Science exploratoriums: Connecting pre-service teachers, practicing teachers, students, and university science educators

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ABSTRACT

Engaging students in inquiry-based learning is viewed by the science education community as the cornerstone of science education reform. Pre-service teachers often enter science methods courses in teacher education credential programs with significant trepidation of science, a lack of strong science content knowledge, a lack of confidence in science teaching, and negative attitudes about science. As a method to increase pre-service teachers' content knowledge and self-efficacy in science teaching and to promote inquiry and science learning supports for elementary students, interactive science exploratoriums were presented to fifth-grade students in elementary school settings in 2008, 2009, and 2011. Pre-service teachers' anecdotal reflections reveal that inquiry-based science teaching requires in-depth knowledge of content and pedagogy beyond what is required for a lesson, significant amounts of planning, and careful orchestration of differentiation to address culturally diverse student populations and learning styles. A perceived increase in teaching self-efficacy was also reported by pre-service teachers. Surveys given to fifth-grade Exploratorium participants indicate that hands-on and learning aspects of the Exploratorium were highly regarded as was enjoyment. Survey data related to fifth-graders' experiences in having conducted science experiments and collecting data prior to the Exploratorium were also analyzed. Open ended response surveys given to fifth-grade teachers indicate that teachers demonstrate some understanding of inquiry teaching and learning but fail to clearly address or describe the essential features of classroom inquiry. The results support research findings that practicing elementary teachers may not have a firm understanding of inquiry or knowledge of how to implement it.

Key words: Pre-service teachers, teacher preparation, science inquiry, elementary science methods

INTRODUCTION

Engaging students in inquiry-based learning is viewed by many in the science education community as the cornerstone of science education reform. According to the National Research Council (NRC, 2000), the focus and methods of inquiry serve as a pathway to effective science teaching when centered on high-level teacher performance and knowledge indicators with the goal of helping both students and teachers understand inquiry to build a conceptual understanding about science. In the current conceptual framework for new K-12 science education standards, the National Research Council (2011, p. viii) underscores the need for "integrating the ideas of science with engagement in the practices of science" with special attention given to the practices of engineering. Inquiry, therefore, is now viewed from the perspective of scientific practices.

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. As a pivotal strategy intended to teach science for understanding, inquiry teaching scaffolds science learners by providing opportunities to engage in scientifically oriented questions to formulate explanations based on evidence. Inquiry-based approaches support learners in developing deeper understanding of subject matter content and scientific skills and habits of mind (NRC, 2000). In relation to the science classroom, inquiry learning refers to activities through which knowledge and understanding of scientific ideas and the processes used by scientists to study the natural world are developed by students (National Research Council, 1996). Therefore, inquiry is intended to be a goal of science learning by students as well as a pedagogical method used by teachers (NRC, 2000).

Organizations that serve as the public voice for reform in science education (e.g., American Association for the Advancement of Science, National Science Teachers Association, Association for Science Teacher Education, National Research Council) underscore the need for teachers to be well-versed in the methods of reform-oriented science education to motivate and steer students to enter science, technology, engineering, and mathematics (STEM) career paths. In addition to providing students with opportunities to become scientifically literate citizens, preparation for STEM-related careers allows students to increase their post-secondary career options to enter fields that hold the key to meeting many of humanity's most pressing and current challenges (NRC, 2011). Too few contemporary people in the United States are equipped with the necessary knowledge, skills, and scientific know-how to meet current demand for highly-skilled workers (Dorph, Tiffany-Morales, Hartry, & McCaffrey, 2011).

Notwithstanding the ongoing call of the National Research Council (NRC, 2000, 2007, 2011) for science education reform, the science education community still struggles with what inquiry instruction and learning should consist of and what best supports the development of science content learning and pedagogical practices. Despite debates about the role and purpose of scientific inquiry as an instructional strategy (e.g., Johnson, 2008; Settlage, 2007), standards documents continue to strongly advocate for scientific inquiry to play a more central role in science education (e.g., American Association for the Advancement of Science, 1993; National Research Council, 1996; National Science Teachers Association, 2007). Nonetheless, inquiry in science classroom still tends to be the exception and not the rule (Campbell, Abd-Hamid, & Chapman, 2010).

Exacerbating the dearth of high-level science instruction in elementary schools is the divide that exists between high- and low socioeconomic school districts. Marx and Harris (2006) point out that inquiry-based science instruction, with its attendant interactive processes and problem solving contexts, occurs mostly in affluent and suburban schools because considerable time is dedicated to high-stakes preparation, particularly in schools under improvement status due to low performance. A stronger emphasis in elementary classrooms is placed on mathematics and language arts in preparation for high-stakes testing every year. Regrettably, science education tends to be given less attention. The authors furthermore describe the conflict between the pressure for students to perform well in high-stakes tests--especially in low-performing schools--and the expectations placed on schools to respond to the national science standards to prepare students to engage in scientific inquiry.

Inquiry learning is particularly important for young learners who are constructing a foundational bedrock of knowledge on which future knowledge will be built (Peters & Gega, 2002). There is significant agreement among science educators that learning science content through inquiry is appropriate for students of all ages and is linked with inarguable positive outcomes such as the development and enhancement of research skills (Peters, 2010). The National Research Council (2007) reminds educators that young learners are underestimated in their ability to engage in thoughtful science learning. Indeed, children are quite capable of learning science and come to school as early as Kindergarten with an impressive capacity to learn, including engaging in scientific thinking, and "develop a rich understanding of how uncertainty enters into scientific inquiry" (Metz, 2004, p. 219). Because they engage and interact with the natural world, young learners have cognitive skills on which to build on as they enter elementary school (National Research Council, 2007). Unless teachers engage students in meaningful scientific investigations as students progress through school learning, interest in science will likely be lost to traditional, less investigate methods of science learning (Watters & Dietzmann, 2007).

Rutherford (1964) emphasizes that science teachers cannot be educated to teach science until they are well versed in the history and philosophy of science and until they perceive scientific inquiry as part of the content of science. Sandifer and Lottero-Perdue (2010) contend that although the existence of inquiry-based science teaching spans decades as a teaching strategy, the concept remains elusive to practicing and prospective teachers. Science methods courses in teacher preparation programs should, therefore, equip pre-service teachers with the skills, knowledge and dispositions to teach science using the practices of science that help their students examine the natural world to develop strong conceptual understanding of science in its many facets. The focus of this paper is to provide a background, rationale, and description of a creative instructional approach used in the researcher's elementary science methods courses that scaffolds pre-service teachers to engage in inquiry practices while concurrently modeling good scientific habits of mind for elementary students.

