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ORIGINAL PAPER

A well-started beginning elementary teacher's beliefs and practices in relation to reform recommendations about inquiry-based science

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Abstract Given reform recommendations emphasizing scientific inquiry and empirical evidence pointing to the difficulties beginning teachers face in enacting inquiry-based science, this study explores a well-started beginning elementary teacher's (Sofia) beliefs about inquiry-based science and related instructional practices. In order to explore Sofia's beliefs and instructional practices, several kinds of data were collected in a period of 9 months: a self-portrait and an accompanying narrative, a personal philosophy assignment, three interviews, three journal entries, ten lesson plans, and ten videotaped classroom observations. The analysis of these data showed that Sofia's beliefs and instructional practices were reform-minded. She articulated contemporary beliefs about scientific inquiry and how children learn science and was able to translate these beliefs into practice. Central to Sofia's beliefs about science teaching were scientific inquiry and engaging students in investigations with authentic data, with a prevalent emphasis on the role of evidence in the construction of scientific claims. These findings are important to research aiming at supporting teachers, especially beginning ones, to embrace reform recommendations.

Keywords Beginning elementary teachers · Inquiry-based science · Reform recommendations

Περίληψη Η παρούσα εργασία στηρίζεται σε σύγχρονες εισηγήσεις για εκπαιδευτική μεταρρύθμιση στις Φυσικές Επιστήμες, οι οποίες δίνουν έμφαση στη μάθηση μέσω διερεύνησης, καθώς επίσης και σε ερευνητικά ευρήματα τα οποία καταδεικνύουν τις δυσκολίες που αντιμετωπίζουν οι νέοι εκπαιδευτικοί δημοτικής εκπαίδευσης. Βασισμένη στη μεθοδολογική προσέγγιση της μελέτης περίπτωσης,

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η εργασία αυτή εξετάζει τις πεποιθήσεις και τις διδακτικές πρακτικές μίας εξαίρετης εκπαιδευτικού, της Σοφίας, για τη μάθηση μέσω διερεύνησης. Σε χρονική περίοδο εννέα μηνών, είχαν συλλεχθεί δεδομένα από ποικιλία μεθόδων: προσωπικό πορτραίτο και γραπτή εργασία, προσωπική φιλοσοφία διδασκαλίας, τρεις συνεντεύξεις, τρία αναστοχαστικά ημερολόγια, δέκα σχέδια μαθήματος και δέκα βιντεοσκοπημένα μαθήματα. Η ανάλυση των δεδομένων υποδεικνύει πως τόσο οι αντιλήψεις όσο και οι διδακτικές πρακτικές της Σοφίας εμπεριείχαν χαρακτηριστικά πλαισιωμένα από μεταρρυθμιστικές εισηγήσεις. Στο επίκεντρο των πεποιθήσεων της Σοφίας βρισκόταν η εμπλοκή των μαθητών σε επιστημονικές διερευνήσεις με αυθεντικά δεδομένα με σκοπό την ανάπτυξη επιστημονικών επεξηγήσεων και εξαγωγή συμπερασμάτων. Τα ευρήματα αυτά είναι σημαντικά ειδικά για ερευνητές που ασχολούνται με την κατάρτιση των εκπαιδευτικών και θέματα μεταρρύθμισης στις Φυσικές Επιστήμες.

Reform recommendations in science education have called for a redesign of learning environments and emphasized scientific inquiry (National Research Council 2012). Scientific inquiry refers to posing questions, making observations, designing investigations, collecting information, analyzing and interpreting data, explaining and communicating findings (National Research Council 1996). The importance of learning science as inquiry has been illustrated through major reform documents such as *2000 and Beyond* in the UK (Millar and Osborne 1998), the *National Declaration for Education* 2001 (Australian College of Education 2001) in Australia and the *National Science Education Standards* (National Research Council 2000) in North America. These reform documents emphasize the active engagement of learners with scientific investigations for purposes of both establishing and evaluating scientific knowledge claims:

> When children or scientists inquire into the natural world they pose questions, they plan investigations and collect relevant data, they organize and analyze collected data, think critically and logically about relationships between evidence and explanations; use observational evidence and current scientific knowledge to construct and evaluate alternative explanations and communicate investigations and explanations to others. (National Research Council 1996, pp. 122, 145)

A decade later, the National Research Council's report *Taking Science to School* (2007) defined the following four strands of proficiency, for successful science learning:

- Knowing, using, and interpreting scientific explanations of the natural world
- Generating and evaluating scientific evidence and explanations
- Understanding the nature and development of scientific knowledge
- Participating productively in scientific practices and discourse (p. 33)

What becomes obvious in the above is a prevalent emphasis on the construction of evidence-based explanations, which is at the heart of the account of these reform recommendations. Many researchers have argued about the benefits of inquiry-based science approaches for student learning (Schwarz and Gwekwerere 2007). However, a review of the literature indicates that inquiry-based science practices are challenging, particularly for beginning science teachers who face a number of constraints and barriers in implementing inquiry-based science lessons, which results to a mismatch between their beliefs and their practices (Davis, Petish and Smithey 2006).

Given reform recommendations emphasizing scientific inquiry and empirical evidence pointing to the difficulties that beginning teachers have in enacting inquiry-based science, I aimed to explore a well-started (i.e., exemplary) beginning elementary teacher's (Sofia—a pseudonym) beliefs and practices in relation to reform recommendations. This question is broken down in two sub-questions, around which the findings are presented: (a) What are Sofia's beliefs about science teaching? and, (b) How are Sofia's beliefs about science teaching put into practice in the context of an inquiry-based science unit?

Inquiry-based practices and competencies

Mark Windschitl (2003) argued that scientific inquiry can take various forms in classrooms and discussed the notion of inquiry 'continua', indexed by the degree of independence students have in asking and answering questions. In doing so, he described several levels of science inquiry:

1. Traditional laboratory confirmation experiences providing students with step-by-step procedures to verify known principles in structured inquiry;
2. Structured inquiry in which the teacher presents a question, lab equipment and procedures for students to discover an unknown answer;
3. Guided inquiry through which teachers allow students to investigate a prescribed problem using their own methods of gathering and analyzing data and drawing conclusions;
4. Student-directed inquiry, in which the teacher presents a topic and lets students develop their own questions and design their own investigations;
5. Open inquiry through which pupils form their own questions and conduct independent investigations.

