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HOW CAN TEACHER-DIRECTED PROFESSIONAL DEVELOPMENT LEAD TO THE IDENTIFICATION, UTILIZATION, REFLECTION ON, AND REVISION OF 5E LEARNING PROGRESSIONS?

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Abstract

Though inquiry-based teaching has long been touted as an effective pedagogy, its application by elementary classroom teachers has been problematic. Two case studies were used to investigate effective professional learning experiences for teachers and the concomitant development of scientific proficiency in children. Both case studies used a newly developed instrument, the Classroom Observation Inventory, to collect data regarding teachers' use of the 5E model of inquiry-based teaching. The data indicates that teachers continually cycle through the stages of engage/elicit, explore, and explain with few teachers using the stages of expand/elaborate or evaluate. It is the recommendation of this study that the Classroom Observation Inventory and a newly developed 5E unit outline be used in conjunction with a variety of professional development scenarios as a collaborative data collection tool and discussion facilitator to support teachers in making informed instructional decisions that will enhance classroom practices to support students in reaching full science proficiency.

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Introduction

Inquiry-based teaching and learning is a replication of authentic scientific investigation and a means of channeling natural human curiosity towards specified learning outcomes. And even though this approach has long been touted as an effective pedagogy, its application by elementary classroom teachers has been problematic. Originally conceived by Karplus and Their (1967), the basic premise of inquiry-based teaching lies in its reliance on student experience and engagement with phenomena. Given these direct experiences, children have an innate ability to develop conceptual understanding that is scientifically accurate and developmentally appropriate. Bybee (1997) refined these original conceptions of inquiry and published the 5E model of inquiry, which has become the basis for many current classroom resources (FOSS, SCIS, STC, and Insights) as well as pre-service methods courses and in-service professional development programs. These contemporary resources demonstrate a very consistent and sustained call for inquiry in classrooms since the 1960's and yet these calls have "had…little impact on teacher practice" (Wilson, Taylor, Kowalski, & Carlson, 2009, p. 1). However, two large-scale studies point to the "uncommonness of inquiry based teaching in the US" finding that "teaching practices and student objectives characteristic of inquiry consistently occurred with less frequency and emphasis than traditional teaching methods and learning goals" (ibid, 2009, p. 1).

It appears that the majority of US classrooms are tethered to the more traditional approach to science teaching that involves a lecture style presentation of facts followed by verification laboratories. And though experts in the field recognize that inquiry might be the better solution, elementary teachers continue using this more traditional approach and our students continue to fall behind the rest of the world in terms of science achievement.

The National Science Teachers Association recently released this statement regarding US "improvements" in the science results of the 2011 National Assessment of Education Progress (NAEP):

> Overall, the results show miniscule gains in student achievement. The majority of our eighth-grade students still fall below the proficiency level and only 16 of the 47 states that participated had higher science scores than in 2009. When you consider the importance of being scientifically literate in today's global economy, these scores are simply unacceptable. (Wheeler, 2012)

This position statement not only focuses on the inadequacy of student achievement in this country, but Wheeler goes on to talk about the integral role teachers play in science education.

> Having quality teachers who have a strong background in the science they are teaching, access to ongoing professional development, adequate resources, and time in the school day to plan with colleagues is critical if we want to increase student achievement in science. Despite widespread support from national and state leaders to reform science education, many schools and districts have had to reduce funding for teacher training and science classroom resources. Even during these difficult economic times we must support science teachers and give them the tools they need to improve science education. (Wheeler, 2012)

It is apparent that even though the resources for changing this situation are available, they don't seem to be within reach of elementary science teachers and their students. According to Wilson Taylor, Kowalski and Carlson, "…it is nevertheless surprising that such a sustained and largely consistent drive for reform has had such little impact on teacher practice" (2009, p. 1). Hence, the purpose of the study is to describe viable and effective professional development strategies focused on the identification, utilization, reflection on, and revision of inquiry based teaching in elementary classrooms.

Conceptual Framework

The conceptual framework that undergirds inquiry as a form of teaching and learning has its roots in the Interactionist worldviews of Dewey, Duckworth, and Vygotsky among many others. Dewey's "educative experience" (1938), Duckworth's "wonderful ideas" (1987), and Vygotksy's "social discourse" (1978) provide the theoretical foundation for inquiry-based teaching. In all three cases, it is neither the learner nor the environment that is the focal point. Rather, it is the seamless **connection or interaction** between the learner and environment where the learner sees an end-in-view simultaneously as the anticipation of and consummation of an "educative experience." Similarly, Duckworth's "wonderful ideas" represent "new connections…being made among things already mastered" (1987, p. 14). Because of the need for interaction of students with their environment, Vygotsky proposed the need for discourse as a mechanism of engagement. Vygotsky "suggested that language helps children be strategic, rather than purely impulsive, in their approach to complex problems, and it helps them to gain control over their own thinking and behavior (Vygotsky, 1978). "The foundation of instruction is dialogic; in other words, we learn through exchange and discussion with a specific academic goal" (Darling-Hammond, Austin, Orcutt, & Martin, 2003, p. 127, http://www.learner.org/resources/series172.html).