SCIENCE INQUIRY AND THE CLASSROOM LEARNING ENVIRONMENT

In response to concerns regarding the purposes, planning, and implementation of inquiry in science teaching and learning, the National Research Council (NRC, 2007) suggests that students need to derive learning based on four strands of scientific practice that comprise the knowledge and skills students need for in-depth science learning: (a) know, use, and interpret scientific explanations of the natural world, (b) generate and evaluate scientific evidence and, explanations, (c) understand the nature and development of scientific knowledge, and (d) participate productively in scientific practices and discourse (p. 51). The four strands are interrelated as students develop scientific understanding across grade levels (NRC, 2007) and when considered together, are able to provide students with rich opportunities to enact solid scientific practice. In regards to teaching, Sandifer and Lottero-Perdue (2010) describe four principles of inquiry-based practice to help teachers determine the extent of inquiry in a given lesson. Inquiry-based teaching (a) begins with a question, (b) is student-centered, (c) involves deep thinking about answers to inquiry questions, and (d) emphasizes evidence-based reasoning. Elmore (1997) asserts that increasing students' engagement in learning is tied to curriculum, instructional tools and materials, and strategies for teaching.

The National Research Council (1996) has long proposed that instructional design move from demonstration to active participation, from the management of materials to the management of ideas, and from the use of a single process skill to the use of multiple process skills. Harris and Rooks (2010) admit that these proposed, ambitious goals require careful and different classroom management systems. The researchers offer a pyramid model to describe five interconnected components that define a science inquiry classroom: (a) students, (b) tasks, (c) science ideas, (d) materials, and (e) classroom community.

Classroom Discourse and Science Inquiry

A general consensus exists in the literature related to discourse in science that teachers should develop understanding of the different kinds of discourse needed to explore ideas, compare explanations, and evaluate evidence. Gyllenpalm, Wickman, and Holmgren (2010) explain that discourse in science learning is an essential component of science inquiry that affects students' view of the nature of science. According to Lemke (1998), learning science involves learning to talk science. Lemke (2001) also asserts that conceptual learning is mediated by written and spoken discourse that should complement the visual, mathematical, and linguistic components that characterize science. Discourse that supports reasoning is valued in science because it leads to the development of scientific argument, but unfortunately is absent in many classrooms. However, Yore, Bisanz, and Hand (2003) observe that discourse in science classrooms is unfocused and is of low quality and quantity. Students who are only exposed to lecture and discussion contexts for science learning, for example, do not develop the necessary skills and dispositions for inquiry learning and practices, and hence may need to be oriented to scientific habits of mind (Zachos, Hick, Doane, & Sargent, 2009).

Teacher-centered classrooms give little opportunity for students to engage in science-related discourse and metacognition related to their learning (Peters, 2010). Alexander (2005) argues that classroom discourse is generally dominated by teachers, and scant classroom discourse is dedicated to talk that promotes reasoning. For teachers to be able to teach the scope of content, processes, and skills required in science inquiry, the use of discourse is particularly significant. Consequently, teachers need to develop functional language that goes beyond helping students learn factual knowledge but instead helps them to formulate intellectually active arguments and reasoning based on evidence.

In a study of eighth-grade students' discourse during science instruction over a nine-week chemistry unit, Chin (2001) reveals that students' level of questioning was directly related to the quality of their thinking and conceptual understanding. Open-ended problem-solving activities elicited higher level questioning than teacher-directed activities. Teachers, therefore, need to know how to support students to develop the cognitive and social skills and dispositions needed to navigate an environment that requires high expectations and performance levels (Holbrook & Kolodner, 2000).

Problem-Solving in Classroom Inquiry

Inquiry learning often requires students to engage in scientific problem solving and open-ended inquiry. Wells (2001) describes open inquiry as relevant questions posed by learners leading to tentative answers that should then be taken into consideration for careful investigation. The researcher argues for students determining the importance of asking relevant questions that are worthy of investigation. In such a setting, students make choices about which scientific problems to pursue, how to approach and conduct investigations as well as which resources and tools they will use. Students should be helped to "articulate their ideas and explanations, reason from data, and improve the quality of their argumentation" (Lunetta, Hofstein, & Clough, 2007, p. 403). In addition, students are encouraged to collectively construct scientific knowledge within a social context. When students' work and conceptual understandings are validated by peers, confidence in the validity of their work increases (Peters, 2010).

Flick (2004) reminds that inquiry learning calls for a broad spectrum of cognitive, physical, and social skills not used in teacher-centered learning, and learning goals should be relevant and meaningful to science learning. Unless these complex aspects of inquiry learning are effectively orchestrated and managed, students will receive "an authoritative picture of how the world works" (Anderson, 2002, p. 9), will view science learning as a collection of scientific facts that need to be provided to them instead of discovering science concepts and ideas by themselves (Chin & Brown, 2000), and will be ill-prepared to engage in inquiry (Flick, 2004).

CHALLENGES TO PRE-SERVICE TEACHERS IN TEACHER PREPARATION PROGRAMS

"Although there are exceptions, the overwhelming majority of subject matter courses for teachers and teacher education courses in general, are viewed by teachers, policy makers, and society at large as having little bearing on the day-to-day realities of teaching and little effect on the improvement of teaching and learning" (Ball, Thames, & Phelps, 2008, p. 404). Kennedy (1999) and Feiman-Nemser and Buchman (1986) acknowledge a disconnect between acquiring knowledge that is learned in teacher preparation coursework and applying that knowledge in the classroom.

Ball, Lubienski and Mewborn (2001) suggest that whatever is learned by pre-service teachers in their preparation programs tends to be "washed out" in their field placement settings (p. 437). Novice teachers often describe their teacher preparation coursework as not well connected to their fieldwork (Darling-Hammond, 2006) and methods courses as lacking in intellectual substance and not sufficiently connecting theory to practice (Bransford, Brown, & Cocking, 2000). Clift and Brady (2005) likewise acknowledge incongruencies between coursework and field experiences.

