 0 activity would be considered inquiry if students are analyzing data to answer a research question as confirmation of a previously learned topic. This characterization contrasts with Schwab's original definition of enquiry, which suggests that having enquiry follow instruction only gives the appearance, not the reality, of enquiry (Schwab, 1962, p. 55). However, the history of science provides many examples of scientists engaging in inquiry to confirm (or not) each other's works (Collins & Pinch, 1998), with the 'discovery' of cold fusion being one such example. Furthermore, confirmation investigations provide an initial step in scaffolding activities for students to engage in more sophisticated scientific practices. Thus, the framework used in the present work includes four levels of inquiry, starting with confirmation as level 1 (Bell et al., 2005).

The four levels, called the ELF, correspond to Herron's levels 0–3 and remain characterized by whether students are provided the question, methods, and solution for an activity. *Confirmatory* inquiry (level 1) typically comes after the content is taught, and students analyze data to *confirm* a general principle with a specific application/prediction. Placing a confirmatory activity before content-oriented instruction results in a *structured* inquiry activity (level 2) because students do not know the answer prior to conducting the investigation. In confirmatory and structured inquiry students are provided a procedure; however, it is important to note that not all procedural investigations constitute inquiry. A key feature of the simplified definition of inquiry is that students are analyzing data and using evidence to solve a problem (Bell et al., 2013; Maeng & Bell, 2012). If students merely follow steps and collect data without substantive analysis, it is not considered inquiry. A *guided* inquiry activity (level 3) provides students with a specific question, but students develop the methods/procedure for answering the question. *Open* inquiry (level 4) places the most responsibility on students. Students develop their own question and procedures, and they do not know what results to expect in the investigation. The specific levels of inquiry investigated in this study align with these four levels of structuring inquiry.

One benefit to ELF is the ability for science teachers to incorporate these levels in a variety of content and contexts, providing practical use for the classroom (e.g. Kluger-Bell, 1999; Wheeler & Bell, 2012). Only one research study directly identified and examined the teacher's role in implementing inquiry levels (Blanchard et al., 2010). The researchers compared the effect of guided inquiry versus verification laboratories on secondary students' understanding. These results imply that the teacher plays an important role in effectively implementing inquiry in the classroom. Furthermore, ineffective implementation of guided inquiry may negatively affect student understanding.

Social Constructivism

A social constructivism framework guided this study. Two main assumptions provide the foundation for social constructivism: (a) knowledge is constructed by people who are active participants in the process and (b) social interactions within an individual or between individuals play an important role in constructing knowledge (Ferguson, 2007). As new knowledge is gained, it can be tested and modified based on new experiences.

The PD program that provided the context for the present study, described in detail later in the article, uses a Learn, Try, Implement with Feedback and Research model of PD (Sterling & Frazier, 2010). In this model, participants are provided the opportunity to *learn* about reforms-based instructional methods, *try* the method during the PD, and *implement* these practices in their own classroom instruction. Each participant receives *feedback* from the implementers during the PD and feedback from coaches during classroom implementation. Participants are also encouraged and supported in conducting *research* on students' learning in their classroom. This model of PD aligns with a social constructivist framework as participants are actively engaged in learning how to implement best practices in the science classroom. Through the feedback process, participants are interacting with veteran teachers and experts in science education to help modify their understanding of best practices.

Purpose

Despite the research on the teacher beliefs, understandings, and practices of inquiry following PD, two main limitations are present in this body of literature. First, to our knowledge, no research explores teacher conceptions and practice of ELF following PD. Second, while it is reasonable to conclude that the PD programs in each study described earlier influenced teachers' conceptions and practice, there is no indication whether these teachers' conceptions and practices would have changed without PD. This necessitates a study to compare secondary teachers' practice of inquiry with and without PD. Therefore, the purpose of this experimental study was twofold. We wanted to determine the extent to which secondary science teachers who received the PD implemented inquiry and inquiry levels when compared to control group teachers. ELF has the potential to provide teachers a straightforward and easy-to-use method of structuring inquiry, and we hypothesize that using ELF as a heuristic for PD will facilitate teachers' implementation of inquiry instruction. We also wanted to characterize two treatment teachers' implementation of ELF and the factors influencing their implementation. Three research questions guided the investigation:

(1) Do teachers in the PD implement inquiry and ELF more frequently than teachers in the control group?
(2) How do two secondary science teachers in the PD integrate inquiry and ELF into instruction for their students?
(3) What patterns exist between two teachers' conceptions (i.e. understandings and beliefs) about inquiry and their classroom implementation of inquiry and ELF following the PD?

Methodology

Explanatory sequential design (Hesse-Biber, 2010) within an interpretive paradigm (Erickson, 1986) served as the methodological approach for the study. In this approach, the quantitative data collected provided an overview of secondary treatment and control teachers, and the qualitative data helped explain or contradict the quantitative results. Quantitative methods were used to assess outcomes to determine how successful the PD program was in changing participants' inquiry practice. Social constructivism informed the qualitative methods of the study. The researchers' focus during classroom observations included students' active involvement in inquiry and interactions during inquiry. Specifically, we looked for student–student interactions and student–teacher interactions during an inquiry-based lesson as they related to the characteristics of scientific practices. While the participants were not explicitly taught about scientific practices, because scientific practices overlap with the five features of inquiry and also encompass additional practices, we believed this was an appropriate framework to gauge student interactions in inquiry. Open-ended survey questions and interview protocols were developed to gain an understanding of how participants gained knowledge through the PD and also how their interactions with students changed their understanding of and beliefs about inquiry.