Interactionist concepts like those described above are very difficult to translate into practice. These theoretic ideals have been translated by practitioners into "…simple recommendation(s) for more labs, field trips, projects, group work, or hands-on activities" (Wong, Pugh, and the Dewey Ideas Group at Michigan State University, 2001, p. 322). However, Dewey

> …helps us appreciate that neither student activity (i.e., having them do something) nor particular kinds of environments (having stimulating or novel materials or equipment) are sufficient for producing educative experiences. Similarly, educative experiences can neither be choreographed (e.g., as set of instructions) nor presented to students (e.g., as a demonstration, exhibit). Instead, the educative experience is evoked, it emerges from the participation of students with the environment as they create and become involved in the drama of its plot. (Wong, et. Al., 2001, p. 322).

Theoretically, the 5E model is tied to the Interactionist worldview; in practice, the 5E model can be observed in many elementary classrooms' science kits/curricula. While the model is theoretically consistent with Interactionist constructs, its application still requires teachers to understand and interpret these complex, nuanced constructs. In this study, teachers' application of the 5E model serves as a means of demonstrating the gaps in the translation from theory to practice and recommendations for closing these gaps.

Literature Review

Effectiveness of the 5E Model

Lawson (1995) reviewed more than 50 research studies on the learning cycle (5E model) that were conducted through the 1980s. The results of this review point toward the fact that the 5E model can: have positive effects on the learner's subject matter knowledge; increase scientific reasoning; and cultivate interest and positive attitudes about science. More recent studies that compare the 5E model with traditional teaching strategies (lecture followed by verification labs) provide a growing body of research which suggests that student understanding is enhanced by using the 5E model. As reported by Cardak, Dikmenli and Saritas (2008), a variety of studies demonstrate that the 5E model is more successful in: helping students correctly construct concepts in the mind by removing concept errors existing in their pre-information; providing greater understanding of the information covered especially in areas that require interpretation increasing achievement in science and attitudes toward science; promoting learning concepts and the removal of conceptual errors; and releasing students from a monotonous class environment. Though there have been some researchers that deny the effectiveness of the 5E model of inquiry (Chen and Klahr, 1999; Klahr and Nigam, 2004; Kirshner, Sweller & Clark, 2006), more and more researchers are beginning to use "scientifically-based research methods that meet the standards required by the evidence-based reform movement to establish causality" (Wilson, Taylor, Kowalski, and Carlson, 2009, p. 5). Their study in particular found that "The superior effectiveness of the inquiry-based instruction was consistent across a range of learning goals (knowledge, scientific reasoning, and argumentation) and types of measures (dichotomous items, open-response items, and clinical interviews)" (ibid, p. 5).

Professional Development in Inquiry

If the 5E model is an effective approach to helping elementary students reach science proficiency, then elementary classroom teachers need to be able to use this strategy so that is mirrors the theoretical underpinnings that support its effectiveness. Professional development of teachers has been heralded as an effective means of bringing standards-based reforms to schools. Many professional development experiences have been designed to help teachers flip from direct instruction approaches to inquiry in science. However, there is a paucity of empirical research that demonstrates the effectiveness of these experiences. Of 835 studies related to inquiry based professional development, (Capps, Crawford, and Constas, 2012), only 17 met the criteria for empiricism. After a rigorous review of the remaining 17 studies, the researchers reported a "range of outcomes, including enhanced teacher knowledge, changes in teacher beliefs and practice, and growth in student knowledge" (p. 306). However, these same researchers did not find any studies that reported all of these outcomes.

Not only is there a dearth of empirical research to support the use of professional development in the 5E model of inquiry, there are also systemic barriers that hinder elementary teachers' participation in these programs. The type of professional development sessions that teachers typically select depends on the focus of their classroom teaching. "Currently, the majority of elementary staff development time centers on cultivating teachers' abilities to improve their students' performances on standardized tests in reading and math. This emphasis results in very little time being designated to the actual teaching of science" (Borger, 2011, p. 65). If there is little emphasis on science teaching, then teachers will not devote their limited professional development time to science.

Connections between Professional Development of Teachers and Science Proficiency in Students

According to the National Staff Development Council, "increasing the effectiveness of professional learning is the leverage point with the greatest potential for strengthening and refining the day-to-day performance of education (Learning Forward, 2012, ¶3). If professional development holds this capacity, then it is necessary to examine the most effective and efficient means of delivering these opportunities. Standards for effective professional development include a concentrated focus on professional learning experiences that must be based on content derived from standards; include reflection, practice, and planning time for teachers; be comprised of activities that build inquiry skills and demonstrate modeling of these skills; highlight effective and consistent assessment activities; address concerns regarding changes in teaching, school and students; and be intensive and sustained (Parsons & Summers, 2004; Supovitz & Turner, 2000; Danter, 2005).