Pre-service teachers exit teacher preparation programs with knowledge of inquiry-based constructivist science teaching methods but often abandon these approaches in favor of traditional approaches to science instruction (Gilbert, 2009). A study by Smith and Gess-Newsome (2004) that focused on how adequately teacher education programs were preparing elementary science teachers found that, although science teachers plan inquiry-based lessons for their students, their professed understanding of what constituted inquiry in an elementary classroom was not uniform. Science methods courses in teacher preparation programs, therefore, need to seek creative ways of helping pre-service teachers overcome their fear of teaching science while concurrently equipping them with the necessary knowledge, skills, and dispositions to appropriately teach inquiry-based science.

According to Bybee (2010), when science educators can determine what citizens should know, value and be able to do to prepare for 21st century life and work, only then can they know how to plan to teach science. Elmore (1997) explains that there are only three ways to improve student learning to make a significant difference: (a) increasing students' active learning, (b) increasing the level of and emphasis on content, and (c) increasing teachers' knowledge and skills in teaching content. The author further asserts that change is not possible without changing the instructional core consisting of students, teachers, and learning outcomes. Increasing students' engagement in learning is tied to curriculum, instructional tools and materials, and strategies for teaching. Change in content is usually brought about by national, state or local organizations, and improving teachers' knowledge and skills through careful professional development can lead to increased student engagement (Elmore, 1997). "In sum, science education as currently structured does not leverage the knowledge and capabilities students bring to the classroom. For students from diverse backgrounds, this problem is even more profound" (National Research Council, 2007, p. viii).

PRE-SERVICE TEACHERS' CHALLENGES IN SCIENCE LEARNING

Pre-service teachers often enter science methods courses in teacher education credential program with significant trepidation of science, a lack of strong science content knowledge, a lack of confidence in science teaching, and negative attitudes about science in general. This researcher observes that the lack of confidence may result in part from (a) limited science content background, (b) being taught science in a lecture and "teaching as telling" approach, and (c) pre-service teachers' lack of observations of science teaching in elementary schools. The combination of these deficits may impede teacher candidates from planning high-level learning experiences for their students and teaching science for understanding in their practicum classrooms. The deficits may also lessen the probability that they will understand inquiry as a valuable method in teaching science for conceptual understanding.

Self-Efficacy Challenges

Helping pre-service teachers overcome their perceived or real fears towards science teaching requires careful incorporation of strategies that address these issues. In addition, careful scrutiny and examination of their background content knowledge, attitudes toward science, and self-efficacy in science teaching are called for as starting points to plan learning experiences that build on current knowledge and enhance confidence to teach K-8 science concepts. Providing pre-service teachers with meaningful teaching experiences that are geared for motivating and inspiring young learners is essential for boosting prospective teachers' self-efficacy.

Another factor challenging pre-service teachers is that they are often overwhelmed with the vast amounts of knowledge and skills that they must learn in a brief period of time to become practicing teachers who will eventually teach science (among other subjects): learning science content, planning curriculum in alignment with state content standards, learning pedagogical methods related to teaching science for understanding, knowledge of theories about how children learn, effective assessments methods, differentiating instruction, using technology to enhance science learning, and understanding the processes and skills germane to scientific inquiry (Schwartz & Gwekwerere, 2007). In addition, elementary science methods courses traditionally span one semester of learning, which further underscores the need to provide pre-service teachers with needed support to manage these cognitively demanding requirements.

Inquiry Learning Challenges

According to Fulp (2002), elementary teachers feel unqualified to teach science more than any other subject for which they are responsible in a self-contained classroom. Elementary teachers often lack an understanding of inquiry and do not have the skills or experiences to effectively teach science through inquiry (Crawford, 2000; Lederman & Niess, 2000). Keys and Kennedy (1999) describe an elementary teachers' difficulty in balancing inquiry-based instruction with district-mandated curriculum materials and assessment strategies. Spector and Strong (2001) hold that pre-service teachers accustomed to scripted, direct instruction have difficulty learning through inquiry and are more likely to have difficulty in helping their future students learn through inquiry.

Windschitl and Thompson (2006) conclude that pre-service science teachers perceive inquiry-based science as a difficult component of teaching science for deep understanding. In a study on the effectiveness of teacher preparation programs on elementary science teachers, Smith and Gess-Newsome (2004) find that, although science teachers plan inquiry-based lessons for their students, their understanding of what constitutes inquiry in an elementary classroom is not clearly understood.

Spector, Burkett, and Leard (2007) report that pre-service teachers cling closely to beliefs about teaching and learning and often resist ideas related to teaching science through inquiry. Not surprisingly, recent attempts to develop understanding of science inquiry in pre-service teachers have met with mixed results (e.g., Crawford & Cullen, 2004; Davis, 2006; De Jong & Van Dreil, 2001; Justi & Van Dreil, 2005). Schwartz & Gwekwerere (2007) determined that pre-service teachers initially had difficulty in understanding the nature and purpose of science inquiry models for teaching, and at the end of the methods course, varied in the extent to which they aligned lesson plans with an inquiry model used in the study. However, a significant number (two-thirds) of pre-service teachers shifted their teacher centered, direct teaching approaches to using conceptually focused, inquiry and guided inquiry.

Gess-Newsome (2002) argues that teachers' understanding of the nature of science (NOS) and science inquiry (SI) may be positively linked to the use of the teaching methodologies advocated by the current science education reforms. The researcher describes an elementary science methods course in which pre-service teachers' science lessons reflected a purposeful interweaving of science content, the NOS, science inquiry (SI), and science pedagogy. Gess-Newsome (2002) determined that teachers' conceptions of science as primarily a body of knowledge changed to an appropriate blend of scientific products and processes as a result of an active approach to scientific inquiry.

In a multi-year study (Fazio, Melville, & Bartley, 2010) of secondary pre-service teachers' perceptions of inquiry-based science teaching, the field practicum proved to be minimally supportive of pre-service teachers' learning of scientific inquiry as obtained in their science methods course. However, beginning teachers are capable of teaching inquiry-based science if adequate preparation and support are provided in their teacher preparation programs (Crawford, 1999; DeHaan, 2005). The researchers propose that support should consist of exploring the nature of science, active involvement in science investigations, clinical experience in classrooms that model inquiry-based teaching and planning of lessons and units that elucidate core scientific concepts.

To address the concerns that science educators have regarding pre-service teachers' tenuous understanding of inquiry, teacher education researchers (e.g., Schwartz & Gwekwerere, 2007) suggest the need for pre-service teachers to engage in the construction of inquiry-based instructional materials in science methods courses of teacher preparation programs. Davis (2006) maintains that developing pre-service teachers' ability to analyze and modify instructional materials is essential to helping them to examine the value of those materials and revise them to promote students' increased learning of science. Duncan, Pilitsis, and Piegaro (2010) agree that pre-service teachers in teacher preparation programs be trained in the ability to evaluate, adapt, and create inquiry-based instructional materials.