Context

This study is part of a larger five-year statewide PD program that utilized an experimental design with a randomized assignment of treatment and control participants. Treatment participants received PD and support throughout the academic year, while control participants did not receive PD or instructional support. The program was offered at three different universities by a team of science education researchers who collaborated on the development and implementation of the PD. The main goal of the PD was to improve teacher practice through PD focused on reforms-based practices such as inquiry, problem-based learning, and explicit nature of science instruction. The emphasis of this study is on inquiry-based instruction, defined in the PD as '(1) asking questions; (2) collecting and analyzing data; (3) using evidence to solve problems' (Bell et al., 2013; Meang & Bell, 2012, p. 3). Participants were also provided a veteran teacher coach to help support and provide feedback on implementing reforms-based instruction.

The PD spanned two years and catered to first- and second-year secondary science teachers in public school districts in a mid-Atlantic state. Participants completed one science methods course the fall semester each year of the program at one of three implementation sites across the state. This study focused on participants in the first cohort of the PD in their first year of the program. Participants met for a week-long session prior to the beginning of the school year, totaling 30 contact hours. Participants then met for 7 follow-up sessions during the fall semester, totaling 15 contact hours.

The focus of the first-year science methods course included the following: (1) standards-based curriculum design, (2) research-based teaching strategies, (3) inquiry-based lessons for students to investigate science, (4) assessing student understanding of science, and (5) classroom management strategies (Maeng & Bell, 2012, p. 47). The week prior to the academic year focused on science teaching strategies, classroom management, laboratory safety, and curriculum development. During this week, participants learned about inquiry and ELF through the Learn, Try, Implement with Feedback model of the larger PD, which has shown to be an effective method of supporting teachers' use of reforms-based practices (Sterling & Frazier, 2010). During this week, participants *learned* the definition of inquiry and about the ELF, as defined earlier. Participants *tried* inquiry-based activities as students, working in groups to follow a procedure that helped them gather data, analyze data, and draw conclusions (i.e. structured inquiry). To solidify their understanding of ELF, participants also received examples of the different inquiry levels and learned how to modify lessons based on inquiry levels. For example, in a whole-group discussion participants identified how to take a confirmatory activity and make it a guided inquiry activity by taking away the procedure and moving the activity prior to the content. Finally, participants developed a unit plan incorporating inquiry, and *implemented* this unit during the fall semester. They received *feedback* on the unit plan from the PD implementers and fellow PD participants. Participants also received feedback on the implementation of their inquiry unit from their coach.

Participants

Prior to the PD, 21 teachers were randomly assigned to treatment ($N = 11$) and control ($N = 10$) conditions (Table 2).

Survey responses were used to purposefully select two average participants who intended to implement inquiry to provide insight into how the inquiry levels were implemented following the PD. Treatment participants indicated they would include inquiry in an average of 6.15 (SD = 2.71) units during the school year.

Table 2. Demographic information for treatment and control participants

		Treatment ($n = 11$)	Control ($n = 10$)
Gender	Male	3	2
	Female	8	8
Ethnicity	Caucasian	10	7
	African-American	1	2
	Hispanic	0	1
	Asian	0	0

The two purposefully chosen treatment participants, Chris and George,[1] indicated they would implement inquiry in 5 and 6 of their science units.

George, a second-year physics teacher, taught at a secondary school with 3000 students in grades 7–12 in a large suburban area. The population at George's school was approximately a third Caucasian students and a third African-American students. The remaining 30% of the school population was evenly split between Asian and Hispanic students. George taught both regular and honors Physics on an alternating-day block schedule. Chris was a first-year teacher and one of three Biology teachers working in a small city high school located in a suburban area. The student population at the high school where Chris taught was less than 800 students; almost half of the student population was Hispanic, a third Caucasian, and a small portion African-American. The high school at which Chris taught served students from both affluent and low-income neighborhoods. The school was fairly new, and the only one in the city, but there was little technology in the classrooms. Like George, Chris also taught on an alternating-day block schedule. He taught four regular Biology classes, one inclusion Biology class, and one English as a Second Language Biology class.

Data Collection

Data sources included classroom observations, observation forms, pre/post-surveys, and interviews. These multiple data sources allowed for triangulation of the data and increased the trustworthiness of the findings. To provide support for face and content validity, each instrument was reviewed by a panel of experts in science education and evaluation and suggested revisions were incorporated in the final versions of the instruments.

During the academic year, each participant completed an observation form for the four observed lessons. This form provided information about the extent to which inquiry was implemented in participants' classroom, the classroom setting, and the lesson context. Participants described what they taught three days prior to and three days after the observed lesson, with explicit responses about whether they taught inquiry and why they believed the lesson incorporated inquiry (Appendix 1). Participants completed Perceptions Surveys prior to and following the science methods course (Appendix 2). Surveys assessed participants' understanding of the constructs emphasized in the PD. A subset of open-ended questions evaluated participants understanding of inquiry and how well their definitions of inquiry aligned with what they learned in the methods course. Participants defined inquiry and explained their perception of what inquiry instruction looks like in a classroom. The Post-Perceptions Survey also assessed the extent to which the participants found the PD helpful. The data set for the present study included all survey responses pertaining to inquiry.

The two purposefully selected participants, Chris and George were observed in the spring following the methods course, totaling 8 hours of classroom observations. These observations occurred when the participants specifically indicated they were teaching through inquiry. Field notes of each observation included details about the interactions between the participant and student, interactions between students, evidence of student engagement, and the types of scientific practices (e.g. planning investigations and engaging in argumentation) present in the lesson. Following the PD, George and Chris were interviewed using the Teacher Perceptions Interview (Appendix 3). This 30-minute interview explored their understanding of inquiry and experience in the methods class. A second 30-minute interview, conducted prior to the live classroom observations, gained further insight into these participants' meaning of inquiry and inquiry levels and ascertained the frequency and types of inquiry incorporated into instruction (Appendix 4). These data were later triangulated with observational data. Following each observed lesson, George and Chris were interviewed to better understand the implementation of their inquiry instruction. The main topics of these four 20-minute interviews included lesson objectives, idea origin, participants' perception of lesson success, and identification of the inquiry level for the activity. Interviews were recorded and transcribed for analysis.