The expectation that scientific inquiry must reflect the knowledge building practices of the scientific community is expressed best in the National Research Council's most recent report, *Taking Science to School: Learning and Teaching Science in Grades K-8,* (2007). In this report, four strands of an intertwined rope represent science proficiency as an interconnected way of thinking that is not static and is linked to the ability to initiate investigations, develop explanations, evaluate other's claims, and refine arguments. Each strand represents an area of proficiency necessary for understanding the scientific enterprise.

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.

(NRC, 2007, p. 36)

If students are to reach proficiency, elementary science instruction must engage students in inquiry practices that incorporate all four strands. Strand one supports the need for students to understand, synthesize, and integrate scientific facts into well developed theories or models, with the intention of using this conceptual understanding to build cohesive explanations. Strand two represents the need for all students to understand and correctly utilize a wide range of practices when conducting scientific investigations, with the ultimate goal of using the data collection to build and refine arguments. Strand three considers science to be a way of knowing. It supports the need for students to appreciate that explanations are more valuable when they account for all available evidence and that it is not uncommon for some phenomena to have multiple interpretations. Therefore, constant refinement of scientific explanations is an ongoing scientific endeavor that elementary students need to experience. Strand four requires that all students cultivate a scientific habit of mind such as a willingness to ask questions, seek help, and develop a critical stance.

Research has delineated five barriers that can impede teachers' abilities to design and use instructional strategies that potentially support students in reaching science proficiency: 1) a teacher's beliefs about the goals of elementary science, 2) a teacher's knowledge base which includes subject specific knowledge, knowledge of inquiry pedagogy, and Pedagogical Content Knowledge, 3) lack of well developed science curriculum, 4) a teacher's knowledge base of instructional strategies, and 5) a lack of ongoing professional learning opportunities for teachers. (Erduran, Simon, & Osbourne, 2004; Gess-Newsome & Lederman, 1999; Haefner & Zembal-Saul, 2004; Hershberger, Zembal-Saul, & Starr, 2006; Magnusson, Krajcik, & Borko, 1999; Metz, 2004; NRC, 2007; Simon, Erduran, & Osbourne, 2009; Tippett, 2009; Weiss & Pasley, 2004; Weiss, Banilower, McMahon, & Smith, 2001; Vasquez, 2008). Reaching science proficiency will require a rededication to inquiry based instructional practices with an emphasis on explanation and theory building. This shift in priorities will change the teachers' role from knowledge source and manager of hands-on activities, to facilitator of students' ideas and scientific discourse practices.

Based on this literature to date, there may be a need to shift toward an Interactionist view of teaching and learning, i.e., the 5E model. If professional development is the means to this end, then there needs to be more detailed descriptions of viable and effective professional development strategies focused on the identification, utilization, reflection on, and revision of inquiry based *practices* in elementary classrooms.

Case studies and Grounded Theory Rationale

Case studies were selected as the method for conducting this empirical inquiry into a series of events focused on the use of inquiry in relation to two different classroom contexts. Since case study research relies on multiple sources of evidence and the inclusion of pre-conceived theoretical constructs, case study methodology is well suited for this investigation (Merriam, 1998; Corbin & Strauss, 2008). The methodology of this study can best be described as a qualitative intrinsic case study because no specific hypotheses were initially formulated but emerged as the study progressed.

Grounded theory was the qualitative analysis used throughout this research study because researchers wanted to pull from current practice the specific professional development needs that would improve the effectiveness of inquiry lesson design and implementation. According to grounded theory, data is systematically collected and organized resulting in the emergence of core theoretical concepts. Researchers code and analyze their extensive notes to develop major themes that provide a rich understanding of the phenomena under study. In this tradition, no specific hypotheses are initially formulated but instead well-considered explanations emerge through the continual process of constant comparison analysis (Merriam, 1998; Corbin & Strauss, 2008). Through the continuous process of constant comparison analysis a grounded theory emerged that represented a well considered explanation for the phenomenon of interest (Trochim & Donnelly, 2008). Grounded theory provided the opportunity to explore deeply two case studies in which expectations for science proficiency impact specific aspects of professional development needs.

Grounded theory emerged from two case studies whose purpose was to identify, utilize, reflect on, and revise 5E inquiry-based *practices* in elementary classrooms. Case study research was selected as an intrinsically bounded instance of concern – effective teaching practices in science education – where the researcher would be able to describe and analyze the qualities of effective professional development strategies through direct observation in natural settings (Merriam, 1998). Process is the focus of case study research and in this instance, the question was one of "monitoring…describing context and population, discerning the extent to which the [professional development] program has been implemented, and providing immediate feedback of a formative type" (Bromley, 1986, p. 23). Both case studies represent samples of convenience which helped to illuminate the questions surrounding effective professional development strategies that have the capacity to yield improved teaching grounded in the Interactionist tradition (5E model of inquiry) and increased science proficiency in students.