A study of two consecutive science methods courses focused on developing such skills in pre-service teachers by using inquiry-based teaching methods determined that pre-service teachers' ability to critique lessons and revise them to reflect greater inquiry practices increased over the span of both courses. Pre-service teachers' involvement in instructional design may increase their ability to shift from teacher-centered to student-centered lessons as reflected in their lesson critiques and revisions (Duncan, Pilitsis, & Piegaro, 2010). In addition to strengthening the ability to plan inquiry learning experiences, assessing and adapting inquiry curriculum materials allows pre-service teachers to (a) gain understanding of how such materials are developed, (b) gain insights to the composition of sound instructional materials, and (c) engage in valuable experiences in adapting these materials while preserving the intent, soundness, and reliability of the materials (Brown & Edelson, 2003).

According to Schwartz and Gwekwerere (2007), a cause for pre-service teachers' difficulty with science inquiry may be that they often enter science methods courses with preconceived ideas of science, pedagogical methods, and strong teaching orientations that may conflict with inquiry teaching. Therefore, these attitudes and beliefs need to be addressed and reflected on while providing pre-service teachers with inquiry teaching models to consider (Friedrichsen & Dana, 2003).

INQUIRY AS A FRAMEWORK TO PLAN SCIENCE INSTRUCTION

Derived from work that expands the National Science Education Standards (NRC, 1996) to focus on inquiry as a way to (a) learn science, (b) learn to do science, and (c) learn about science, the National Research Council (2000, p. 29) provides a framework for the essential features of classroom inquiry and their variations in science teaching and learning. Pre-service teachers learn that there are many strategies in teaching science that effective teachers of science should know and be able to demonstrate.

Although inquiry is not the only strategy for teaching science, pre-service teachers learn that inquiry as a learning goal and as a teaching method is essentially valuable in addressing the fundamental abilities of inquiry and the fundamental understandings of inquiry as delineated in the National Science Education Standards (NRC, 1996). The Standards characterize an ideal and comprehensive view of what science teaching should be and how students should learn. Therefore, the framework proposed by NRC (1996) places inquiry in the context of the science classroom as it relates to teaching and learning. The degree of inquiry may vary depending on how much structure is provided by the teacher or "the extent to which students initiate and design an investigation" (NRC, 1996, p. 28). According to the National Science Education Standards (NRC, 1996), inquiry-based learning includes:

> A multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

THE SCIENCE EXPLORATORIUM AS A TOOL TO PROMOTE INQUIRY

Background

Pre-service teachers in the California State University San Marcos College of Education teacher credential program mirror the limitations reflected in the literature of scant science content knowledge and exposure to quality science learning on entering the program. Most recount their science learning as traditional and lecture-based with little or no connection to hands-on learning experiences. Therefore, little science content has been retained in memory in spite of required science courses in high school and college. Furthermore, this researcher has observed in science methods courses that many pre-service teachers do not have sufficient knowledge of basic science content to explain simple phenomena such as the cause of lunar phases or the seasons.

A further, exacerbating dilemma is that although the Science Framework for California Public Schools (California Department of Education, 2004) specifically mandates the teaching of science in grades Kindergarten through twelfth grade, elementary science teaching is generally lacking in grades K-5. Unfortunately, it is not until fifth grade that elementary students are tested for the first time in science in a standardized manner for science content knowledge in fifth grade. Therefore, students in K-5 may be at risk of receiving inadequate science instruction due to the overarching emphasis on reading and mathematics in favor of science instruction.

In the researcher's clinical practice observations of elementary pre-service teachers engaged in science teaching, science lessons are, for the most part, contrived and do not reflect inquiry-based teaching and learning practices. In their clinical practice, pre-service teachers rarely observe inservice teachers teaching science, let alone observing inquiry-based science. Pre-service teachers resort to teaching science lessons in an artificially arranged context for the purpose of being observed and assessed by their clinical practice supervisor. Hence, pre-service teachers need (a) strong support to overcome their perceived fear of teaching science, (b) to build self-efficacy in teaching and learning, (c) deeper knowledge of science content and skills and how to teach content, (d) to develop deeper knowledge of specific science topics, especially those that challenge students, and (e) unique learning experiences in the practice of teaching science.

Scaffolding Pre-Service Teachers to Learn Aspects of Inquiry

To address the deficits in science that pre-service teachers often possess, teacher candidates (the name given by the State of California to matriculated pre-service teachers) enrolled in the Multiple Subject (MS) Credential Program of the School of Education of California State University San Marcos (CSUSM) are purposefully exposed to unique and creative ways to support their learning of science content to adequately develop their pedagogical content knowledge in relation to science teaching in their elementary practicum classroom. Not unlike what research related to pre-service teachers' challenges in science teaching and learning reveals (e.g., Crawford, 2000; Davis, 2006; Lederman & Niess, 2000; Schwartz & Gwekwerere, 2007; Windschitl & Thompson, 2006), teacher candidates in the CSUSM MS credential program are similarly challenged in their ability to learn how to effectively teach science for various reasons not the least of which is limited exposure to science learning for understanding.

Candidates often find themselves overwhelmed with learning and becoming facile with the various pedagogies that must be coupled with the science content that is mandated by the State of California (e.g., California Department of Education, 2004). In addition, pre-service teachers frequently find that science teaching requires significant amounts of planning, preparation, and science background knowledge to effectively implement hands-on, inquiry-based lessons in their practicum classrooms. Due to teacher candidates traditionally being ill-equipped with inadequate science content knowledge and because inquiry learning is poorly understood by them, candidates frequently resort to planning lessons that are directive and teacher-centered.

As previously mentioned in the review of the literature section of this paper, the National Research Council (1996) proposes that instructional design move from demonstration to active participation, from the management of materials to the management of ideas, and from the use of a single process skill to the use of multiple process skills. Therefore, teacher candidates need to learn how to support their own students to develop cognitive and social skills and dispositions needed to thrive in an environment that requires high expectations and performance levels (Holbook & Kolodner; 2000). As well, candidates need to learn how to effectively manage the various aspects on inquiry learning in diverse classrooms (Harris & Rooks, 2010) and how to promote high-level science discourse (Peters, 2010) in diverse classrooms.