Data Analysis

Quantitative data from observation forms were analyzed using descriptive and inferential statistics. Two researchers independently coded for the presence or absence of inquiry on all observation forms. First, the researchers reviewed the observation form table explaining the context of the lessons to see if the participant reported any inquiry in their instruction. If the table indicated that inquiry was present, the participant's explanation of why they considered the lesson inquiry was used to determine if it aligned with the PD definition. The presence of inquiry aligned with the PD was coded as a 1, and the absence was coded as a 0. For observation forms containing inquiry, the researchers also coded the ELF category. Reliability between the two researchers for coding for the presence of inquiry and ELF was 88%, with 100% agreement upon discussion.

Normality assumptions for participants' coded responses from the observation forms were tested to ensure a normal distribution for the small data set. Levine's test for homogeneity of variance was met for all observations except observation 4. This significance test is understandable since, according to observation form 4, no control participants implemented inquiry. The codes for all four observation forms for each participant were averaged to assess overall implementation of inquiry. Independent sample *t*-tests were performed for each individual observation and for the overall average to determine if significant differences between treatment and control participants' implementation of inquiry existed. Frequency counts were tabulated for inquiry and ELF identified on the observation forms.

The researchers employed a constant comparative approach to analyze the qualitative data (Boeije, 2002; Glaser, 1965). In this approach each category contains confirming and non-confirming data, resulting in a range of data describing the category. In the present study, initial categories about participants' understanding of inquiry and the levels of inquiry stemmed from the literature. Using participant data about their understanding helped develop a range of properties for the category. For example, all participants' understanding of inquiry before the PD contained some component of the literature definition; however, after the PD more characteristics of inquiry were present in their definition. Some participant understandings of inquiry also contained details not aligned with the PD definition of inquiry.

No research addresses teacher beliefs on ELF; thus, the categories pertaining to teacher beliefs were developed from the data. The resulting categories drew from interview, survey, and observational data. For example, teacher beliefs about the levels of inquiry appropriate for high school science arose from the data. As another example, scientific practices grounded the category related to teacher practices of inquiry and ELF. Observational data indicated that different teachers emphasized different scientific practices, providing the range of data describing this category. The theoretical framework also helped explain differences in the implementation of scientific practices for each participant. The data analysis concluded when multiple data sources continued to provide iterative data representative of this category.

Results

The purpose of this study was to examine the frequency of inquiry implementation of treatment and control participants, and to characterize two treatment participants' ELF implementation. In alignment with the explanatory sequential mixed methods approach, the quantitative data related to frequency of implementation are presented first. The qualitative data that follow describe inquiry practice and factors which may influence practice, including understandings of inquiry, and beliefs about inquiry.

Frequency of Inquiry Implementation

Observation forms revealed that treatment participants implemented significantly more inquiry over the course of the academic year compared to control participants (Table 3). Of the 11 treatment participants, 9 implemented inquiry at least twice during or within the context of the four observations (82%). Only 2 of the 10 control participants (20%) implemented inquiry at least twice. When analyzing individual observation forms across the year, there were no significant differences in

Table 3. Mean coded scores for enquiry implementation according to observation forms

Condition	Overall	Obs. 1 (October)	Obs. 2 (December)	Obs. 3 (January)	Obs. 4 (March)
Treatment	.60*	.36	.60	.91*	.55*
Control	.18	.30	.33	.10	.00

Note: No inquiry for all participants = 0, inquiry present for all participants = 1.

*Significant difference between groups, $p < .01$.

inquiry implementation between groups for the first half of the academic year (first and second observation forms). However, there was significantly more implementation of inquiry in the second semester of the year (third and fourth observation forms) for treatment participants compared to control participants.

Treatment participants' use of inquiry may be related to the emphasis on ELF as a framework for structuring inquiry. Both Chris and George believed the levels were a simple, practical method of implementing inquiry in their classrooms. When asked what he would implement from the methods course in the coming year, Chris indicated he would implement the levels of inquiry as a method of modifying his activities:

> I think I'm going to keep sticking with the inquiry based lab activities and how do you take a cookie cutter lab and make it into something where the students have to think with their own curiosity and make it an inquiry based lab with different levels. (Follow-up interview)

Chris saw ELF as useful because he was able to use what he already had and could make small modifications in order to make it inquiry based. This use of inquiry levels was also evidenced in the observation forms. Of the 22 instances of inquiry for treatment participants, 10 (45%) were using an inquiry level. Control observation forms only revealed seven instances of inquiry, and of those only one (14%) was identified as an inquiry level.

Two Participants' Practice of Inquiry

For the purposeful observations of George and Chris, both implemented either confirmatory or structured inquiry with their students; however, there were differences in the implementation of ELF. In George's classroom, students engaged in more scientific practices than Chris's students, and how each teacher provided support for these practices varied. Students analyzed and interpreted data in their individual groups in George's classroom, while Chris modeled the process of analyzing data for students. Furthermore, student–student interactions dominated George's classroom and were associated with conceptual understanding and process skills, whereas student–teacher interactions were present more often in Chris's classroom and focused on procedural and behavioral issues.