Across this spectrum of inquiry-based practices, different researchers around the world have conducted studies that provide evidence of the benefits of implementing inquiry-based approaches (Crawford 2000) with examples of successful enactment of inquiry-based science (Avraamidou and Zembal-Saul 2010), and describe a number of difficulties and constraints that both beginning and experienced teachers face in enacting inquiry-based practices (Davis, Petish and Smithey 2006). A common outcome of existing studies is that enacting inquiry-based science requires not only sophisticated understandings of scientific inquiry but also a repertoire of skills and abilities to translate those understandings into practice. The question then becomes one of what do beginning teachers need to know and be able to do in order to enact inquiry-based science?

Alake-Tuenter, Biemans, Tobi, Wals, Oosterheert and Mulder (2012) conducted a comprehensive review of the literature in order to respond to the following question: What elements of competencies required by primary school teachers who teach inquiry-based science are mentioned, discussed and researched in recent literature? The findings of this study illustrated twenty-two elements that were categorized in three clusters of the competencies underlying capabilities: subject matter knowledge, attitude and pedagogical content knowledge. These are summarized in the following: teachers' pedagogical design capacity, lesson preparation and adaptation of curriculum, teachers' instructional strategies, facilitating scaffolded inquiry evaluation and assessment, teachers' knowledge of and attitudes towards science teaching and science learners and learning, teachers' attitudes towards (the nature of) science, and, themselves as science teachers and professional development. These clusters illustrate that learning to teach inquiry-based science is no simple task and involves an array of knowledge, skills and attitudes.

Inquiry-based science

The ways in which teachers' views, knowledge and beliefs about inquiry are put into practice has been the focus of a set of studies in the past decade around the world. Chew-Leng Poon et al. (2012) examined the practice of four teachers in Singapore in order to describe the actual science inquiry practices that were taking place in their classrooms. Two teachers who participated in their study were more experienced while the other two were beginning elementary teachers. In their study the researchers aimed to explore the pedagogical components and sequences of inquiry science as perceived and enacted by these four teachers and the ways in which the enactment of inquiry science informs practice-oriented elements of inquiry teaching. Analysis of videotaped classroom observations revealed that the participants placed emphasis on the following: (a) preparing students for investigations, both cognitively and procedurally; (b) iterating pedagogical components where helping students understand and construct concepts did not follow a planned linear path but involved continuous monitoring of learning; and, (c) synthesizing concepts in a consolidation phase. These findings, as the researchers described, underscore the dialectical relationship between practice-oriented knowledge and theoretical conceptions of teaching/learning thereby helping educators better appreciate how teachers adapt inquiry science for different contexts. In agreement with the above findings, in previous related work, I have provided evidence that it is possible to come across beginning elementary teachers that enact reform-based practices and place emphasis on scientific inquiry. However, as I have argued, supporting the development of teachers' pedagogical content knowledge for scientific inquiry is a difficult and complex activity, which requires the combination and interaction of a variety of learning experiences (Avraamidou and Zembal-Saul 2010).

Challenges beginning elementary teachers face in enacting inquiry-based practices

In addition to documenting successful enactment of inquiry-based practices, several other researchers have studied the difficulties and constraints that teachers face when attempting to enact such practices. A review of the literature indicates that inquiry-based practices are challenging, particularly for beginning science teachers who face a number of constraints and barriers in implementing reform-based lessons (Roehrig and Luft 2004). These barriers and constraints are mainly associated with a lack of pedagogical content knowledge (Cochran, DeRuiter and King 1993) and inadequate knowledge of the nature of science (Brickhouse 1990). This is even more problematic with beginning teachers as research findings show that they have limited subject matter knowledge (Cochran and Jones 1998), they struggle to transform and represent science concepts for teaching (Feiman-Nemser and Parker 1990), they experience a conflict between their personal beliefs about science teaching and their practices (van Driel, Beijaard and Verloop 2001), and they follow the curriculum closely (Loughran 1994).

Other difficulties are associated with the school context and culture. In a study with five beginning mathematics and science teachers who were graduates of a reform-based teacher education program, Randy McGinnis, Carolyn Parker and Anna Graeber (2004) showed that all five teachers were prepared and intended to enact reform in their practices, however, they experienced constrains that were associated with the school culture which was unsupportive. Mijung Kim and Aik-Ling Tan (2011) examined the experiences of thirty-eight third-year university students in a science methods course in Korea in order to understand the challenges and barriers for them in making decisions about conducting inquiry-based practical work. The findings of their study showed, as other studies have done, that prospective teachers were concerned about issues such as lack of science content knowledge, classroom management, safety issues, motivation, tests, and so on. Moreover, the findings of this study also showed that pre-service teachers’ personal beliefs about what science is, the societal expectations of a good science teacher, and their ideas about science pedagogical values influenced their decision-making processes and shaped their actions. These studies are important and useful to our understanding of teachers’ beliefs and practices, particularly in relation to reform recommendations. However, the vast majority of these studies are situated within the secondary education context leaving a gap in the literature of elementary science education, which this study aims to address as it is situated within the elementary education context.

The relationship between beginning teachers’ knowledge, views, beliefs, orientations to science and science teaching, and understandings about science teaching and how those find (or not) their way into practice has been at the center of attention of various researchers (Avraamidou 2013). The study reported in this paper continues research on beginning elementary teachers’ beliefs about science teaching and how those compare to classroom practice, as it addresses the challenge of enacting inquiry-based science (Avraamidou and Zembal-Saul 2005). The idea of this study comes as a response to Elizabeth Davis et al.’s (2006) argument that “literature tells us very little about new teachers’ understandings of inquiry, how they teach inquiry, or what specific challenges they face in doing so” (p. 31).

In this manuscript I use the construct of ‘beliefs’, usually thought of as views, opinions and principles, to refer to a form of cognition that influences a teacher’s practices (Pajares 1992). As Frank Pajares (1992) argued, all teachers hold beliefs about their work, their students, their subject matter, and their roles and responsibilities.

In a chapter providing an overview of literature on teachers’ beliefs in science education, Carolyn Wallace (2014) summarized a set of assumption about the nature of teacher beliefs grounded within research over the past three decades:

- Beliefs are far more influential than academic knowledge in framing, analyzing, and solving problems and making teaching decisions.
- Some beliefs are more strongly held than others, resulting in “core” and “peripheral” beliefs.
- Beliefs do not exist independently of one another, but are arranged in an ecology or an “internal architecture” of systems that have psychological importance to the individual.
- Individuals may have competing belief sets about the same topic.
- When one belief is changed, it is likely to affect other beliefs throughout the system.
- Belief systems occur in “nests” or sets of beliefs that are linked or grouped together. (pp. 18–19)

In this study, I use the term 'beliefs about science teaching', which includes a set of beliefs about how children learn science, beliefs about scientific inquiry, and beliefs about the role of the teacher in science teaching and learning.