The first case study was originally conceived as a means of identifying indicators of effective instructional practices drawn from research-based professional development literature ; As part of her sabbatical investigations, researcher #1 entered into an agreement with her university-sponsored charter school to spend a year working with the science classroom teachers (K-5) as their professional developer and mentor. The preliminary findings of this year-long case raised questions about how teachers *actually* practice inquiry verses practices that are consistent with authentic inquiry in the form of the 5E model. During this case study a Classroom Observation Inventory was collaboratively developed and field-tested as the direction that the stakeholders (teachers, administrators, and researcher #1) chose to take. The second case study utilized the Classroom Observation Inventory to delve deeper into the differences in teachers' actual practice and the expectations of the authentic 5 E inquiry model. The implications from both qualitative case studies point towards omissions in teachers' practice that may impact the level of effective inquiry instruction students' experience and indicate specific professional development needs for elementary teachers. Hence descriptions of viable and effective professional development strategies focused on the identification, utilization, reflection on, and revision of inquiry based teaching in elementary classrooms emerged as the teachers and researchers gathered data to identify those teacher-led professional development strategies that might yield real changes in classroom practice.

Methodology

Case study #1 took place in a university sponsored charter school over the academic year 2009/10, beginning in the summer of 2009. The charter was approved by the state in 2007 as an elementary school that began as a K-1 building and grew by one grade each year. By the end of the study, the school had reached capacity and a new charter was drafted to include the opening of a middle school, both linked to the university.

In the summer of 2009, researcher #1 provided a week-long professional development session for the entire staff of the charter school. Researcher #1 (university professor) continued training the teachers in this urban charter school located in one of the lowest performing school districts in the state over the school year and culminated this preliminary investigation with a follow up summer institute in 2010.

The data sets collected in case study #1include the following:
~ Environmental Education and Training Partnership (EETAP) surveys (written surveys administered at the conclusion of the summer institute, 2009);
~ journal reflections stored in a wiki (from both summer institutes 2009, 2010)
~ teacher interviews and observations (Fall 2009)
~ teacher interviews, observations, and peer observations (Spring, 2010 – researcher #1 spent this semester in the charter school as part of her sabbatical semester).

All of the data focused on the use of 5E inquiry based practices in elementary classrooms. To prepare teachers to use inquiry effectively, the materials used in both institutes were developed so that teachers could experience the thinking processes involved in the 5E model as a student first; these learning experiences were followed by reflections on the pedagogy in the form of journals and the EETAP survey. During the intervening academic year, teachers were interviewed to discover the viability of teaching according to the 5E model developed during their first summer experience; during the spring semester of that year, researcher #1 became the science educator in residence making classroom observations of teacher use of 5E inquiry skills. Once observations were completed, researcher #1and teachers decided that what they needed was a checklist of behaviors that would demonstrate the use of the 5E model; This decision emerged as the teachers and researcher discussed the viability of seeing exactly what they do and don't do in terms of inquiry. The team collaborated on the development of an instrument for observing and identifying indicators of inquiry that would support teachers in moving their inquiry practices from a more teacher directed approach to a more student directed, Interactionist experience.

Researcher #1 collected multiple versions of classroom observation instruments and criteria that represent best practices in the 5E model and inquiry (Ash & Kluger-Bell, 1999; Brown, 1973; Carlson, 1980; Maroney, Finson, Beaver, & Jensen, 2003; National Institute for School Leadership[NISL], 2010; National Science Teachers Association [NSTA], 2008; Ochanji, 2006; Richardson, 1960; Wahlberg, 1994). Researcher #1 presented a draft instrument derived from a synthesis of this research to two local science educators for their input. The draft checklist was then used by participating teachers and researcher #1 to view videos created by the Annenberg Center. "The Annenberg videos show inquiry teaching and learning in action, with real teachers and students in real classrooms" (http://www.learner.org/resources/series129.html).

The use of the video viewing was twofold: first, it was seen as a means of helping teachers get past their trepidation regarding inquiry because they did not learn this way themselves when they were students or during their preparation to become teachers. And second, it gave the team a chance to use the checklist and see where there were gaps, overlaps, misconceptions, etc .The checklist was revised based on teacher and researcher interpretations of what they saw in an effort to ensure content validity. The resulting revised checklist was then field tested with the same set of teachers through an observation cycle of peer observations followed by post-observation discussions among the research triad – researcher #1, teacher-presenter, and teacher-observer; once post observation discussions were completed, adjustments were made to the checklist based on the collaborative efforts of the teachers and the researcher #1. All modifications to the checklist emerged directly from its classroom application.

The checklist was then used again in case study #2 as a means to delve deeper into the use of theory-based inquiry in elementary classrooms. The original checklist was revised again to include the new researcher's focus on argumentation discourse and its importance in the inquiry process. The final revised instrument, the Classroom Observation Inventory, can be found in Appendix A.

Case study #2 was designed as a purposive sampling of one rural public school's 30 regular education teachers who had previously been trained in inquiry-based science methods. This particular public school district is one of the top performing school districts in the same state as the charter school. Teachers participating in the case study received district training in a traditional format within a 5-year curriculum review cycle. Since this study coincided with the five-year science curriculum review, teachers were informed that recommendations from this case study would be considered for future district professional development programs.

Qualitative data in case study #2 was collected through classroom observations, focus group interviews, and in-depth interviews. Focus group sessions were designed to encourage discussion among teachers in an attempt to uncover a deeper level of understanding regarding their instructional practices. Individual in-depth interviews were conducted with six consenting teachers. The purpose of these interviews was to explore the emerging trends that surfaced throughout the case study.