Scientific practices. The number of scientific practices incorporated into the observed inquiry-based activities differed for Chris and George (Table 4). For example, in

Table 4. Overview of enquiry observations

	Chris		George	
Scientific practices	Carrying capacity (structured)	Experimental method (structured)	Static electricity (confirmatory)	Gravitational constant (structured)
Asking questions				x
Developing and using models			x	
Planning and carrying out investigations	x	x	x	x
Analyzing and interpreting data	x	x	x	x
Using mathematics and computational thinking	x			x
Constructing explanations			x	
Engaging in argument from evidence			x	
Obtaining, evaluating, and communicating results			x	

Note: Both participants implemented their inquiry-based activity during one block period with the exception of George's first observation.

Chris's lesson on carrying capacity, students went outside to simulate how many bears could be sustained in an environment over multiple seasons. After students gathered the data outside, Chris modeled how to calculate carrying capacity from their data. Students participated in mathematical thinking for this activity, but it was clearly teacher-led and students were given little opportunity to practice this thinking on their own. Once Chris finished modeling, he told students, 'You have three more questions to do. What we've talked about should help you figure these out' (Observation 1). Students analyzed their data in response to teacher proposed questions on a worksheet and were able to complete it quickly before the end of class. The limited time frame prevented students from fully engaging in analyzing data or using computational thinking.

Conversely, the following classroom observation illustrates how George's students participated in multiple scientific practices during a confirmatory inquiry activity about static electricity:

> Students in one group discuss with each other what is happening. They debate among themselves whether a piece of paper attracted to tape has a positive or neutral charge.

> One of the male students in the group, Dan, attempted to explain the attraction, 'Protons and neutrons are in the nucleus so they can't transfer, therefore, it must be electrons transferring'. The other male student in the group, Larry, tended to dominate the discussion but was not always correct in his explanations. Dan was less dominating but appeared to have good explanations. The last question of the activity asked students for another name for the 'flat and pointy' sides of the tape. Larry thinks the question refers to synonyms so he answers 'dull and sharp'. Dan says, 'I think it's positive and negative'. As Larry and Dan discuss this, Sue, the third member of the group, takes two pieces of tape and places them close to one another to see what happens. Dan sees her doing this and says, 'Try the flat with the pointy, they attract, see?' Sue sees that, then tries the pointy with another point and they repel. The group then collectively decides positive and negative are what they are going to put down for the answer. (Observation 1)

This excerpt illuminates how students were engaged in argument from evidence, and obtained, evaluated, and communicated results. This group of students seemed to have multiple explanations for their observation of the tape, and the student who could best justify their explanation was the explanation the group agreed on. Based on Dan's answer, Sue gathered more observational data in order to evaluate his explanation. Throughout the observation all three students were effectively communicating and arguing about the phenomenon. Students also created conceptual models of the process of static electricity during a whole-group discussion at the end of the activity. The students drew and explained the movement of electrons and related this to current.

In another observation, George's students participated in a structured inquiry activity for determining the gravitation constant. Yet at the end of the inquiry-based activity George provided students the opportunity to come up with their own research question to build upon this experiment. Between the static electricity activity and the gravitational constant activity, George's students engaged in all scientific practices.

Types of interactions. In George's static electricity activity, the student–teacher interactions dominated the beginning of the inquiry activity and focused on the procedure. As the activity progressed George purposefully decreased the number of student–teacher interactions by monitoring student progress from afar. This forced students to interact with each other about the concepts instead of asking George for the answers to the activity. As students made observations, they automatically connected their observations to concepts about the movement of electrons. The ability to interact with other students allowed students to connect their current understanding of static electricity with the new observational evidence, rather than passively accepting an explanation given by George.

In contrast to George's class, Chris's classroom interactions were mainly student–teacher interactions. During the experimental method activity, students created paper helicopters and had to determine whether they wanted to vary size or mass of the helicopter. He gave explicit behavioral expectations in addition to instructions for the activity. He stopped in the middle of his instruction for too much talking and says 'Warning one, I'm not done yet'. During data collection Chris's main interaction with students was to make sure students were on task and correctly making the helicopter. Students had little to no discussions with each other about the data or the activity.

In summary, Chris emphasized data collection and data analysis and student–teacher interactions, while George incorporated a range of scientific practices along with more opportunities for student–student interactions. These differences in implementation may be influenced by each participant's beliefs about inquiry and ELF.

Factors Influencing Two Participants' Inquiry Implementation

Both Chris and George's understanding of inquiry and ELF (i.e. their operational definitions) and their beliefs (i.e. thoughts on how to implement inquiry) appeared to relate to how they actually implemented inquiry into their classrooms. This section begins by examining each participant's definition of inquiry and ELF, how their definitions changed following the PD, and how their definitions appeared to relate to their practice. A discussion of how participants' beliefs about their students' abilities aligned with their practice of inquiry follows. The section concludes with participants' beliefs about ELF and the decisions about ELF and inquiry implementation that played out in the classroom observations.

Understandings of inquiry and ELF. Pre-Perceptions Surveys indicated that George and Chris had incomplete understandings of inquiry and were unaware of how to structure inquiry. Post-Perceptions Surveys indicated that their understandings of inquiry became more aligned with the definition of inquiry (Table 5). In follow-up interviews, they also used inquiry levels to define inquiry-based instruction.