Research framework, teacher preparation program and assignments

The design of the study has the characteristics of a descriptive, single case study research as it examines a phenomenon (i.e., an exemplary beginning elementary teacher's science beliefs and practices) through detailed, in-depth analysis of data collected through multiple sources (i.e., self-portrait, interviews, personal philosophy assignment, classroom observations, journal entries) over time (Merriam 2009). As appropriate with the case study paradigm, I served as the main researcher of this study (i.e., collected and analyzed all data) as I aimed to uncover the characteristics of this unique case. The case was considered 'intrinsic' (Stake 2010) because it contradicts existing literature pointing to the challenges that beginning elementary teachers face (Davis, Petish and Smithey 2006) and presents the case of an exemplary beginning elementary teacher's beliefs about science teaching and practices in relation to reform recommendations about inquiry-based science.

At the time this study was conducted, Sofia was a first-year teacher in a fifth grade at a rural school and was also enrolled in the master's program in Science and Mathematics Education at a private University in Southern Europe, where she graduated a year earlier. As described elsewhere (Avraamidou 2013) prospective teachers who enroll in the elementary education program (4 years of studies, two semesters per year) are required to take three science content courses during the first 3 years of their preparation and an elementary science methods course in their last year of studies. All science courses are designed by science educators based on reform recommendations and are offered through the Department of Education. In the second, third and fourth year of their studies, prospective teachers enroll for a field experience course where they observe and teach forty lessons. Following the three content courses, the elementary science methods course, taught by the researcher, emphasizes scientific inquiry. In this course, prospective teachers engage in activities associated with learning-to-teach science and the design of science units. In the context of this course, prospective teachers also design and teach an inquiry-based lesson to a group of elementary school students who visit the class. In addition to the three science courses and the methods course, Sofia also took three additional science courses specially designed for prospective elementary teachers, as she decided to specialize in science. Similarly with the other science courses, these courses were designed around reform-recommendations emphasizing scientific inquiry and provided prospective elementary teachers with many opportunities to experience scientific inquiry. Evidence gathered through Sofia's assignments, exams, and classroom observations illustrated that her beliefs about science teaching were reform-minded, and that she was able to enact inquiry-based practices. This is, in fact, the main reason that she was selected to participate in the study.

I started collecting data in October (as described in Table 1) and continued until June. Five months into her first-year of teaching, Sofia was designing a 10-week long inquiry-based unit on waste management. Waste management was included in the curriculum with two lessons that emphasized the idea of recycling. Sofia modified the unit completely and enriched it with various activities around the driving question: *Is there a waste management problem in your community*? Table 1 offers a description of the unit's main activities in the 10-week period.

Table 1 Description of the unit main activities

Week	Main activity
Week 1	Introduction to the concept of 'waste': each student brings in and presents to the class a bag with their personal waste that they had been saving for a week. Built on this activity, a discussion follows about kinds of waste
Week 2	Introduction to the concept of 'waste management' and a discussion about 'recycling' 'reusing' and 'minimizing consumption' follows. The students work with their personal waste and put those in three different bags with the tags 'recycling' 'reusing' 'waste'
Week 3	The question is posed: is there a waste management at your community?, and Sofia asks the students to work in their groups to provide an answer to this question based on their existing knowledge and experiences. She emphasizes that they should provide evidence to support their claim and provides some examples (e.g., no recycling bins at the community). The students present their work in posters
Week 4	The students work in their groups to design investigations in order to collect authentic data from their community to respond to the question posed. Some of their ideas include: take pictures of the community, conduct interviews with the local authorities about the laws and regulations in terms of waste management, contact interviews with individuals about their personal habits, analyze existing related statistical data
Week 5	The students work outdoors in their groups to collect data
Week 6	The students work outdoors in their groups to collect data
Week 7	The students work in the classroom to organize and analyze their data in order to develop an evidence-based claim
Week 8	The students work in the classroom to prepare a Powerpoint presentation to describe the processes and findings of their investigations. They are asked to present an evidence-based claim and propose explanations
Week 9	The students present their findings to the classroom
Week 10	The students work in their groups to prepare an action plan with solutions about reducing and managing waste at their community

Who is Sofia?

Sofia was purposefully selected to participate in this study because she exemplifies a unique characteristic, which makes her an atypical and interesting case: she is a beginning elementary teacher who enacts reform-based instructional practices. However, Sofia is typical in terms of age, gender and education: 24 years old female with a background in elementary education. Based on evidence gathered over 5 years in the context of her preparation program (i.e., exams, classroom observations, various assignments) and her graduate program, Sofia can be considered a well-started beginning elementary teacher. By GPA means and through my observations as her instructor in four courses and as her field-experience supervisor, I considered Sofia to be a well-started beginning elementary teacher who had been developing beliefs about science teaching that are in line with reform recommendations. She graduated with a GPA of 4.0/4.0 from her teacher preparation program and she chose to specialize in science at the third year of her studies.

Collecting and analyzing data on Sofia's beliefs about science teaching

In order to explore Sofia's beliefs about science teaching and her associated instructional practices several kinds of data were collected in a period of 9 months (October–June): a self-portrait and an accompanying narrative, a personal philosophy assignment, three interviews that lasted for an hour and a half each (See "Appendix" for interview questions), three journal entries (4–5 pages each), ten lesson plans, and ten classroom observations (80 min long each). A detailed description of the data sources is offered in Table 2, in chronological order, with the first one being the self-portrait. The analysis of the data was grounded within a conceptualization of the essential features of inquiry, as defined by the *National Science Education Standards* (2000): (a) engaging in scientifically oriented questions; (b) giving priority to evidence; (c) formulating explanations from evidence to address scientifically oriented questions; (d) evaluating explanations in light of alternative explanations; and, (e) communicating and justifying proposed explanations. The analysis of the data related to Sofia's beliefs about science teaching and instructional practices were based on categorical aggregation and open coding techniques (Creswell 2008). I first divided the data into two main categories drawn upon the main research question of the study: (a) characterizing Sofia's beliefs about science teaching; (b) characterizing Sofia's instructional practices. Following that, I used a line-by-line analysis and assigned open codes to the data, in order to construct sub-categories. In terms of Sofia's beliefs about science teaching the following sub-categories were constructed: (a) self-image as a science teacher; (b) beliefs about scientific inquiry; (c) beliefs about science teaching; and, (d) beliefs about how children learn science. Table 3 illustrates the parallels in research questions, data sources and samples of categories and codes.