The study began with all elementary science teachers attending a presentation during a professional development day that described the use of the Classroom Observation Inventory that was developed and field tested in case study #1. The presentation focused on the instrument as a data collection tool to examine best practices in lesson design; a tool that provided insights and expertise into facilitating instruction to meet science proficiency; and a means for teachers to ask specific questions about the use of the tool and the data collection process.

Before any classroom observations occurred, the observers, the school district's Elementary Science Department Head and case study researcher, reached consensus about terms used in the Classroom Observation Inventory by viewing selected portions of the Annenberg Foundation's video workshop titled, *Learning Science through Inquiry* (retrieved from http//www.learner.org). Additionally video segments were used as practice scoring sessions. A training video created by King's College titled *Ideas, Evidence, and Argument in Science (IDEAS) Project* (2006) was viewed to define discourse patterns and teacher talk moves necessary to support theory building discussions associated with science proficiency.

Both the researcher and the school district's Elementary Science Department Head conducted twenty-one classroom observations utilizing the Classroom Observation Inventory. To increase inter-rater reliability the first five classroom observations were completed together. Following each of these practice observations, researcher #2 and the Elementary Science Department Head discussed their observations. These discussions focused on each observer's notations of evidence of teaching behaviors that fit those behaviors listed in the inventory. The evidence was compared and discussed to reach consensus regarding an operational understanding of each of the behaviors listed on the inventory and, concomitantly, a consistent level of scoring. Though inter-rater reliability was not calculated statistically, researcher #2 and the Science Department Head were in agreement on the match of behaviors exhibited by teachers and their consistency with the inventory in all five practice observations. After the initial five observations, all other observations were completed with one observer per classroom. All teachers were given a copy of the Classroom Observation Inventory (Appendix A) approximately two weeks before any scheduled observations. The building principals scheduled observations and all consenting teachers were informed one week prior to the date of the observation. After the classroom observation, a copy of the completed inventory was given to the teacher and a post conference occurred to discuss the results. This provided the teacher with an opportunity to understand what data was collected during the observation and to correct or clarify any misunderstandings.

In both case studies all teachers were responsible for K-5 science teaching. Data collected was used to determine the authentic use of the 5E model of inquiry-based science instruction supporting the development of science proficiency in elementary classrooms. The findings of both case studies led to a distillation of strategies that may in fact provide the basis for viable and effective professional development strategies focused on the identification, utilization, reflection on, and revision of inquiry based teaching in elementary classrooms.

Findings

Using the Classroom Observation Inventory (Appendix A) in both case studies, high frequencies (greater that 45% of all respondents in at least one case) were noted for the following indicators: states purpose of the lesson, creates curiosity and gets students' attention/focus, raises appropriate questions, elicits responses that uncover prior knowledge, encourages students to work together, provides common experiences, asks probing questions, provides students time to puzzle through problems, encourages students to explain in their own words, uses students' previous experiences, encourages student to student interaction, uses classroom norms and discussion etiquette, uses appropriate wait time after asking questions, and provides closure for lesson. Low frequencies (less than 10% or not evidenced in at least one case) were noted for: identifies and records student thinking, uses audiovisual or electronic resources, uses metacognition strategies to guide discussion, includes questions that justify or allow students to change their minds, all indicators for the elaborate/expand phase, all indicators for the evaluate phase except bringing closure to the lesson/unit.

An examination of the data (see Table 1) reveals an overall pattern - teachers were continually cycling through the stages of engage/elicit, explore, and explain. There were very few teachers' lessons that ventured into the stages of expand/elaborate or evaluate. Observations indicated that inquiry practices support the development of foundational skills of inquiry and do not include those higher level inquiry skills necessary to meet the goal of science proficiency. Observations during the explain phase did not include students critically examining multiple perspectives, which supports the understanding that discrepancies between their ideas and ideas of other members of the scientific community will exist and are a natural part of the scientific enterprise.

TABLE 1
Results: Classroom Observation Inventory

Stage	Teacher Behavior	Frequency Case 1	Frequency Case 2
Engage/	1. states the purpose & expectations for learning	50%	100%
Elicit	2. creates curiosity & gets students' attention/focus	45%	38%
	3. raises appropriate questions	50%	23%
	4. elicits responses that uncover prior knowledge	45%	47%
	5. identifies & records student thinking	30%	4%
	6. creates opportunities for students to question/wonder	50%	0%
Explore	7. encourages students to work together	50%	61%
	8. provides common experiences	55%	100%
	9. observes and listens as students raise questions	45%	9%
	10. asks probing questions to redirect students	45%	66%
	11. provides time for students to puzzle though problems	30%	66%
	12. adds to the collective memory by recording ideas	*	19%
Explain	13. encourages students to explain in their own words	10%	66%
	14. asks for justification and clarification from students	25%	42%
	15. directs lesson by formally providing definitions	25%	19%
	16. uses audio-visual or electronic resources	5%	14%
	17. uses students' previous experiences	20%	61%
	18. encourages student to student interaction	*	47%
	19. uses classroom norms and discussion etiquette	*	90%
	20. uses metacognitive strategies to guide discussion	*	0%
	21. appropriate wait time after asking questions	*	52%
	22. questions that challenge another's thinking	*	19%