Table 5. Participants' definitions of enquiry before and after professional development (perceptions surveys)

	Before professional development	After professional development
Chris	It draws on the curiosity of students to learn about unknown things. For the teacher, this means taking a very hands-off approach and letting students guide the learning process. Because of having to aim towards certain content and standards, it is difficult for a teacher to let students completely guide their activities	Inquiry draws on the curiosity and problem-solving skills of the students. The most open inquiry allows the student to decide the question to investigate as well as how to go about the investigation. In the classroom, a more closed degree of inquiry is generally used because of how much time and effort it takes to set up an inquiry-based activity. In these more closed inquiries, students are given a question, but they have to design and conduct the experiment as well as collect and analyze data
George	The students are the ones who are inquiring about something that they are interested	Have a problem or a phenomenon that is looked at through the scope of the scientific method to discover the truths about that topic

Chris initially believed inquiry was solely open inquiry and implied this is a barrier to implementing inquiry. However, after learning about inquiry levels through the PD, Chris understood that inquiry can be open or more structured. Chris also defined guided inquiry in his post-survey response and included some of the key scientific practices in his definition. He perceived guided inquiry as a more practical approach to implementing inquiry in the classroom than open inquiry. While George's definition of inquiry was general before and after the PD, he discussed the need to limit the 'scope' of inquiry in the classroom, which implied he better understood the need to structure inquiry. George's use of the phrase 'the scientific method' to describe inquiry implied he understood inquiry primarily as an experimental method of gaining knowledge. However, one of the lessons he identified as inquiry based was nonexperimental in nature, signifying that he understood 'the scientific method' can be both observational and experimental.

Both participants had varied views of the levels when asked about different scenarios during the inquiry interview. George correctly identified each scenario according to ELF, and he was also able to give concrete examples of how to modify each scenario to provide more or less support for the students. In contrast to George, Chris grappled with whether one scenario was inquiry, and his modifications to scenario two revealed an incomplete understanding of inquiry levels. When asked how to make scenario two inquiry, Chris responded, 'To make it inquiry they really need to come up with how they're going to do it' (Inquiry Interview). Chris's definition of inquiry excludes confirmatory and structured inquiries where students are provided a procedure in order to collect and analyze data to answer a research question.

While the two participants' understanding of inquiry improved and aligned with the formal definition of inquiry after the PD, there were still some variations among their specific understandings of ELF. George had the most accurate understanding of ELF as evidenced by his ability to identify and modify different inquiry scenarios. He also incorporated the most scientific practices in his inquiry instruction. However, Chris' practices of inquiry did not align with his understanding of inquiry. This may be explained by the misalignment of understanding and practice for Chris. As evident in his discussion of inquiry and its relation to teaching using inquiry:

> I've always thought of inquiry as involving a little bit of curiosity, want to know what's going on. But in terms of designing lessons for science inquiry, I would say it's more an experiment or an investigation. (Inquiry interview)

The idea that curiosity and motivation characterized scientific inquiry, according to Chris, disappeared as he explained inquiry teaching. The translation of scientific inquiry into his classroom may be one reason he limited opportunities for students to engage with each other beyond data collection.

Beliefs about students. George's epistemological view of how students should be interacting during an inquiry activity differed from Chris' view. George believed students should be actively involved in the activity, while Chris believed students' behavior issues limited how they engaged in inquiry. When asked what teachers and students do during an inquiry lesson, George indicated 'Both are asking each other questions' (Post-Perceptions Survey). This type of active interaction between student and teacher was evidenced in his instruction. During a gravitational constant inquiry activity, George took the students outside to the football bleachers to drop objects from different heights. Students had to develop their own procedure. During this laboratory session, George monitored students and asked one group 'Are you guys okay with what is going on?' When a student in the group responded 'Sort of', George probed the student by asking what they meant (Observation 2). Instead of trying to provide answers, George focused on getting students to think and attempt problem-solving on their own. It appeared George believed his role as a teacher was as a facilitator of students' learning, a student-centered approach. This type of self-organization and emphasis on student–student interactions was evident in both of George's observed inquiry-based lessons.

In contrast, Chris believed that his students can act as barriers to inquiry instruction, which was evident in his interaction with students. During the carrying capacity activity, Chris's main interaction with his students focused on behavioral issues. For example, Chris continually reminded students to only pick up one piece of food at a time during the activity, asked students whether they correctly recorded the correct number, and kept students from arguing while waiting their turn. The only student–student interactions observed during this activity were social in nature and never about the content or concepts being taught. After this observation, Chris reflected on what went well and did not go well during the lesson. He responded, 'Behavior management is always a struggle'. When asked about the level of inquiry, he also stated, 'Very limited inquiry, but it's typical of what we normally do, I didn't change it' (Observation 1 interview). Thus, concerns with student behavior appeared to limit the types of interactions students engaged in and how Chris implemented inquiry in his biology classroom.

Beliefs about the enquiry levels framework. When specifically assessing the participants' beliefs about ELF, George and Chris both believed structured and guided inquiries were the best levels to implement in high school. When asked about levels of inquiry George taught throughout the year, he responded:

> I probably stick right about level 2 throughout the year. And that's mostly because the topic's changing, so I don't feel it's appropriate to change the level of how I am explaining a new topic because first year physics is hard enough as it is. So I just don't want them to feel like they're just thrown in and sink or swim. (Inquiry Interview)

George believed that structured inquiry was most appropriate for his students because the physics content is difficult. He appeared to believe he should emphasize content rather than process skills during inquiry instruction.

Chris also emphasized specific levels of inquiry and indicated that during the methods course he, along with other teachers, agreed on the most appropriate level of inquiry:

Table 6. Treatment participants' frequency of ELF

	Obs. 1 ($n = 4$)	Obs. 2 ($n = 6$)	Obs. 3 ($n = 9$)	Obs. 4 ($n = 6$)
Confirmatory	0	0	0	0
Structured	0	2	4	1
Guided	1	1	2	0
Open	0	0	0	0

Note: Number of observations is those identified on the observation form as inquiry; non-inquiry observations are excluded from the table.