Table 2 Data sources description

Data source	Description	Length/duration
Self-portrait	Draw your self-portrait, yourself teaching science in the future. In the accompanying narrative explain your drawing	3 pages
Personal philosophy assignment	Describe your philosophy of science teaching and learning, use examples when necessary to justify your claims about how you think students learn best science	6 pages
Interview 1	The purpose of the interview was to explore the participant's visions of her self as a science teacher as a means for examining her beliefs about science teaching	1.5 h
Interview 2	The purpose of the interview was to examine the participant's thoughts and concerns about teaching science as inquiry, prior to the enactment of the unit	1.5 h
10 lesson plans	Ten lesson plans that defined the unit: waste management	5–10 pages long each
Journal entry 1	You have now completed the two first lessons of the unit. How did you think that go? What things worked well? What things you would do differently?	3 pages
Journal entry 2	You have now completed the six first lessons of the unit. How did you think that go? What things worked well? What things you would do differently?	3 pages
10 classroom observations	Ten classroom observations were conducted with the use of the Practice of Science Observation Protocol	80-min each
Journal entry 3	You have now completed the six first lessons of the unit. How did you think that go? What things worked well? What things you would do differently?	3 pages
Interview 3	The purpose of the interview was to examine the participant's reflections on the enactment of the inquiry-based unit	1.5 h

Table 3 Parallels in research questions, data sources and coding

Research foci	Data sources	Categories	Codes examples
Sofia's beliefs about science teaching	Personal philosophy assignment Drawing activity Interview 1 Interview 2 Journal entries	Self-image	Sofia envisions herself teaching outside the classroom using inquiry-based approaches Sofia envisions herself implementing gender- and race-inclusive practices Sofia pays attention to the nature of the learning environment Sofia pays attention to the nature of her relationship with her students
	Personal philosophy assignment Interview 2 Journal entries	Beliefs about scientific inquiry	Scientific inquiry is about engaging students in data-driven investigations Scientific inquiry as the main approach for learning science Scientific inquiry as the main approach for learning about the nature of science and the work of scientists Use of inquiry-based approaches to support students' interest in science Use of inquiry-based approaches to make science learning fun
	Personal philosophy assignment Interview 2 Journal entries	Views about science teaching and how students learn science	Scientific inquiry Argumentation Teaching about evolution theory The role of women in science Understandings about scientists and the nature of their work Understandings about the nature of science
	Interview 2	Concerns about teaching science as inquiry	Classroom management Time management Curriculum constraints
Instructional practices	Interview 2 Journal entries 1, 2, and 3 10 Lesson plans 10 Classroom observations Interview 3	Inquiry-based science	Providing students with opportunities to design their own investigations Providing students with opportunities to collect and analyze authentic data Providing students with opportunities to communicate the findings of their investigations

My role as the researcher

As appropriate with the qualitative research tradition, I served as the main researcher of the study and was responsible for the data collection, analysis and interpretations. For the last 7 years, I am a faculty member at the Department of Education of the university that served as one of the contexts of the study, and I consider myself familiar with the culture of the program, which adds to the trustworthiness of the study. I have known Sofia for the past 5 years as her academic advisor, her instructor in three science content courses and the methods course, and also her field experience supervisor. Following her undergraduate studies, Sofia enrolled in the graduate program of the University, and since then I have served as her academic advisor but also as her instructor in two courses. In these years Sofia and I have developed a very close and friendly relationship, and she feels comfortable in talking to me openly about her experiences and concerns.

Establishing trustworthiness

In attempting to establish the trustworthiness of the study, I used triangulation strategies as proposed by Yvonna Lincoln and Egon Guba (1985) through: (a) collection of data for the same purpose from various sources; (b) member check from an external researcher and the participant; (c) thick descriptions of Sofia's beliefs and instructional practices. For example, in order to explore Sofia's beliefs about science teaching and how children learn science I collected related data through her self-portrait and accompanying narrative, her personal science teaching philosophy assignment and the first interview. In addition, I shared the coding scheme and the first round of analysis of all data with an external researcher (a science educator, part-time faculty at the same university which defined the context of the study, and with experience in qualitative research), which we discussed and negotiated until we reached a consensus. I then shared the final analysis of the data and my interpretations with Sofia, which we discussed and modified until we came to an agreement. In order to enhance the trustworthiness of the study, and to achieve transferability of the findings, I provided thick descriptions of the context (i.e., design of the unit) and Sofia's beliefs and instructional practices.

Sofia's beliefs about science teaching

In this section I offer my interpretations about Sofia's developing beliefs for science teaching through analysis of several kinds of data: self-portrait and accompanied narrative, interviews, a personal science teaching philosophy assignment, and journal entries.

Self-portrait

In order to examine Sofia's beliefs about science teaching, I had asked her to prepare her self-portrait and draw herself teaching science. As illustrated in Fig. 1, she drew herself working closely with her students in an outdoor setting. In the narrative that accompanied this drawing, Sofia explained her drawing:

> I drew myself teaching a fourth grade classroom with sixteen students at a school in the old city where many political refugees live. In my class there are six students who are foreigners, and some of those do not even speak the national language. My drawing shows my students working in small groups..There are both girls and boys in these groups as well as locals and foreigners. The students work outside the classroom, carrying out inquiry-based investigations, at a small park next to the school. They are asked to examine biodiversity of a specific area. They are asked to collect data in various forms (i.e., pictures of different kinds of trees, pictures of different organisms, samples from the ground) and make a poster when back in the classroom to present the processes and findings of their investigations. (Narrative accompanying self-portrait)

Fig. 1 Sofia's self-portrait as a science teacher

A few contemporary beliefs about her role as a teacher are central in Sofia's self-portrait as a science teacher. First, she envisions herself enacting inquiry-based practices. In addition, she uses an informal context as a learning environment. Moreover, the way in which the student groups are formed illustrates her developing beliefs about inclusive practices, in terms of gender as well as race.

Sofia articulated these beliefs in the first interview I had with her. In that interview I had asked her to describe how she envisioned herself to be in the future and to explain what kind of a teacher she wanted to be and why. First, she talked about the relationship she envisions to have with her students.

> I want to be close to my students and I want them to feel comfortable to share their ideas but also their concerns or problems with me. I want them to look up to me not only as a teacher but also as an adult friend. (Interview 1)

Moreover, Sofia described the learning environment of her future classroom, emphasizing informal environments:

> I want to create a friendly and fun learning environment. Informal learning environments, such as museums and parks, provide wonderful contexts for learning…they are natural, friendly, exciting and attractive. I want my students to have fun during learning - you cannot have much fun in the classroom, but if you are out at a park you can! (Interview 1)

In addition, as Sofia said, she's hoping that she will serve as a role model for her students, especially the girls, and support them in developing positive attitudes towards science.