In this researcher's science education methods courses, teacher candidates learn about five challenges to implementing inquiry-based learning: (a) motivating students, (b) accessibility of investigation techniques, (c) student background knowledge, (d) student management of extended activities, and (e) learning context constraints (Edelson, Gordon, & Pea; 1999). Candidates also learn about the proper use of technology to support teaching and learning in alignment with the International Society for Technology in Education (ISTE, 2007). Furthermore, candidates learn about constructing scientific knowledge that should occur within the social context of collaboration with peers.

Preparing for the Exploratorium

In this researcher's science methods courses in the teacher preparation program of California State San Marcos, pre-service teachers are exposed to teaching science to children through science Exploratoriums that are planned in collaboration with a peer and then presented at a local elementary school. Participating elementary schools are usually partner schools of the School of Education of California State University San Marcos in which cohorts of pre-service teachers are placed for credential coursework and tutoring purposes. However, if a cohort of pre-service teachings engages in credential coursework on-campus at the University, a participating school is contacted by the researcher to request its participation at that particular school.

The researcher's work prior to 2008 with presenting Exploratoriums at elementary schools did not target specific elementary grade levels, but instead worked with various grade levels chosen by the principals. For example, a principal might request that third or fourth grade students be accommodated, while another principal might indicate the choice of grades four and five to attend the Exploratorium. However, working with school principals and teachers to coordinate the logistics of the science Exploratorium presentations in elementary schools since 2008, the researcher currently requests that fifth-grade students participate in the Exploratorium, as this is the grade level in which they are first tested in fourth and fifth-grade science content using high-stakes assessments. The researcher's future plans include gathering data on standardized measures regarding fifth-grade students' science performance on the California Standardized Tests (CST) to examine if there is a positive relationship between participation in the science Exploratorium and science achievement as measured by the CST results. The CSTs were developed specifically to assess students' knowledge of the California content standards which specify what all students in California are expected to know and be able to do in each grade level and course.

In some participating schools, fifth-grade teachers may request the researcher to have pre-service teachers address specific science topics related to fourth- and fifth-grade science content standards. These are usually topics that either present difficulty to students or topics that will not be adequately covered before standardized testing commences. CSTs are conducted in the Spring of an academic school year, and most Exploratoriums are held in Spring as well. However, every Fall semester, one or two Exploratoriums are held at public elementary schools that do not have pre-service teacher cohorts placed there. In this case, these are on-campus California State University San Marcos School of Education cohorts for whom arrangements are made by the researcher to present an Exploratorium at a local elementary school.

The science Exploratorium presentations are the culmination of a process that begins with pre-service teachers working in pairs to first identify a discrepant event or an interesting science activity worthy of investigation that illustrates specific science concepts in alignment with the Science Content Standards for California Public Schools (California Department of Education, 2004) and with the Science Safety Handbook for California Public Schools (1999). Students essentially develop an inquiry-based mini-lesson activity appropriate for elementary students that is based on a discrepant event. The mini-lesson must conform to the elements of the Learning Cycle Model of Instruction (i.e., exploration, concept introduction, and concept application).

The essential features of inquiry as described by the National Research Council (2000) also provide a framework from which to plan instruction. Pre-service teachers then engage in active research and learn the science content related to the discrepant event or investigation to develop an in-depth understanding of the content. The Exploratorium, therefore, is designed to increase pre-service teachers' science content learning and a motivation to pursue more in-depth learning on a given topic.

The next step in the preparation process is to identify and craft essential questions relevant to the discrepant event or investigation that will focus students to important learning outcomes. During the Exploratorium, pre-service teachers are required to provide at least two essential questions to elementary students prior to starting the activities. Essential questions must be framed from the perspective of promoting high-order thinking skills in children in regards to a “big idea” in science. For example, an essential question for a lesson that focuses on sound and pitch might be, “Explain the relationship between frequency and pitch”. Or, “How does the thickness of a vibrating string affect the pitch?” An essential question for a lesson to prove the existence of air might be, “Explain how air can be proven to be a substance that occupies space”. Note that an essential question does not have to be posed as an interrogative statement.

Once science concepts and essential questions are identified based on researching the science topic and the content related to it, pre-service teachers are ready to create an abbreviated lesson plan consisting of the essential elements required by the course instructor: lesson title, grade level, science content area and subject matter, science concepts taught, essential questions, learning objectives, California science content standards and investigation and experimentation standards, materials and resources, and a description of all activities related to the learning cycle model of instruction (i.e., engagement, exploration, concept introduction, concept application). In addition, students must prepare an attractive, attention-getting trifold poster that should indicate science standards, essential questions, lesson objectives, science concepts, some science background information, and graphics that support student learning.

Engaging in the Exploratorium

Following is the development of a sequence of instructional steps that are used to teach grade-level elementary students. At the school site (usually in the multi-purpose room of a school), elementary students gather to engage in the Exploratorium activities at a specific time during the school day. There is usually a two hour window given for the Exploratorium, with one group of approximately 75-100 elementary students participating for one hour and another group of similar numbers participating the second hour. However, school sites may vary in the amount of time allocated to the Exploratorium. More time allocated translates to elementary students engaging with more Exploratorium lessons and concepts.

Groups of six to seven elementary students are placed at each of 12-14 Exploratorium stations (projects) arranged in “science fair” fashion, with two pre-service teachers responsible for one station. Pre-service teachers conduct their mini-lesson to the small group at their particular station for fifteen minutes after which students rotate to another station, and the mini-lesson is taught again. The mini-lesson is repeated several times with different groups of students for the duration of the hour so that students visit at least four stations within that time. The second shift of students is brought in, and the one-hour cycle of pre-service teachers teaching their respective mini-lesson to four groups of elementary students is repeated.

The grade-level students perform the activities and collectively generate explanations with the pre-service teachers. While the process is not different from the typical activities of a methods course, teaching the activity to elementary school children in a school setting provides pre-service teaches with unique learning about teaching science. Pre-service teachers’ learn that unless they are well-versed in the conceptual knowledge related to the science content of their project, participating students will have difficulty learning the intended concepts. In addition, pre-service teachers gather valuable insights related to students’ conceptions and learning difficulties (Smith & Neale, 1989). The Exploratorium component of the methods course allows pre-service teachers to develop deeper knowledge of specific topics in science and confidence in science teaching.