> At our round table discussions we kind of came up with the idea that level 1 and level 2 are pretty much where our kids are at in terms of high schoolers and trying to use inquiry. (Follow-up Interview)

For Chris, levels 1 and 2 are structured and guided inquiries, which aligned with George's belief on what levels of inquiry should be used with high-school students. However, the foundation of Chris's beliefs about the most appropriate levels stems from different beliefs about inquiry in general. Contrary to George's concern about students' academic ability, Chris was more concerned about behavior management.

Observation form data also suggested that other treatment participants believed certain inquiry levels were most appropriate for high-school students (Table 6). Over the course of the academic year, participants only appeared to be implementing structured and guided inquiries in their instruction. There were no instances of confirmatory inquiry or open inquiry.

Chris perceived students as barriers to implementing inquiry and believed guided and structured inquiries were most appropriate. In combination, these beliefs may have contributed to the limited number of scientific practices and focus on student–teacher interactions observed in Chris's classroom. On the other hand, George's student-centered approach to inquiry aligned with the presence of student–student interactions in his classroom. At the same time, his belief that structured and guided inquiries were most appropriate for high-school students conflicted with his use of confirmatory and structured inquiry levels. These contradicting factors may be the reason more scientific practices were evident in his inquiry-based teaching.

Discussion

Our discussion seeks to situate the results of the present investigation within the context of previous research on inquiry and PD. We begin by providing possible explanations for the significant differences in the frequency of inquiry implemented by treatment and control participants. Next, we discuss differences in George and Chris's inquiry instruction and provide insight into the scientific practices observed for both teachers. We conclude by examining the results of George and Chris's understandings of and beliefs about inquiry as they relate to studies examining science teachers' beliefs, understandings, and practice of inquiry.

Frequency of Inquiry Implementation

This study found that participants' practice of inquiry over the course of the academic year was significantly more frequent compared to control participants. However, when analyzing observation forms for each of the four observation windows, there were no significant differences during the fall semester; however, there were significant differences in the frequency of treatment and control participants' inquiry instruction during the spring semester. Comparing the observation forms to the timing of the course components may help explain these results. During the summer, treatment participants learned about and gained experience with inquiry and ELF. The follow-up sessions ran from late September to the beginning of December and were focused on supporting participants' implementation of reforms-based practice and providing feedback on implementation. Luft (2001) found that providing teachers support during the academic year in the form of observations of inquiry instruction, feedback on inquiry instruction, and reflection on teaching helped improve their practice of inquiry. While these practices are helpful, all of these support measures can be demanding of a teacher's time.

Another explanation for these significant differences is the use of ELF in the PD as a method to structure inquiry. Kazempour (2009) reported that an impediment to inquiry implementation is the time needed to create inquiry-based activities. This type of barrier was not evident in the present study, which may be a result of the practicality of ELF as a method for structuring inquiry. Further, Janssen, Westbroek, and Doyle (2014) found preservice teachers' inquiry practice improved when they were able to build upon their current knowledge and viewed their practice positively. Similarly, both George and Chris did not feel they needed to create new lessons, but could modify their own materials to a specific inquiry level. However, Chris's negative beliefs about his students suggest that he did not view his own instruction improving with ELF. Yet, Chris still changed his practice to implement more inquiry, despite his negative perceptions. Therefore, using ELF may reduce barriers to implementing inquiry such as time and beliefs and increase teachers' overall use of inquiry in the classroom.

Inquiry Implementation and Scientific Practices

Both participants incorporated two scientific practices across all observed inquiry-based lessons: planning and carrying out investigations, and analyzing and interpreting results. As seen in Table 1, these two practices align with the simplified definition of inquiry used in the PD. This suggests that using a simplified definition of inquiry with clear components may translate into how the teacher implements inquiry. Conversely, two of the three scientific practices not incorporated into the simplified definition of inquiry (developing models and constructing explanations) were incorporated into only 25% of the observed inquiry-based lessons. Both teachers appeared to engage students in mathematical and computational thinking during one of the two observed lessons (50%). We would expect to observe more mathematical thinking in a physics course, but few conclusions can be drawn on the relationship between scientific practices and inquiry implementation due to the limited number of observations. What is promising is that the teachers used scientific practices beyond those emphasized in the PD.

The ELF variety in participants' classrooms was limited to confirmatory and structured inquiries as evidenced in both the observation forms of all participants and the purposeful observations. George and Chris emphasized different scientific practices and types of student interactions during the same level of inquiry. Over the course of two different activities, Chris incorporated a few scientific practices while George was able to incorporate all scientific practices. George also had fewer student–teacher interactions and more student–student interactions than Chris.

While some researchers assert open inquiry is the best approach (NRC, 2000; Settlage, 2007), the results of the present study suggest that with effective support for a teacher like George, implementing inquiry using confirmatory and structured inquiry levels may provide students opportunities to develop all scientific practices. Schwab (1962) argues that 'enquiry' should always precede classroom instruction of topics in order to provide students the opportunity to engage in how scientific knowledge is gained. This suggests confirmatory inquiry is not 'true' inquiry. However, George's confirmatory activity on static electricity allowed students to use prior knowledge to interpret observations and draw conclusions from those interpretations. Thus, we argue that inquiry activities need not always follow instruction on a given topic. In fact, learning a scientific concept or principle prior to conducting an activity on a specific application of that concept or principle can be a pedagogically sound practice.