> I really hope that I can serve as a role model for them! I know that most students come to school with negative attitudes or at least no interest in science. I want to make my students, and especially girls, to like science. I want them to see my own enthusiasm and passion for science and I hope that I can influence them, the same way that my (female) instructors at the university influenced me. (Interview 1)

As evidenced in the above quotes, when describing how she envisions herself as a science teacher, Sofia emphasized scientific inquiry, the use of informal environments, the relationship with her students, the nature of the learning environment, and serving as a role model for her students.

Beliefs about scientific inquiry

In order to examine Sofia's developing beliefs about scientific inquiry I collected information through the second interview. In that interview I had asked her to provide a definition of scientific inquiry and to discuss the advantages of teaching science as inquiry at the elementary school. In defining scientific inquiry, Sofia stated:

> Scientific inquiry is about letting students free to design their own investigations and collect authentic data of different kinds in order to construct evidence-based explanations to posed questions…What would be ideal is to have students come up with their own questions and investigate those, but I do understand this is not very realistic considering the curriculum! (Interview 2)

It is evident in the above that Sofia was developing sophisticated beliefs about scientific inquiry as she spoke about evidence and explanation. In this interview, Sofia elaborated on her beliefs about inquiry-based science and described several advantages that it has to offer. She first spoke about student engagement and learning science:

> In my opinion, the inquiry-based approach has many advantages. The first one is that it supports students' learning, as they engage in hands-on activities and it gives them a sense of responsibility: to solve a problem. This is fun, and can motivate students to engage in the activities, and hence supports their learning of scientific concepts. (Interview 2)

Moreover, Sofia spoke about inquiry-based science as a means for supporting students to develop attitudes toward science:

> Another advantage of inquiry-based science is that it has the potential to make students like science. As we all know, students don't like science that much, because they find it difficult to understand or because they have to do lots of writing and they get bored. But, inquiry-based approaches make science fun! (Interview 2)

Supporting students' understandings about the nature of science and the work of scientists is another knowledge domain that can be supported through inquiry-based science, as Sofia explained, in her personal philosophy assignment.

> I believe that inquiry-based science can support students to understand the practice of science, the nature of science and the work of scientists. Because, in some sense, scientific inquiry models the work of scientists: the collection and analysis of data and the communication of scientific explanations. Moreover, scientific inquiry portrays aspects of the nature of science as well, for example, that it's a social practice,

> that it relies on evidence, and that theories can change when new evidence is found! (Personal philosophy assignment)

Summing up the above, it is important to note that Sofia has been developing contemporary beliefs about scientific inquiry, which included an emphasis on evidence and explanation as well as beliefs about the nature of science and the work of scientists.

Beliefs about how children learn science

In this section various quotes from Sofia's personal teaching philosophy and the first interview I had with her are used to characterize her beliefs about how children learn science. The main outcome of the analysis of the data is that Sofia's beliefs are in line with reform recommendations, emphasizing scientific inquiry and argumentation as well as other contemporary aspects of science teaching such as the role of women in science, the nature of science and the work of scientists, and evolution theory. A content analysis of Sofia's personal philosophy assignment illustrated that scientific inquiry featured in it centrally:

> I believe that children learn science best when they engage in inquiry-based science…when they get the chance to design their own investigations or experiments in order to respond to posed questions. What's unique about scientific inquiry, in my opinion, is the emphasis on the use of authentic data and the role of evidence when constructing scientific explanations. (Sofia, personal philosophy)

It becomes clear in the above that Sofia had been developing contemporary beliefs about scientific inquiry, and that she placed an emphasis on the role of evidence in the construction of scientific explanations. In line with reform recommendations, Sofia articulated her beliefs about the importance of engaging students in argumentation:

> One approach that is central to my personal science teaching philosophy is argumentation. I believe that when engaging in argumentation, students not only learn science but they also learn *about* science…I think argumentation models the practice of science…after all this is what scientists do, right? So, in a sense, students act like scientists and they develop an understanding of the nature of the work of scientists. (Interview 1)

An important aspect of Sofia's beliefs about science teaching as illustrated in her personal philosophy assignment as well as in interviews I had with her, was learning outside the classroom:

> Another approach that has an important role in my personal philosophy is learning in outdoor settings, or learning in informal learning environments such as museums and science centers. I think this approach is highly motivating for the students because it's unique and innovating but it also supports students in understanding the different forms or kinds of science…the wide range of scientific practices and the different kinds of works that a scientist could do. For example, a scientist could be studying fish, snakes or spiders or could be doing more theoretical science at a laboratory. (Personal philosophy)

What is important to note in the above quote, besides Sofia's beliefs about the role of informal learning settings in supporting student learning, are her developing beliefs about the nature of science and the work of scientists. The work of scientists and social stereotypes about scientists came up in the first interview I had with Sofia, where she spoke about gender inclusive practices:

> I am conscious about enacting gender inclusive practices because I know that young girls generally have negative attitudes towards science, and they think that scientists are mad people…you know, most girls think that science is not for them and that science is for boys. I will try to change their views with the use of various strategies that motivate and encourage girls to participate in the science lessons. I will try to use my self as an example of a woman who is passionate about science, and hopefully serve as a role model for them, as my methods course instructor did for me. I will also try to introduce young women scientists to my students in order to help them reconstruct their stereotypical views about scientists. (Interview 1)

In addition to these beliefs about scientific inquiry, outdoor-learning and gender-inclusive practices, Sofia articulated beliefs about evolution theory. This was surprising given that the social context in which the study took place is rather conservative in this sense and no public discussions (in the context of educational reform documents or professional development) about these ideas has been made. However, evolution theory was a topic in an advanced science education course that Sofia enrolled during her preparation. Ten prospective elementary teachers enrolled in this class and all of them, except Sofia articulated a disagreement and disbelief towards the theory, because it conflicted with their religious beliefs and they argued that evolution theory should not be taught in public schools. Sofia expressed different beliefs as articulated in the first interview I had with her:

> I will definitely teach about evolution theory in my own classroom in the future even though I know that it is not part of the curriculum, and I might even get in trouble for teaching this subject. I believe that it's important that students, especially the older ones, learn about Darwin and his work. For a long time I had a personal conflict about this because I am religious. I rarely go to church, but I do believe in God…I *need* to believe in something I guess. But, I do not think that you have to be an atheist in order to believe in evolution theory – evolution theory simply illustrates how species have lived and survived through the years. (Interview 1)

It is interesting to note in this quote that Sofia acknowledges the importance of teaching evolution theory in school, and she intends not to follow the curriculum and teach a unit that is not part of it. Summing up the above, Sofia's beliefs about science teaching indicate contemporary beliefs about science teaching such as inquiry-based science, argumentation, learning in informal environments, the practice of science and the work of scientists, gender-inclusive practices and teaching about evolution theory.

