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Reconceptualizing Elementary Teacher Preparation: A case for informal science education

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The purpose of this case study was to explore the ways in which 3 different informal science experiences in the context of an elementary methods course influenced a group of prospective elementary teachers' ideas about science teaching and learning as well as their understandings about the role of informal science environments to teaching and learning. In order to address this question, data were collected in a period of an academic semester through the following sources: journal entries for each of the 3 experiences, a personal teaching philosophy statement and a 2-hour long semi-structured interview with each of the 12 participants. Open coding techniques were used to analyze the data in order to construct categories and subcategories and eventually to identify emerging themes. The outcomes of the analysis showed that the inclusion of informal science experiences in the context of teacher preparation has the potential to support beginning elementary teachers' development of contemporary ideas about science teaching and learning related to inquiry-based science, the nature of scientific work and the work of scientists, connecting science with everyday life, and making science fun and personally meaningful. These findings are discussed alongside implications for policy, teacher preparation, and research under these themes: (a) addressing reform recommendations; (b) developing positive orientations toward science and science teaching; and (c) constructing understandings about scientists' work.

Keywords: *Teacher preparation; Informal science; Elementary science education*

Over the past few years there emerges an increasing interest in science learning that takes places outside the school classroom in contexts that have been described in the literature as *informal science environments* (e.g. Aubusson, Griffin, & Kearney, 2012; Bell, Lewenstein, Shouse, & Feder, 2009; Fallik, Rosenfeld, & Eylon, 2013; Osborne & Dillon, 2007; Stocklmayer, Rennie, & Gilbert, 2010). More recently, the *Framework for K-12 Science Education* has been published in the USA as the

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basis for the development of new standards in K-12 science education (National Research Council [NRC], 2012). As summarized in the report, the overarching goal for K-12 science education is to ensure that

> By the end of 12th grade all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)

This goal is based upon several underlying principles. One of these principles is connecting to students' interests and experiences. According to the report, 'research suggests that personal interest, experience, and enthusiasm—critical to children's learning of science at school or in other settings—may also be linked to later educational and career choices' (p. 28). It is obvious that the above overarching goal covers a wide and demanding range of knowledge, skills, and attitudes toward science that are developed not only in school but also in out-of-school settings. As a matter of fact, the National Science Education Standards proposed that 'the school science program must extend beyond the walls of the school to include the resources of the community' (NRC, 1996, p. 45). A question that emerges is whether elementary teachers are able to teach science in such ways, and most importantly, if they are able to teach in a variety of contexts and settings in order to achieve this goal.

To address this challenge and as a response to calls for reform, an innovative elementary science methods course was designed to serve as the context for this study. The course integrated a set of learning-to-teach science experiences situated within different kinds of informal environments. As argued in the report *Learning science in informal environments* (Bell et al., 2009), informal science environments and schools can pursue complementary goals. The report proposed six strands of science learning framework, built upon the framework developed for K-8 science learning in *Taking science to school* (Duschl, Schweingruber, & Shouse, 2007), to propose how learners in informal environments can:

- Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.
- Come to generate, understand, remember, and use concepts, explanations, arguments, models and facts related to science.
- Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.
- Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.
- Participate in scientific activities and learning practices with others, using scientific language and tools.
- Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science. (p. 3)

This framework articulates science-specific capabilities supported by learning within informal environments. Built upon this framework, the purpose of this study was to explore the impact of three informal learning-to-teach experiences (each of those addressing different strands as illustrated in Table 1) on a group of prospective elementary teachers' ideas about science teaching and learning. Specifically, the research questions that guided the data collection and analysis were the following:

- How did the participants perceive their engagement in a series of informal learning-to-teach science experiences?
- How did the inclusion of a set of informal science experiences in an elementary science methods course influence the participants' ideas about science teaching and learning?
- How did the inclusion of a set of informal science experiences in an elementary science methods course influence the participants' ideas about the role of informal science environments to science teaching and learning?

Theoretical Underpinnings

Researchers have used the term 'informal science learning' (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003) to refer to the learning that happens outside formal settings. In agreement with this view, I make neither an epistemological nor an ontological distinction between 'learning' and 'informal learning'. Instead, I make a distinction based on the *context* where learning takes place and I distinguish between learning within formal environments and learning within informal environments. In this paper, I use the term 'informal science environments' to refer to the environments outside any physical context of formal schooling. To respond to the research questions I pay attention to two kinds of learning activities: (a) organized or formal instructional activities at the teacher preparation level within an informal setting that impact teacher development; and (b) unorganized real-world activities within an informal setting that impact teacher development.