George's implementation of ELF also contradicts a study of two physics teachers' inquiry practice (Dudu & Vhurumuku, 2012). Dudu and Vhurumuku make the assumption that when the teacher provides a step-by-step procedure, students are automatically passive recipients of information; however, the present study indicates otherwise. In George's classroom, students were clearly involved in confirmatory and structured inquiry activities while actively participating in the scientific practices of argumentation and communication of results. Therefore, the results from the present study contradict the research of Dudu and Vhurumuku (2012). In fact, the so-called closed inquiry-based activities such as confirmatory inquiry may provide opportunities for students to actively be involved in explaining and communicating results.

Teacher Beliefs, Understanding, and Practice of Inquiry

The difference in ELF implementation may be influenced by participants' understandings about inquiry and ELF. Chris struggled to translate his understanding of scientific inquiry into inquiry teaching, yet still held accurate understandings of ELF. Similarly, Wee et al. (2007) found that induction teachers were able to develop inquiry-based lessons incorporating scientific practices such as 'high levels of evidence as priority, analyzing data, and justifying explanations' (p. 80), yet these scientific practices did not translate into the classroom. Contradictory to Wee et al. (2007), George's deeper understanding of inquiry appeared to translate into the classroom through his students' ability to communicate results and justify explanations. Therefore, teacher understandings may influence inquiry instruction.

Two main barriers influenced Chris and George's implementation of inquiry in the present study: beliefs about student abilities and beliefs about ELF. Using a social constructivist lens helped us better understand how student abilities influence a participant's implementation of inquiry. In social constructivism, social interactions influence the process of gaining knowledge. The main student–teacher interactions in Chris's classroom were procedural or behavior management based. Chris believed that the behavior of his students was not conducive to inquiry-based practices; thus, his implementation of inquiry emphasized student–teacher interactions and focused on data collection and analysis. These types of interactions may have influenced Chris's beliefs about students as barriers to inquiry-based instruction.

In contrast, George believed that students struggled with the physics content, but he believed in a very student-centered approach to inquiry. Using a social constructivism lens, George interacted with students about procedures, but he also interacted with students about their conceptual understanding through his use of guiding questions. His inquiry-based activities were very structured and incorporated student interactions, allowing students to collect and analyze data as well as explain, communicate, and argue results. The difference in the types of interactions George experienced with his students may be one explanation for why he did not perceive students as barriers to inquiry. Thus, the interactions the teachers experienced with their students influenced their beliefs and consequently their practice.

Implications

The results of our study suggest that two components of our PD may be effective in supporting secondary science teachers' implementation of inquiry: (1) the practical use of ELF to structure inquiry and (2) implementation with feedback component of the PD model. The results of this study suggest that using a simple and practical method to structure inquiry, such as ELF, may reduce the need for exclusive inquiry-based PD programs and intensive follow-up support. Professional developers should consider including ELF within any science-based PD to support integration of science practices into instruction. Yet, only one of the two teachers in this study held student-centered beliefs about inquiry, reflecting his implementation of more scientific practices within confirmatory and structured inquiries. This suggests that teacher beliefs are difficult to change; therefore, a conceptual change model may be an appropriate method of changing teacher beliefs to align with inquiry-based practices. Inquiry-based research focuses on studying how conceptual change is used in practice, as reviewed in Keys & Bryan (2001), but to our knowledge no research has examined the role of conceptual change in an inquiry-based PD.

Using scientific practices to characterize George and Chris's implementation provides a better understanding of inquiry instruction in light of the Next Generation Science Standards (NRC, 2012). This study reveals that teachers may be naturally incorporating some scientific practices including mathematical thinking. However, it may be difficult for teachers to know how to incorporate all scientific practices in inquiry-based instruction without support, even those such as George, who work to incorporate them. These results may provide insight into ways of structuring PD to help teachers implement newly learned scientific practices.

The small sample size of the present study limits the generalizability of our results. Future studies will seek to generalize these findings through a randomized controlled design that explores how a PD that employs a conceptual change model to teach secondary science teachers to successfully implement inquiry influences their beliefs about inquiry and ELF. Additionally, research indicates teachers' conceptions of inquiry do not typically emphasize evaluation or communication of results in inquiry-based instruction (e.g. Kim, Tan, & Talaue, 2013). Future research should focus on teachers who incorporate these scientific practices into inquiry investigations in an effort to understand how teachers can effectively use student–student interactions to engage students in evaluating and communicating their findings during confirmatory and structured inquiries. Clearly, this study suggests that secondary science teachers in their first years of teaching can not only effectively implement inquiry activities incorporating all scientific practices but also implement these practices through confirmatory and structured levels of inquiry. Providing beginning science teachers the opportunity to learn about ELF may help improve inquiry-based teaching for secondary science teachers.

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Note

1. Pseudonyms are used to protect the identity of the teachers.

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Appendix 1. Collaboratives for Excellence in Teacher Preparation Core Evaluation Classroom Observation Protocol (CETP-COP), (Lawrenz, Huffman, Appeldoorn, and Sun, 2002)

Section I. Background Information

Observer: ____ Observation # (circle one) : 1 2 3 4

Teacher Name: _______ School: ________________

Subject Observed: _ __________________ Grade Level: __ ____

Schedule Type: Traditional (45-60mins) _____ Block (60min-over) ______

Date :______ Class Period: _______Start Time: _____ End Time: _____

__24 students__ Total number of students in class

Section II. Contextual Background
Ask teacher before observing:

A. Objective(s) for lesson:

Recording changes in matter to determine if a Physical Change or a Chemical Change has occurred.

B. Classroom setting. Describe anything about the classroom layout that would constrain the teaching of science.

The teacher desk is in front of the classroom. On both right and left sides of the class are three laboratory tables. Student desks are set in the middle of the classroom in three rows and three lines.