After the Exploratorium

Immediately after the Exploratorium, teacher candidates are debriefed by the researcher regarding their perceptions of teaching science to a number of students who may differ in learning styles, cognitive ability, and linguistic ability. Candidates are not aware of how students may differ in these aspects. Therefore, they are challenged to provide equitable, hands-on learning to students in a way that is clearly understood, engaging, motivating, and is based on good science for students. A consistent and interesting remark by most teacher candidates is that student behavior management issues are non-existent. Participating teachers are significantly astounded and consistently remark to the researcher that their "trouble makers" are engaged and enjoying learning science. Teachers of students with special needs comment that the Exploratorium levels the learning field for their students because they do not "stand out" from the general education students.

Data collection by the researcher is conducted immediately following the Exploratorium. For example, insights to participating elementary students' thinking regarding the purposes of the Exploratorium are gathered using a survey after the conclusion of the Exploratorium. Participating teachers are given the student surveys to conduct in their classrooms and are returned to the researcher. Students respond to questions related to what they liked about the Exploratorium, what was learned, and if they have ever done science experiments and collected data before the Exploratorium. Participating teachers are also given a survey to complete consisting of four open-ended prompts involving inquiry teaching. The context for data collection as it relates to the total number of schools, teachers, classrooms, and fifth-grade student participants in the Exploratorium for three distinct academic semesters are presented in Table 1, Table 2, and Table 3 (Appendix A).

The survey given to students after the Exploratorium consisted of four open-ended questions. An analysis of Questions 1, 2, and 4 is provided in this paper. The survey questions were:

1. What did you like about the science activities?
2. What did you learn today?
3. Before today, have you ever done science experiments?
4. Before today, have you ever collected science data?

The survey given to teachers during the Exploratorium consisted of four open-ended prompts. An analysis of prompts 1, 2, and 4 is provided in this paper. The survey prompts were:

1. Inquiry occurs when…
2. I promote inquiry learning in my class by…
3. My opinion of inquiry teaching is…
4. Some obstacles to inquiry teaching and learning are…

SURVEY RESULTS COMPARING FIFTH-GRADE EXPLORATORIUM PARTICIPANTS FOR SPRING 2009, SPRING 2011, AND FALL 2011

Table 4 (Appendix B) presents fifth-grade Exploratorium participants' responses to the survey question, "What did you like about the science activities?" Spring 2009 fifth-graders' responses to this question resulted in first and second largest frequencies for “learning” and “hands-on” aspects of the Exploratorium respectively. Spring 2011 fifth-grade largest frequencies reflected “learning” and “fun/cool/exciting” aspects of the Exploratorium. Fall 2011 participants mirrored the preferences of Spring 2009 participants in terms of first and second largest frequencies. However, a proportionally lower percentage of Fall 2011 participants than Spring 2009 participants expressed “learning” as a response to what they liked best about the science activities. In addition, a significantly lower percentage of Spring 2011 participants than Spring 2009 and Fall 2011 participants expressed “learning” as the aspect that they liked best. Interesting to note in the data is that significant numbers of fifth-grade students in all three groups considered learning as important to their engagement in the Exploratorium.

The “hands-on” response frequencies for all three groups were similar. Although Fall 2011 frequencies were lower in this category, a proportionally larger percentage is reflected in these frequencies. Spring 2011 frequencies were higher for the “fun/cool/exciting” response than for Spring 2009 and Fall 2011 responses in this same category. Proportionally, there was a significantly higher percentage of Spring 2011 fifth-graders than Spring 2009 and Fall 2011 fifth-graders that considered the Exploratorium as “fun/cool/exciting”. While Spring 2009 and Spring 2011 participants responded in equal proportions in the “other” category (which grouped “everything” responses and responses about a particular science activity), Fall 2011 participants responded in proportionally lower numbers to this category.

The data in Table 5 (Appendix C) relates to whether fifth-grade participants had ever done experiments prior to their participation in the Exploratorium. The data reveals that a higher percentage of Spring 2009 fifth-graders than Spring 2011 fifth-graders had previously done so, and therefore, a higher percentage of Spring 2011 fifth-graders had not done science experiments prior to the Exploratorium. However, a slightly higher percentage of Fall 2011 participants than Spring 2009 participants had done so. In regard to Spring 2011 participants, one-fifth had not ever done science experiments prior to the Exploratorium, a statistic not in alignment with the National Research Council’s (2007) missive that young learners should engage in thoughtful science learning. This researcher contends that science inquiry should begin in Kindergarten; delaying these experiences until fifth-grade puts students in a disadvantaged position of not developing and building the cognitive skills required to engage in scientific thinking. In addition, more than 10% of Spring 2009 and Fall 2011 fifth-graders had not done experiments before the Exploratorium.

Table 6 (Appendix D) presents data related to the survey question, “Before today, have you ever collected science data?” In relation to this question, it is interesting to note that a proportionally higher percentage of Spring 2011 fifth-grade participants (over two-fifths) than Spring 2009 and Fall 2011 fifth-grade participants had not done so when compared on respective student totals. Correspondingly, a lower percentage of Spring 2011 fifth-graders had ever collected science data. Proportionally, a higher percentage of Fall 2011 fifth-graders had collected data before the Exploratorium, and this percentage was slightly higher than that of Spring 2009 fifth-graders. Not surprisingly, a higher percentage of Spring 2011 participants than Spring 2009 and Fall 2011 participants had also not ever done science experiments, as the data in Table 5 (Appendix C) illustrates. This researcher contends that both a lack of experience in doing science experiments and a lack of experience in collecting science data place fifth-graders at a significant disadvantage in developing and building cognitive skills, reasoning, and analytical thinking required for meaningful engagement in science learning. A further, deleterious disadvantage is that these students will enter middle-school science courses with serious deficits and limitations.

SURVEY RESULTS COMPARING SPRING 2008 LOWER AND UPPER ELEMENTARY STUDENTS

The first year of this researcher collecting student data related to the science Exploratorium was in Spring 2008. Table 7 (Appendix E) represents data for four elementary public schools and four grade levels. At this time, the researcher had not yet decided to target fifth-grade students for the Exploratorium experience. As previously mentioned in this paper, the researcher's decision to present the experience to only fifth-grade participants after 2008 was based on fifth-graders in California being tested for the first time in science content. Therefore, the researcher wanted to provide support for the high-stakes testing that followed approximately one to two months after the Exploratorium.