Characterizing Sofia's teaching practices as classroom-based inquiry

In the context of the graduate course Sofia was enrolled in at the time this study took place, Sofia designed a 10-week, inquiry-based unit on waste management and taught that in a fifth-grade elementary classroom. The analysis of the unit as well as Sofia's classroom practices showed that the unit was designed based on reform-recommendations and emphasized scientific inquiry as it provided students with opportunities to collect and analyze authentic data in order to respond to the question: *Is there a waste management* *problem in our community*? A general description of the unit's activities is offered in Table 2.

In order to characterize Sofia's instructional practices I observed and videotaped the ten lessons she taught about waste management. It became evident, through my observations of Sofia's instructional practices, that she was able to put in practice her beliefs about science teaching. She had managed to create a friendly and fun learning-environment, she was very close to her students, and seemed excited about teaching. The students also appeared to be excited to be in the classroom and were engaging in the activities with enthusiasm. During my observations and analysis of the videotaped classroom episodes, I aimed to examine the degree to which Sofia's practices were aligned with reform recommendations, emphasizing scientific inquiry. I hence looked for instances where, for example, Sofia was providing her students with opportunities to collect and analyze data in order to serve as evidence for constructing explanations. The analysis of the data illustrated that to a great degree Sofia's practices were inquiry-based as she provided students with opportunities to engage in scientifically oriented questions, in giving priority to evidence in responding to questions, in formulating evidence-based explanations, and in communicating and justifying their explanations. Below I offer a few vignettes from Sofia's classroom that highlight these aspects of her practices.

In the second lesson of her unit, Sofia introduced students to the driving question of the unit. The question was scientifically oriented, contextualized, motivating, and meaningful for the students, feasible and answerable in the context of the school classroom and the community. A classroom vignette reads as follows:

> As I am sitting in the back of the room I see the students running excited into the classroom as the bell rang, some of them have tablet pcs with them and some others have digital cameras and audio recorders. The following question is written on the classroom board: *Is there a waste management problem in our community*? As the students take their seats Sofia explains that they will work outside the classroom, in small groups, in order to collect evidence and respond to the posed question. She says: *We will take a tour in our community based on the map that you have in front of you. Our goal is to record our observations and collect evidence, different kinds of evidence that will help us respond to this question. What do I mean by evidence*? A student raises his hand and says: *Data…data that we will work with to become evidence*. Sofia responds by saying: *That's right. But, we want different kinds of data. What kinds of data can you think of*? Six students raise their hands, one of them says: *Interviews with people*, another one says: *Photographs, or videos with waste*. Sofia responds: *Excellent*! (Classroom vignette, lesson 2)

What's interesting to notice in the above vignette, apart from the scientifically-oriented question, is how students understood the use of the words 'evidence' and 'data', which shows that they were familiar with this kind of discourse. I observed similar discourse, in the third and fourth lesson where students were outside the classroom engaging in collecting data that would serve as evidence to support their claims about whether there's a problem with waste management in their community. In the third lesson of the unit, for example, a group of students are examining three recycling bins.

Boy1: There are recycling bins here, lets put these on the map?
Girl1: Yes, I will do it. Here (showing a place on the map), right?
Boy1: Yeah, exactly

Girl1: I am gonna write that these are for: plastic, paper, aluminum, glass and trash. They are full, and there are so many things outside…that's evidence right?
Girl2: Yes! That's there is a problem with waste management. We need more recycling bins for the community!
Girl1: Great! I am also gonna make a draft drawing of this!
Boy1: Look what's inside…there's supposed to be only plastic in this one but there's all sort of trash. People don't know how to use them?
Girl2: Or they just don't bother? Perhaps it was the only bin that had room for more?
Boy1: Yeah…maybe. That's more evidence for our claim!
Girl1: Perfect. I'm writing that down
Girl2: Lets take a picture of these bins to show in class?
Boy1: Yeah…take one to show the trash outside the bins!
Girl1: And a picture that shows what's inside the bins! (Team 4, Lesson 3)

As illustrated in the above conversation, the students were engaging in practices such as collecting data that would serve as evidence for their claim. It is interesting to see how these students were thinking about different kinds of evidence (i.e., whether there is a sufficient number of bins in the community, how people use the recycling bins) and different ways of representing these data (i.e., descriptive text, drawing, pictures). What's also important to notice in this conversation is how the word 'evidence' is part of the students discourse. Similarly, in the ninth lesson of the unit, Sofia prompted the students to use this kind of discourse when preparing their presentations.

> The purpose of your presentation is to communicate to everyone not only your claim but also the processes of your investigation. What did you do? How did you work? What kinds of data did you collect? How did you work with that data to construct evidence? What kinds of evidence did you find that support your claim? It's also important to refer to any evidence that does not support your claim. Moreover, make sure that you come up with some probable explanations as to why there is or there is not a problem. (Sofia, instructions to students, lesson 9)

As illustrated in this quote, Sofia emphasized the use of evidence to support a claim but also the use of evidence that does not support a claim, and the construction of explanations. In analyzing data from the ninth lesson (i.e., classroom observations and Powerpoint presentations) it became apparent that students were able to construct evidence-based claims and to formulate possible explanations. A vignette from the last lesson follows:

> The students take turns and present in Powerpoint presentations the processes and findings of their investigations. They describe how they worked during their investigations. They show the data they had collected to support their claims. They use words such as 'data', 'evidence', 'claim' and 'explanations'. Team 1 consists of two girls and two boys and each takes turns to talk. One of them says: Our claim is that there is a problem with waste management in our community. We found several pieces of evidence to support our claim. We took pictures in certain areas of the community and we found lots of waste thrown at non-designated areas. We took pictures of what's inside the recycling bins. We found out that those are not used correctly. Some of these bins were full and so some items were placed outside the bins. One explanation that we have about this problem is that the recycling company does not do a good job with picking up the bins as often as they should, and that's why they are full. Another explanation is that many people do not know about

> recycling or reusing of materials. In our interviews with four people we collected evidence to support this explanation. (Classroom vignette, Lesson 9)

Other groups of students made analogous presentations even though each group had different kinds of data to share with the classroom. The students also proposed possible explanations. A quote below from Team 2 illustrates a typical example of how they were thinking about explanations.