C. **Other relevant details about the time, day, students, or teacher that you think are important?** (i.e., teacher bad day, day before spring break, or pep rally previous hour)

D. How does a lesson fit in the current context of instruction? (e.g. connection to previous and other lessons; what topics / activities / lessons occurred in the three science lessons prior to this lesson? what topics / activities / lessons will be covered in the three science lessons following this lesson?)

	Topics	Activities	PBL?	NOS?	Inquiry?	Technology?
Days preceding	Day 1					
	Day 2					
	Day 3					
Days following	Day 1					
	Day 2					
	Day 3					

Note: If participant indicates yes for PBL, NOS, Inquiry, or Tech, ask them what made it a PBL/NOS/Inq/Tech lesson. Record evidence here.

Appendix 2. Relevant Open-ended questions from Perceptions Survey

Pre- and Post-Perceptions Survey:

1. Define Problem-based Learning:
2. Define Science inquiry:
3. Define Nature of Science:
4. Describe what teachers and students are doing in a typical lesson/activity that emphasizes PBL:
5. Describe what teachers and students are doing in a typical lesson/activity that emphasizes science inquiry:
6. Describe what teachers and students are doing in a typical lesson/activity that emphasizes nature of science:

Post-Perceptions Survey:

7. If you have participated in professional development experiences that addressed topics covered in the VISTA Secondary Teacher Program, how does the VISTA Secondary Teacher Program compare to these previous professional development experiences (if any)?
8. What are the most important content and strategies that you have learned during the VISTA secondary methods course? (Please describe as many as apply).

9. How will you use the content, materials, and/or strategies that you learned during the VISTA secondary methods course? (Please describe as many as apply).
10. Describe your interactions with your VISTA coach to this point.

Relevant Questions from Perceptions Follow-Up Interview Protocol

Describe your overall impressions of the VISTA Secondary Teacher Program (STP) course.

1. How were you explicitly exposed to the key definitions of inquiry instruction, problem-based learning, and nature of science instruction?
   a. Do you feel you have a solid understanding of each of these constructs to implement them in your classroom? Why or why not?
   b. How did your participation in VISTA affect your thinking about these instructional approaches?
   c. Do you feel you had adequate opportunities to practice these approaches during the Methods course? Why or why not?
   d. Did the pace/order of the program instruction influence this in any way?
2. Describe your experiences learning about implementing technology to support inquiry-oriented science instruction during the VISTA Secondary Science Methods course.
3. Which components of the VISTA SSM course do you plan to implement in the coming year? In what ways? (Give concrete examples).
4. Which components of the VISTA Secondary Science Methods course did you find to be most valuable? Why? What recommendations do you have to improve the course in future years?

Appendix 3. Teacher Inquiry Interview

1. Define science inquiry.
   a. Probe: Describe the levels of science inquiry.
2. On the following sheet of paper are four scenarios. Read each scenario and determine whether they are inquiry or not. (For each scenario, the interviewer asks the following questions):
   a. Probe: Does this scenario describe science inquiry? If so, why? If not, why not?
   b. Probe: If a participant responds the scenario is inquiry: Which level of inquiry is it? Why?
   c. Probe: If a participant responds the scenario is inquiry: How would you modify the activity to make it a different level. What is the inquiry level of the activity as described? Why? Repeat for all 5 scenarios.
3. How often do you incorporate inquiry activities into your teaching?
   a. Probe: Think of a unit in which you do the most inquiry-oriented teaching. What is this topic of this unit? How many lessons are inquiries? What levels of inquiry are the inquiry activities in this unit?
4. Do you try to scaffold the levels across the year?

5. Where do you get your materials/ideas for inquiry instruction?
6. How have you modified your materials/ideas?
7. Describe an inquiry lesson you have taught.

   a. Probe: What level of inquiry do you believe this activity was? Explain.
   b. Probe: What were the primary learning goals of this activity?[2]
   c. Probe: What were the roles of the students and the teacher during this activity?
   d. Probe: How did these roles facilitate the learning goals?
   e. Probe: How did this lesson demonstrate the characteristics of inquiry?
   f. Probe: What aspects of the inquiry activity were effective or ineffective in terms of the goals for the students? Why do you think so?

Scenario Questions

Directions: Read each of the following scenarios and determine whether it is inquiry or not. You will be asked to justify your answers.

1. In a chemistry class, students design an investigation to answer the question: What effect will temperature have on the reaction rate of aluminum foil and hydrochloric acid? The students work in groups/pairs to develop a hypothesis and procedure to answer the question. The teacher approves each group's procedure, and the groups perform their experiment to gather data. After they finish collecting data, the students analyze their data and develop a conclusion. Each group presents their results to the class.
2. In a biology class, students are given a leaf collection project where they collect and press 30 different leaves. The instructions indicate that each leaf must be mounted on a piece of paper and have an identification label. The students combine the pages into a notebook and turn it in to the teacher.
3. In a physics class, students use a computer simulation to determine the relationship between mass and velocity. The teacher gives the students instructions on how to use the program. They are also instructed to use specific masses in order to measure the velocity. After gathering the data from the simulation, students analyze the data to determine the relationship between mass and velocity.
4. In an earth science class, students work in groups of three to define and describe the effects of El Nino by using information from the Web. They gather data from the national weather website and regional data websites on El Nino, and with the teacher's help analyze the data to find trends. Each group presents their findings on a poster, which are displayed in the hall.

Appendix 4. Informal Interview Topics

1. What lessons will you do after the observed lesson today?
2. Overall how did you feel the lesson went?
3. Where did you get the activity from?
4. What level of inquiry do you think this lesson was? Was that what you planned for?