	23. questions that justify: What are your reasons?	*	9%
	24. questions that allow students to change their minds	*	9%
Elaborate/	25. encourages students to use formal labels	15%	42%
Expand	26. encourages students to apply or extend concepts	5%	14%
	27. reminds students of alternative explanations	0%	0%
	28. refers students to existing data and evidence	5%	0%
Evaluate	29. observes students as they apply new concepts	0%	9%
	30. compares thinking in engage phase to present	5%	0%
	31. allows students to assess their own learning	0%	0%
	32. asks open-ended questions	0%	38%
	33. brings closure to the lesson/unit	0%	100%
	34. evaluates collective memory of the class	*	4%
	35. encourages students to self-assess their own learning	*	0%

* These indicators were added as part of revision process of instrument for case study 2

Completing a fine grain analysis of the stages observed in both case studies, additional trends were discovered. The engage stage only included stating the question under investigation and having students form a hypothesis. Those few teachers who did elicit previous knowledge from the students and noted it on a large KWL chart, never returned to the chart during the lesson or at the closure of the lesson to have students gage their changing conceptual understanding. In short, students' conceptual thinking was collected, but never used to facilitate growth.

During the explore stage whole classes of students were working in small groups to complete a teacher directed experiment. The student-to-student interaction focused on accurately recording results into science notebooks and checking each other's notebooks for accuracy. Students' discussions were noted as a means of copying the correct answers down and not on evaluating their worth. Most teachers went group to group asking probing questions that centered on pushing for clarity, summarizing results, and refining the discussion to include appropriate scientific terms. Teachers were not observed probing students to take a position, explicate reasoning, or support skepticism or dissent.

During the explain stage each small group was encouraged to summarize their findings in their own words in their notebooks. Discussions at this time centered on all members working together to form a collaborative theory based upon the group's evidence collection. Students were not encouraged to evaluate their results in the context of a real world application or opposing views. Small groups were encouraged by the teacher to collaboratively form similar explanations. The explain stage ended with a teacher orchestrated discussion that encouraged all groups to share their conclusions. There were no position driven discussions observed and all groups had similar results and formed the same general explanation.

Student directed investigations within the elaborate and expand stage were not observed. The evaluate phase did not include the use of formative assessments. Students were held accountable for their learning through small and whole group discussions.

However, teachers were not observed using checklists or rubrics to document their learning. Students were not observed writing reflections on their own learning or on the group process. While students wrote in notebooks, none were collected for review at the close of the lessons.

These indicators support the belief that observed inquiry practices were supportive of the development of foundational skills of inquiry and do not include those higher level inquiry skills necessary to support the knowledge building practices included in the science proficiency indicators.

Discussion

The findings of this study indicate that while participants were able to plan for and implement the engage and explore phase of the 5E model, when they get to explain, they revert back to teacher directed activity. They pool all student ideas toward verification of the scientific concept under study. Even when students' findings do not match the textbook explanation, there is no attempt to explain these inconsistencies or misconceptions. Teachers are not reflecting the 5E model in its entirety and therefore, they are not providing instruction that would meet the National Research Council's call for inquiry (2007).

According to the NRC, there are four strands for reaching science proficiency (K-8). It appears that current instructional practices found in this study are designed to reach strand one which represents foundational knowledge, use, and interpretation of scientific information. However, by misusing the explain phase and omitting the expand/elaborate, and evaluate phases, the essence of the remaining strands are not being met. The students are not given opportunities to develop the ability to initiate investigations, develop explanations, evaluate claims, and refine arguments.

In additions, while these expectations are a part of NRCs call for science proficiency, they are not reflected in the high stakes standardized tests mandated by the federal government. As part of current federal legislation standardized tests in science are required at the elementary level. The problem is that teachers focus their instruction on helping children succeed on the assessments which tend to be measuring retention of scientific vocabulary. As a result, teachers are forced to choose between students succeeding on standardized tests or reaching science proficiency.

If professional development strategies can impact the use of inquiry in the elementary school classroom, then attention has to be given to teacher's beliefs about science instruction and their pedagogical and content knowledge (Erduran, Simon, & Osbourne, 2004; Gess-Newsome & Lederman, 1999; Haefner & Zembal-Saul, 2004; Hershberger, Zembal-Saul, & Starr, 2006; Magnusson, Krajcik, & Borko, 1999; Metz, 2004; NRC, 2007; Simon, Erduran, & Osbourne, 2009; Tippett, 2009; Weiss & Pasley, 2004; Weiss, Banilower, McMahon, & Smith, 2001; Vasquez, 2008). By focusing teachers on ALL five phases of the 5E model and creating professional development opportunities that lend themselves to exploring and refining lesson design, NRC's four strands of science proficiency could be met and the five barriers to effective inquiry could be broken down.