> Most of the bins were full…there were many trash items outside them, on the road. One explanation for this problem is that there are not enough recycling bins for the community. Moreover, these bins should be placed at the most crowded or busiest places of the community, for example, the main square, outside the coffee house and outside the soccer field. We suggest this because we saw a set of recycling bins that were almost empty, while the rest were all filled. We saw some bins that did not have the right waste inside. An explanation for this is that people do not use the recycling bins correctly either because they do not care enough about recycling or because they do not know. Many old people live in the community that never attended school, so, perhaps they do not know about the advantages of recycling. (Team 2, Lesson 9)

The above quote shows how students were able to form explanations based on the data they had collected and also to propose solutions. The other teams of students shared similar explanations as well.

Organizing and discussing the research findings

Emerging reform-minded beliefs about science teaching

The purpose of this study was to examine a well-started beginning elementary teacher's beliefs about science teaching and related instructional practices. As apparent in the analysis of the data, Sofia's beliefs can be characterized as reform-minded, as they were in line with reform recommendations emphasizing scientific inquiry. The findings of the study showed that Sofia articulated contemporary beliefs about scientific inquiry and science teaching and was able to translate these beliefs into practice. Central to Sofia's beliefs about science teaching and learning was scientific inquiry, and engaging students in investigations with authentic data with a prevalent emphasis on the role of evidence in the construction of scientific claims. Sofia's instructional practices as shown in the data analysis, were at level 3 of scientific inquiry (Windschitl 2003), as she enacted guided inquiry in which she allowed students to investigate a prescribed problem using their own methods of gathering and analyzing data and drawing conclusions. In doing so, Sofia was able to engage students with an investigation question that was contextualized, motivating and meaningful for them, in giving priority to evidence in responding to the question, in formulating explanations from evidence and to propose solutions, and in communicating and justifying their claims (Forbes, Biggers and Zangori 2013).

Of course, there were limitations to Sofia's practices (i.e., absence of opportunities for providing alternative explanations) and her beliefs about science teaching and reform recommendations were not as sophisticated (i.e., beliefs about the nature of science). However, there is not doubt that Sofia articulated contemporary beliefs about science teaching emphasizing science inquiry, and enacted reform-based instructional practices providing students with opportunities to work with data to respond to a posed question and form evidence-based claims. This finding is in agreement with my previous related research which provides evidence of well-started beginning elementary teachers' instructional practices that are in line with reform recommendations and give priority to evidence in science teaching (Avraamidou and Zembal-Saul 2010). This is important when viewed in light of existing literature illustrating that elementary teachers' classroom practices are not aligned with reform initiatives (Smith and Southerland 2007), that first-year teachers are not able to implement inquiry-based activities and follow closely the curriculum (Loughran 1994), and that beginning teachers' views, knowledge, or understandings are not in line with their practices (Simmons et al. 1999).

The fact that Sofia's beliefs and instructional practices were reform-minded contradicts existing literature stating that beginning elementary teachers face numerous challenges in embracing and enacting reform recommendations (Davis et al. 2006). Contrary to these findings, Sofia was self-confident throughout her first-year of teaching and was able to enact her beliefs and teach science with the use of inquiry-based approaches. A possible explanation is that Sofia was well trained in her teacher preparation program that emphasized such reform approaches to science teaching. This will be discussed further in the last section of the paper alongside implications for future research.

Challenges related to teaching science as inquiry

Despite her contemporary beliefs about scientific inquiry, Sofia articulated some challenges in enacting inquiry-based science, which were connected to time management and classroom management issues. These findings are in line with the results of Roehrig and Luft (2004) study that investigated the constraints that impacted the enactment of inquiry-based instruction of fourteen beginning teachers. Even though this study was situated within the secondary education context, the findings are relevant to this discussion, as they revealed five main constraints that impacted their enactment of inquiry-based instruction: an understanding of the nature of science and scientific inquiry, content knowledge, pedagogical content knowledge, teaching beliefs, and concerns about management and students. Contrary to these findings, Sofia articulated reform-minded beliefs and was able to enact those. This finding concurs with the findings of Lotter, Harwood and Bonner's (2007) study about three high school teachers' conceptions and use of inquiry-based instructional strategies. The results of their study showed that the teachers' conceptions of science, their students, teaching practices and the purpose of education influenced the nature and type of inquiry instruction that they enacted in their classrooms.

A related line of research is an examination of teachers' beliefs in relation to reform-recommendations. In a study examining three public school elementary teachers' classroom practices and beliefs in relation to science education reform in the US, Thomson and Gregory (2013) revealed their struggles in trying to implement these reforms, as well as common themes in their conceptions. The participants in this study, similarly with Sofia, articulated concerns associated with time and problems of pressure to obtain high scores on state student achievement tests. The participants' reflections on their views about science reform and their classroom science practices are similar to those of Sofia's emphasizing inquiry-based investigations, illustrating a sense of self-confidence and self-efficacy in teaching science as inquiry. As Thomson and Gregory (2013) summarized, four themes were common among the three teachers' interviews, and those were related to teachers' science teaching strategies (i.e., hands-on investigations), science teaching efficacy beliefs (i.e., all participants were confident in their abilities to teach science content), learning outcomes (i.e., promote student curiosity, support them in thinking like scientists) and resources (i.e., time, well-equipped classrooms, science kits).

The significant role of the context

When studying teachers' instructional practices is important to also examine the contexts in which those take place. In this study, the elementary school where Sofia was placed and which defined the context of the study appeared to be supportive. Even though a detailed evaluation of the context is beyond the scope of the study, evidence gathered through interviews as well as classroom observations illustrates the significant role of the context in supporting beginning teachers to enact reform-based practices. The school headmaster, as Sofia described in her journal entry, was very open to new ideas and gave her permission to try out this unit and not follow the curriculum. Likewise, the teachers were enthusiastic about the enactment of this study, and two of them actually helped out in managing the groups of students when collecting data outside the classroom. This finding is significant especially when viewed in light of existing literature indicating that the first-year of teaching is a cultural shock for beginning teachers who face various socialization and adaptation to the new context issues (Wideen, Mayer-Smith and Moon 1998).