The data reflect three salient themes (responses) that emerged for both lower elementary students (first- and second graders) and upper elementary students (fourth- and fifth graders). The researcher chose to compare the same three themes (responses) for lower elementary students as those salient responses that emerged most frequently for upper elementary students. It should be noted that the researcher did not include "other" as a response category.

Proportionally, "learning" was more highly regarded by lower elementary (LE) participants, while "cool fun" was more highly regarded by upper elementary (UE) participants as evidenced by the respective percentages within each group. Lower elementary participants equally regarded "fun/play" and "hands-on" aspects of the Exploratorium, while upper elementary regarded "fun" almost twice as much as they did "hands-on" aspects.

Table 8 (Appendix F) presents Spring 2008 data comparing lower elementary students to upper elementary students in regards to ever having done science experiments prior to the Exploratorium. Positive responses were proportionally higher for upper elementary students as reflected in the data. The results clearly point to the importance of providing exposure to science learning in early elementary grades. Forty percent of lower elementary students not having done science experiments speaks to the pressing need for elementary curriculum to include early intervention and exposure to science as proposed and encouraged by the National Research Council (2007). Although less than 10% of upper elementary students had ever done science experiments prior the Exploratorium, it may be argued that students should have exposure to high-level science in early elementary grades but most certainly by upper elementary grades to prepare students with a strong foundation for entrance into middle school science courses.

SURVEY RESULTS OF FIFTH-GRADE TEACHERS' RESPONSES ABOUT INQUIRY

Table 9 (Appendix G) presents combined results of an open-ended survey given to eleven participating teachers in the Spring 2011 (n = 7) and Fall 2011 (n = 4) Exploratoriums. The responses indicate that teachers demonstrate a somewhat cursory understanding of inquiry teaching and learning and fail to clearly address or describe the essential features of classroom inquiry and their variations in science teaching and learning (National Research Council, 2000, p. 29). Some participating teachers use the verbiage of inquiry, for example, "explore a question", "create understanding", "discover by doing", but do not describe how these actions could be accomplished. Their responses do not reflect an understanding of the continuum of inquiry as described by the National Research Council (2009) and others (e.g., Diaconu, Radigan, Suskavcevic, & Nichol, 2012). The survey responses furthermore support research findings that elementary teachers do not have a firm understanding of inquiry or knowledge of how to implement it. As the literature reveals, elementary teachers often lack an understanding of inquiry and do not have the skills or experiences to effectively teach science through inquiry (Crawford, 2000; Lederman & Niess, 2000).

Table 10 (Appendix H) provides participating teachers' responses to the survey prompt related to how they promote inquiry in their classroom. A majority of responses included some variation of using questions in inquiry, for example, "posing or asking questions", "students posing questions", "questioning students". These teachers appear to recognize that inquiry involves some aspect of posing and answering questions. However, some teachers perceived inquiry as students asking questions and finding answers on their own, but did not frame the response in the context of using evidence to answer questions, formulating answers based on evidence, connecting explanations to scientific knowledge, or communicating and justifying explanations (National Research Council, 2000). Another teacher perceived inquiry as "students asking their own questions and coming up with their own ideas". This researcher assumes that the response reflects the teacher's perceptions of students inquiring about a topic after the teacher provides instruction and information. Overall, the teachers' perceptions of inquiry based on survey responses did not go far enough to provide evidence of understanding inquiry as "the ability to formulate empirically answerable questions about phenomena to establish what is already known, and to determine what questions have yet to be satisfactorily answered" (Pratt, 2012. p. 11).

Teachers often give negative rationales for why using inquiry-based teaching approaches present challenges and impractical constraints. Similarly, Exploratorium teachers cited obstacles to promoting and implementing inquiry in their classrooms as (a) test-driven school environments that emphasize math and language arts but not science, (b) time constraints to prepare science curriculum and materials and to locate effective resources, (c) lack of teacher preparation and motivation, and (d) challenges to classroom management and student behavior (Table 11, Appendix I). In this researcher's interactions with elementary science teachers, the lack of administrative support in providing time to plan and prepare science curriculum is also cited anecdotally as an obstacle to inquiry teaching and learning. In addition, teachers express fear of failure and risk-taking in using inquiry as an approach to teaching science. Arguably, this may be due to elementary teachers feeling unqualified to teach science more than any other subject for which they are responsible in a self-contained classroom mainly due to minimal science content background (Fulp, 2002).

Notwithstanding the trepidation teachers feel about teaching science through inquiry, all participating Exploratorium teachers overwhelmingly expressed great excitement about the Exploratorium and were highly encouraged by the excitement and motivation to learn that was clearly being experienced by their students. In subsequent discussions with the teachers, the researcher learned that teachers appreciated that they could refer to the Exploratorium experiences when teaching science topics to their students. Teachers were motivated to learn more about inquiry and planned to implement it in their future teaching of science. Anecdotal comments from teachers also included asking why the students could not have more experiences like the Exploratorium. As well, several teachers commented how their struggling and oftentimes unmotivated students were now motivated to learn science. For these teachers, teaching science in the spirit of learning for enjoyment is preferable to teaching in a teacher-centered, directive fashion.

CONCLUSION

Through the Exploratorium experiences, pre-service teachers acknowledge anecdotally that science teaching requires (a) an in-depth knowledge of content and knowledge of how to teach the content, (b) content knowledge beyond what is required for a lesson, (c) differentiating instruction to accommodate prior knowledge and the variety of learning styles, (d) significant amounts of planning and preparation, and (e) effective teaching methods for culturally and linguistically diverse student populations that need to be carefully planned and orchestrated using protocols designed to address the learning requirements of English learners and students with special needs. In addition, pre-service teachers acknowledge that every subsequent iteration of teaching their lesson results in confidence-building, an increase in self-efficacy in teaching science, and a more positive attitude towards science teaching and learning, as they become "experts" on their science topic and are motivated to continue learning.

Through the Exploratorium experiences, practicing teachers find that science learning is very engaging to students and that there is strong retention of what their students learn in terms of science content. Even students who typically show scant interest in classroom learning are highly motivated and engaged during the Exploratorium. Pre-service teachers note that student behavioral issues or management problems are virtually non-existent and that there is a level playing field during the Exploratorium as high ability students are not distinguished from students who struggle academically. Some students with special needs may need accommodations but do not "stand out" from the general education population. As well, pre-service teachers acknowledge that (a) instructional differentiation is essential for students to succeed in learning science, (b) peer collaboration promotes good science learning, and (c) science learning in a science Exploratorium context is a strong support to prepare students for high-stakes testing.