Recommendations for Professional Development

Reform based professional development opportunities have been found to be more effective than traditional professional development (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010; Putnam & Borko, 2000). The third edition of *Designing Professional Development for Teachers of Math and Science* (Loucks-Horsley, et al., 2010) delineates quality reform based professional development to include the following principles: results driven, job-embedded, sustained over time with extensive teacher input, directly linked to classroom practices that support high student achievement. This style of professional development supports teachers in exploring with colleagues their own instructional practices within the context of their grade level curriculum, and their students' needs. Through this examination teachers gain a deeper understanding of their own strengths and weaknesses within the context of their instructional practices. Reformed based professional learning situations create an environment for learning that is supported by research (Bransford, Brown, & Cocking, 1999) because they support the belief that by encountering understandings of other learners, we gain and deepen our own understanding.

The Committee on Science Learning (NRC, 2007) recommends that professional development reflect a clear focus on improving student learning by engaging collaborative groups of teachers in examining the strengths and needs of learners, in understanding the aspects of quality science instruction, and in continually refining instructional practices to support all students in reaching science proficiency. This requires the articulation of clear concise aspects of quality science instruction in ways that support teachers in continually designing, refining, and reflecting upon their own instructional practices.

It is the recommendation of this study, that the Classroom Observation Inventory (Appendix A) be used as a collaborative data collection tool and discussion facilitator with small groups of teachers to support their abilities to make informed instructional decisions that will enhance classroom practices to support students in reaching science proficiency.

As a result of this investigation, both researchers continued to collaborate on the development of a unit plan outline (Appendix B) to be used as a complimentary tool for improving teacher awareness of their implementation of inquiry across a learning progression that includes all 5Es. Though the 5E Unit Plan Outline was not a part of this study, it is a tool that is consistent with the expectations of inquiry-based teaching afforded by the Inventory and supports designing instruction that facilitates science proficiency.

The Classroom Observation Inventory offers elementary teachers a clear image of the components of effective science instruction that supports the theory building nature of the scientific enterprise for elementary students. In conjunction with the 5E Unit Plan Outline, individual teachers can begin to examine their own instructional practices over a backdrop of current instructional expectations. Teachers now have a way to examine their own capacities to design instructional learning progressions that encourage a more student centered, theory building approach with the support of their colleagues. They can begin to use strategies that embrace a question focus rather than an answer focus, shifting their roles as managers of hands on activities to facilitators of students' scientific reasoning.

The combined strength of the Classroom Observation Inventory and the 5E Unit Plan Outline can be seen in their use by small groups of teachers working collaboratively and continuously with colleagues and other experts in numerous reform based professional development scenarios. These scenarios include mentoring programs, peer coaching formats, professional learning community models, lesson design studies, and tuning protocol discussions (Easton, 2004; McDonald, Mohr, Dichter, & McDonald, 2007). When the Inventory and 5E Plan are used within the context of these collegial professional development programs, they can become a springboard for discussion that prompts the inclusion of specific instructional strategies that promote current science proficiency expectations. These sorts of teacher led professional development sessions have the capacity to improve elementary science proficiency in elementary aged students because teachers can make informed changes in practice based in theoretic constructs. Through this collegial process teachers deepen their expertise in learning science content, practice integrating curriculum and learning experiences associated with science proficiency, and understand the need to learn instructional strategies that support students in developing their own scientific understanding as opposed to designing activities to help students remember science concepts and skills.

Conclusion

By designing reform based professional development learning situations to include the use of the Classroom Observation Inventory (Appendix A) and the 5E Unit Plan Outline (Appendix B), the data collections will enumerate the strengths and weaknesses of classroom instruction against current expectations which will encourage teachers participating in the professional development program to have focused science specific discussions about designing learning progressions that support the goal of science proficiency. If the target of science proficiency via inquiry is clearly delineated and if supportive materials such as the Classroom Observation Inventory and the 5E Unit Plan Outline are provided within the context of collaborative professional development programs, then teachers can develop instructional experiences that lead to science proficiency. Refining teachers' day-to-day performance through professional development places them on a path of continuous reflection and improvement providing the leverage point for strengthening science inquiry in elementary classrooms. Using these tools, teachers can collaborate in reform based professional development settings to identify, utilize, reflect on, and revise learning progressions that truly emulate the 5E model and lead towards science proficiency.

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APPENDIX A
Classroom Observation Inventory