Limitations of the study

A limitation of this study, being situated in a specific context and bounded within a specific science unit, is that one must be cautious when speculating about classroom-based inquiry and producing generalizations. One could argue that the specific unit lent itself to inquiry, given its nature and characteristics (i.e., open-ended). However, the purpose of this study was not to form generalizations. Rather, the intent was to provide a concrete example of a beginning elementary teacher's reform-minded beliefs in practice and to share an image of how classroom-based inquiry within the elementary school context could look like. The design of this study could inform future related research with a larger sample and within different contexts. Moreover, the outcomes of the study, even though not generalizable, could be transferred to similar contexts. In the section that follows, I discuss in further detail the contribution of this study to the field of science education alongside implications for teacher preparation and future research.

Contribution and implications for teacher preparation and future research

The main contribution of this study is that it provides a concrete example of inquiry-based science within the elementary school contexts and adds to the case study research on beginning elementary teachers' beliefs and instructional practices. This study offers interpretations about a well-started beginning elementary teacher's reform-minded beliefs about science teaching and related instructional practices. These may be useful to teacher educators as they attempt to support beginning elementary teachers in understanding and enacting reform recommendations. The findings of this study are also significant in terms of research, given the scarcity of empirical studies of successful enactment of reform recommendations within the elementary education context and especially with beginning teachers (Luft 2007). Hence, the present study adds to this gap in the literature by offering a concrete example of an exemplary teacher's reform-minded beliefs in practice.

The findings of the study have much to contribute to practice, research and teacher education, as illustrated above. However, this study has probably generated more questions than answers. Many important questions have risen through the findings of this study. Perhaps, the most important question that remains unanswered is how Sofia came to be? Or, how did she come to develop her reform-minded beliefs about science teaching? What kinds of experiences, actions and interactions throughout her life supported her in developing reform-minded beliefs about science teaching? Why is Sofia different from the majority of beginning elementary teachers around the world? What made her a well-started beginning teacher? What experiences nurtured the development of her beliefs about inquiry-based science? What contributed to her self-confidence and self-efficacy in teaching science as inquiry? Answers to the above questions are beyond the scope of this study, however, answers to these questions remain significant for science education. In a related study, situated within a similar context, aiming to trace the development of a beginning elementary teacher's identity for science teaching, I aimed to address the above questions (Avraamidou 2014). The findings of that study underscored the significant role of teacher education and university coursework. Likewise, in this study, the fact that Sofia's beliefs and practices were reform-minded can probably be attributed to the fact that she was well-prepared to teach science given that her teacher preparation program emphasized scientific inquiry and provided her with various opportunities to experience learning science in such ways. Even though an evaluation of the teacher preparation program does not lie within the purpose of the study, the findings point to the significance of teacher education programs in supporting beginning elementary teachers to develop reform-minded beliefs about science teaching. Reporting on the findings of a study on several iterative cycles of design-based research aimed at fostering preservice teachers' understandings of practice through modeling-centered scientific inquiry, Christina Schwarz (2009) showed that preservice teachers were most likely to advance their knowledge and practices within a coherent approach that focused on modeling-centered inquiry and provided opportunities to reform-based instructional frameworks. Analogous findings have been reported within the secondary education context. Daniel Capps, Barbara Crawford and Mark Constas (2012) synthesized the literature on general teacher professional development and specific inquiry-focused professional development to identify a set of features of effective inquiry professional development. The outcomes of their work included the following features: adequate time for teacher learning; extended support that goes beyond the initial professional development; opportunities to participate in authentic inquiry experiences; curriculum materials that are aligned with local, state, and national standards; opportunities to develop inquiry-based lessons; opportunities to participate in modeled inquiry experiences; time and support to reflect on one's experience; support transferring what was learned into the classrooms; and a focus on teacher content knowledge. These findings are particularly useful when designing teacher preparation and teacher professional development programs aiming at addressing reform recommendations.

In closing, this study provides a significant contribution to the field of science education because: (a) it documents a well-started beginning elementary teacher's beliefs about scientific inquiry; and, (b) it offers a concrete image of classroom-based inquiry within the elementary school context. This study provides descriptions of how reform-minded beliefs about teaching science are translated into practice in the context of a fifth-grade classroom, and models how classroom-based inquiry looks like within the elementary school context. This image of classroom-based inquiry and concrete example of an inquiry-based unit may be useful to teacher educators as well as practicing teachers, who attempt to enact reform recommendations. As Richard Duschl et al. (2007) have suggested, it is important to provide teachers with models of classroom instruction that incorporate the four strands of science proficiency in K-8. Given this need, I argue that it might be worthwhile to consider the production of a series of analogous case studies illustrating inquiry-based instructional practices within the context of the elementary school classroom, for the purpose of obtaining a more diverse image of classroom-based inquiry. Such research exists in the secondary context (e.g., Crawford 2000) however these studies are rare within the elementary school context. Identifying a variety of images of scientific inquiry within the elementary school context can reflect the broad range of inquiry-based practices situated in various contexts and topics. Summing up, the findings of this study are important to research aiming at supporting elementary teachers, especially beginning ones, to embrace reform recommendations, as proposed by Luft, Dubois, Nixon and Campbell (2015). The approach pursued in this study provides a means for developing more thorough knowledge about beginning elementary teachers' beliefs and practices in relation to reform recommendations emphasizing scientific inquiry. Other such means ought to be explored in order to examine how beginning elementary teachers construct beliefs about science teaching over time and within various contexts.

Appendix

First semi-structured interview protocol

- Tell me about yourself as a teacher of science. How do you envision yourself to be teaching science?
- How will your classroom look like?
- What kind of approaches will you be using?
- What does your self-portrait show? Provide explanations
- Elaborate on your personal science teaching philosophy. Provide explanations.
- How do you think learn science best?
- What's your view about reform recommendations emphasizing scientific inquiry?
- What are advantages of the inquiry-based approach to science teaching?

Second semi-structured interview protocol

- Describe your experience as a substitute teacher so far? How is the school culture?
- What are the goals of this unit?
- How does the design of this unit relate to your personal science teaching philosophy?
- Do you feel confident, ready and well-prepared to teach this unit?
- Do you feel confident in teaching this unit using an inquiry-based approach?
- Did you follow the curriculum when designing this unit? If you made modifications what kinds of modifications did you make?
- Do you have any worries or concerns about enacting this unit?

This semi-structured interview protocol

- How do you rate the overall enactment of the unit? Was it successful or not? Explain.
- Were the goals of the unit met? Provide examples.

- What in your opinion were the strengths of the unit? Provide examples.
- What in your opinion were the weakenesses of the unit? Provide examples
- What things you would do differently? Explain why.

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