Through the Exploratorium experiences, elementary students learn that (a) scientists have special methods and tools they use to investigate scientific questions and problems, (b) hands-on learning is enjoyable and helps them understand and remember science concepts, (c) "doing" science is preferred to simply reading about science, (d) science has many everyday applications, (e) peer collaboration helps learning, and (f) they wish to explore more science topics. The positive aspects of hands-on, active learning in a collaborative setting clearly promote positive dispositions for science in students.

Through preparing pre-service students to teach using inquiry methods for the Exploratorium experience, science educators learn that support for all aspects and phases of the planning process is required, especially during initial brain-storming of ideas for lessons. Science educators need to formatively assess pre-service teachers' lesson ideas for accuracy and for scientific value to provide elementary students with essential connections to inquiry learning. During the science methods course and prior to the Exploratorium, science educators need to often model good science lessons that mirror inquiry. The provision of numerous opportunities provided to pre-service teachers to learn science content and practice teaching it is essential for them to plan strong science learning experiences for their future elementary students. Finally, science educators need to ensure that pre-service teachers have access to high-level resources and that they critically assess and evaluate them to ensure alignment with the Science Content

Standards for California Public Schools (2004) and to ensure alignment with the spirit of inquiry learning.

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APPENDIX A

Table 1

Fifth-Grade Exploratorium Participants: Spring 2009

Schools	Teachers	Classrooms	Grade 5 Students
n = 2	n = 6	n = 6	n = 199

Table 2

Fifth-Grade Exploratorium Participants: Spring 2011

Schools	Teachers	Classrooms	Grade 5 Students
n = 2	n = 6	n = 6	n = 163

Table 3

Fifth-Grade Exploratorium Participants: Fall 2011

Schools	Teachers	Classrooms	Grade 5 Students
n = 1	n = 4	n = 4	n = 128

APPENDIX B

Table 4

Fifth-Grade Students' Salient Responses to Survey Question 1: What did you like about the science activities?

Spring 2009 n = 199	Frequency (% of Total)	Spring 2011 n = 163	Frequency (% of Total)	Fall 2011 n = 128	Frequency (% of Total)
Hands-On	40 (20.10)	Hands-On	39 (23.93)	Hands-On	35 (27.34)
Learning	116 (58.29)	Learning	69 (42.33)	Learning	67 (52.34)
Fun/ Cool/ Exciting	27 (13.57)	Fun/ Cool/ Exciting	41 (25.15)	Fun/ Cool/ Exciting	23 (17.98)
Other (including "everything")	16 (8.04)	Other (including "everything")	14 (8.59)	Other (including "everything")	3 (2.34)
Total	199	Total	163	Total	128
Percentage of Total Participants	(100)	Percentage of Total Participants	(100)	Percentage of Total Participants	(100)

APPENDIX C

Table 5

Fifth-Grade Students' Salient Responses to Survey Question 3: Before today, have you ever done science experiments?

Academic Year	Yes	Percentage of Total	No	Percentage of Total	No Response	Percentage of Total
Spring 2009 (n = 199)	169	84.92	26	13.07	4	2.01
Spring 2011 (n = 163)	129	79.14	33	20.25	1	.61
Fall 2011 (n = 128)	110	85.94	17	13.28	1	.78

APPENDIX D

Table 6

Fifth-Grade Students' Salient Responses to Survey Question 4: Before today, have you ever collected science data?

Academic Year	Yes	Percentage of Total	No	Percentage of Total	No Response	Percentage of Total
Spring 2009 (n = 199)	135	67.84	60	30.15	4	2.01
Spring 2011 (n = 163)	91	55.83	70	42.94	2	1.23
Fall 2011 (n = 128)	88	68.75	35	27.34	5	3.91

APPENDIX E

Table 7

Elementary Students' (Spring 2008) Salient Responses to Survey Question 1: What did you like about the science activities?

Lower Elementary (Grades 1,2) n = 175	Frequency (% of Total)	Upper Elementary (Grades 4, 5) n = 120	Frequency (% of Total)
Fun and Play	19 (10.86)	Cool Fun	39 (32.5)
Hands-On	19 (10.86)	Hands-On/Experiments	21 (17.5)
Learning	25 (14.28)	Learning	28 (23.33)
Total	63	Total	88
Percentage of Total Lower Elementary Participants (n)	(36)	Percentage of Total Upper Elementary Participants (n)	(73.33)

APPENDIX F

Table 8

Elementary Students' (Spring 2008) Salient Responses to Survey Question 2: Before today, have you ever done science experiments?

	Yes	No		Yes	No
Lower Elementary n = 175	105	70	Upper Elementary n = 120	109	11
Percentage of Total	60	40	Percentage of Total	90.83	9.17

APPENDIX G

Table 9

Spring 2011 and Fall 2011 Exploratorium Teachers' Responses to Survey Prompt 1: Inquiry occurs when…

Teacher Responses (n = 11)	Frequency
Students create their own understanding to investigate what interests them.	2
Students explore their learning in their own way.	2
Students are presented with a guided question & students allowed to explore how it might be solved.	3
Children discover by doing.	2
Students look into a problem and use a variety of strategies to find a response to the inquiry.	1
Students use the scientific method and pose a question then do activities to figure it out.	1

APPENDIX H

Table 10

Spring 2011 and Fall 2011 Exploratorium Teachers' Responses to Survey Prompt 2: I promote inquiry learning in my class by…

Teacher Responses (n = 11)	Frequency
Trying not to give the "full information—save the punch line for last to see if they can figure it out."	1
Questioning students	1
Posing a question or a situation to explore alone or collaboratively	1
Engaging in a series of questions with students so they can come up with their own answers	1
Students ask questions and find answers on their own after we have just begun learning about something.	1
Using interactive journals in science, social studies, math for students to ask their own questions and come up with own ideas	1
Through learning menus, current events, mini science fair.	1
Using anticipation guides	2
Science experiments and novel projects	1
No Response	1

APPENDIX I

Table 11

Spring 2011 and Fall 2011 Exploratorium Teachers' Responses to Survey Prompt 4: Some obstacles to inquiry teaching/learning are…

Teacher Responses (n = 11)	Frequency
Test-driven environment—the vocabulary on the CA Standards Test needs to be understood.	3
Time and not having materials and facilities.	5
Lack of teacher preparation, motivation and fear of failure and taking risks.	1
Behavior and classroom management.	1
No response	1