Teacher Name: **Observer Name:** **Date:**

Stage - Circle if observed	**Teacher Behavior - check off those behaviors exhibited by the teacher**	**Evidence - list example from lesson**
Engage Elicit	1. ___ states the purpose of the lesson & expectations for learning 2. ___ creates curiosity & gets students' attention/focus 3. ___ raises appropriate questions 4. ___ elicits responses that uncover prior knowledge of the concept 5. ___ identifies & records student thinking including any misconceptions through formative probes, cartoons, discrepant events 6. ___ creates opportunities for students to question/wonder	
Explore	7. ___ encourages students to work together without direct instruction from the teacher 8. ___ provides common experiences for all to participate on a level playing field 9. ___ observes and listens as students raise questions, develop hypotheses, collect evidence & data, and record/ organize information 10. ___ asks probing questions to redirect students' investigations when necessary (What else can you tell me about that? Can you explain what you mean?) 11. ___ provides time for students to puzzle though problems and confront their ideas in small groups 12 ___ adds to the collective memory by recording student ideas	
Explain Explain	13. ___ encourages students to explain concepts and definitions in their own words 14. ___ asks for justification (evidence) and clarification from students 15. ___ directs lesson by formally providing definitions, explanations, &new labels 16. ___ uses audio-visual or electronic resources to support explanation 17. ___ uses students' previous experiences as the basis for explaining concepts 18. ___ encourages student to student interaction, the opportunity to listen to multiple interpretations of data/evidence, and the refinement of ideas 19 ___ uses classroom norms and discussion etiquette to demonstrate respect for all ideas	

	20. ___uses metacognitive strategies to guide discussion (When I try to do X, the first thing I do is…., then I….) 21. ___uses appropriate wait time after asking questions 22.___ uses questions that challenge another's thinking: Can someone explain why they disagree? Can someone share a different point of view? 23.___ uses questions that justify: What are your reasons? What have you noticed or found out? 24.___ uses questions that allow students to change their minds: Does anyone see what I mean? Can someone convince me otherwise? Is this a good way to look at it?	
Elaborate Expand	25. ___ encourages students to use formal labels, definitions, and explanations provided previously 26. ___ encourages students to apply or extend concepts and skills in new situations 27. ___ reminds students of alternative explanations 28. ___ refers students to existing data and evidence and asks "What do you already know?" "Why do you think so?"	
Evaluate	29. ___ observes students as they apply new concepts or skills 30. ___ looks for evidence that students have changed their thinking or behavior (i.e., looks at prior knowledge of students at the engage phase) 31. ___ allows students to assess their own learning and group process skills 32. ___ asks open-ended questions, such as "Why do you think? What evidence do you have? What do you know about x? How can you explain it?" 33. ___ brings closure to the lesson/unit 34. ___ evaluates collective memory of the class using the KWL or KWEL chart 35. ___ encourages students to self-assess their own conceptual understanding/reasoning	

APPENDIX B
5E Unit Plan Outline

MARKING PERIOD:	GRADE LEVEL:	TIME FRAME:	STANDARDS/ THEMES:	ESSENTIAL QUESTIONS:

5E PHASES	EXAMPLES OF LEARNING EXPERIENCES	LEARNING EXPERIENCES	MATERIALS
ENGAGE/ELICIT 1. states the purpose of the lesson & expectations for learning 2. creates curiosity & gets students' attention/focus 3. raises appropriate questions 4. elicits responses that uncover prior knowledge of the concept 5. identifies & records student thinking including any misconceptions 6. creates opportunities for students to question/ wonder	* brainstorming * concept mapping/KWL * question production * discrepant event * demonstration * open-ended questions	Learning Objective: Activity: Formative Assessment	
EXPLORE 7. encourages students to work together without direct instruction from the teacher 8. provides common experiences for all to participate on a level playing field 9. observes and listens as students raise questions, develop hypotheses, collect evidence & data, and record/ organize information 10. asks probing questions to redirect students' investigations when necessary 11. provides time for students to puzzle though problems and confront	* prioritize questions * group tasks * investigation * test ideas * research * learning centers	Learning Objective: Activity: Formative Assessment:	

their ideas 12. adds to the collective memory by recording student ideas			
EXPLAIN 13. encourages students to explain concepts and definitions in their own words 14. asks for justification (evidence) and clarification from students 15. directs lesson by formally providing definitions, explanations, & new labels 16. uses audio-visual or electronic resources to support explanation 17. uses students' previous experiences as the basis for explaining concepts 18. encourages student to student interaction regarding multiple interpretations of data 19. uses classroom norms and discussion etiquette to demonstrate respect for all ideas 20. uses metacognitive strategies to guide discussion 21. uses appropriate wait time after asking questions 22. uses questions that challenge another's thinking 23. uses questions that justify student thinking 24. uses questions that allow students to change their minds	* reporting/presenting * group discussion * providing information for concept names and definitions	Learning Objective: Activity: Formative Assessment:	
ELABORATE/EXPAND 25. encourages students to use formal labels, definitions, and explanations 26. encourages students to apply or extend concepts and skills in new situations 27. reminds students of alternative explanations 28. refers students to existing data and evidence	* further practical work * videos * debates * research * field trips	Learning Objective: Activity: Formative Assessment:	

EVALUATE 29. observes students as they apply new concepts or skills 30. looks for evidence that students have changed their thinking or behavior 31. allows students to assess their own learning and group process skills 32. asks open-ended questions 33. brings closure to the lesson/unit 34. evaluates collective memory of the class using the KWL or KWEL chart 35. encourages students to self-assess their own conceptual understanding and reasoning	* refining materials developed in the engage phase * open ended questions * reflection prompts * summary of learning	Learning Objective: Activity: Summative Assessment:	

Revised from http://bendigoeducationplan.wikispaces.com/E5+instructional+model