In recent years, a number of researchers and institutions around the world have shown interest in learning that takes place outside the school or the university classroom, and which operates across a broad range of contexts and disciplines and reaches out to people of all ages (e.g. Aubusson et al., 2012; Dillon, 2012; Kisiel, 2013; Kong, Dadney, & Tai, 2014; Rahm, 2010). Informal science environments, such as science museums, natural history museums, cultural and history museums, zoos, aquariums, botanical gardens, science centers' after-school programs, and everyday life settings such as the community and the family environment, offer unique educational environments and provide exciting opportunities for learning (Falk, 2004; Falk & Dierking, 2000; Griffin, 1994; Hein, 1998; McLeod & Kilpatrick, 2001; Rennie, 1994; Stocklmayer et al., 2010). In a report prepared by Bell et al. (2009) for the American National Research Council, it is argued that across informal social settings, such as on trips to museums and zoos, in the home, and in activities with friends and community projects, learners may develop awareness, interest, motivation, social competencies, and practices. As described in this report, the informal education community pursues a range of learning outcomes that are connected to the idea of lifelong, life-wide, and life-deep learning. This idea has been influential in

Table 1. Parallels between informal science experiences and strands of learning in informal environments

Experience	Description	Informal science aspects	Strands of science learning in informal environments
Field study	The participants designed and conducted an inquiry-based investigation to examine the water quality of a lake in the context of an informal environmental education institution	The context was defined by an informal education institution	Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world
	The participants worked in small groups in order to collect and analyze data (i.e. pH, temperature, nitrate, phosphate, and dissolve oxygen) regarding the quality of the water	Engaging in active participations and hands-on activities	Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science
	The participants collaborated with two informal science educators who worked at the environmental site in order to collect, analyze, and interpret data	Engaging in manipulation of real data in an authentic context	Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world
	The participants developed action plans of their choice (e.g. for education and policy) in order to improve the water quality	Freedom to explore ways to examine water quality	Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science
	The participants engaged in a discussion about themselves as learners of science and as future teachers of science	Freedom to explore ways to present the findings of the investigation	
	The participants engaged in a discussion about the role of outdoor environmental sites in school science	Collaboration with peers and informal science staff	
		The activities are not evaluative and non-competitive	

(*Continued*)

Table 1. Continued

Experience	Description	Informal science aspects	Strands of science learning in informal environments
Interaction with a scientist	The scientist made a presentation with information about snakes in order to support the participants develop content knowledge	Opportunity to use scientific tools	Strand 4: Reflect on science as a way of knowing and on processes, concepts, and institutions of science
	The scientist showed videos of himself working in the field and the laboratory and provided explanations about the tools used in these settings, which the participants also had opportunities to use	Contextualized knowledge	Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools
	The participants engaged in an unstructured discussion with the scientist about the nature of his work, his personal interest in snakes, and the role of snakes in the ecosystem	A visiting field scientist who works in a laboratory	Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world
	The participants were provided with the opportunity to observe various species of snakes (dead samples) with the use of scientific tools	Non-formalized opportunities to interact with a scientist	
	The participants engaged in a follow-up discussion about the importance of student-scientists collaborations as an informal science approach and its importance in science teaching and learning for the purpose of supporting student interest in science, developing knowledge about the nature of science, and reconstructing scientists' stereotypes	The activities are not evaluative and non-competitive	

Science fair	The participants developed a series of various science activities to explore questions of their own, such as the properties of sound, gravity, sink and float, air pressure, solar energy, electromagnetism, and others	Opportunities to work in a safe environment that provided opportunities for interaction with students	Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science
	On the day of the science fair three different elementary school classrooms (different age groups) visited the university at different times of the day in order to participant in the science fair, which was held in an outdoor, open space. In this space, prospective elementary teachers set their 'stations' in a cyclical arrangement where students rotated in small groups and engaged in inquiry-based investigations	Interactions among groups likely to be heterogeneous with regard to age, rather than constrained between same-age peers and formalized with the teacher	Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world
	The participants engaged in a follow-up discussion about the role of science fairs as an informal science approach to science teaching and learning	Interactions with small groups of students, not controlled by university instructors or teachers Open curriculum Opportunities for free-choice learning/ investigation of their own questions The science fair took place in a setting outside the university and formal school, which was rich in resources Opportunities for manipulation of objects and real-life materials The activities are not evaluative and non-competitive	Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science

efforts to develop a broader notion of learning, incorporating how people learn over their life course, across social settings, and in relation to prevailing cultural influences (Banks et al., 2007). According to the report, students acquire much of their knowledge outside the formal school classroom. For example, students acquire knowledge through visits with their families to aquariums, zoos, parks, museums and, in general, through spending time pursuing hobbies, playing games or being involved in any activity in the context of informal environments.

As stated earlier, in this paper the term 'informal science environments' is used to refer to the environments/settings/contexts outside any physical context of formal schooling. Such environments could include science museums, natural history museums, cultural and history museums, zoos, aquariums, botanical gardens, science centers, scientists' laboratories, and after-school (e.g. science camps and scout groups) family and community settings. In agreement with Stocklmayer et al.'s (2010) conceptualization of contexts for learning in the informal sector, informal science environments are viewed in this paper as contexts where:

> - Both attendance and involvement are voluntary or free-choice, rather than compulsory or coercive
> - The curriculum, if any, and whether intended or not, has an underlying structure which is open, offers choices to learners and tends not to be transmissive
> - The activities in which learners can be involved are non-evaluative and non-competitive, rather than assessed and graded
> - The social interaction amongst groups is likely to be heterogeneous regarding age, rather than constrained between same-age peers and formalized with the teacher as the main adult. (p. 10)

Based upon these principles, three informal learning-to-teach experiences were designed to serve as the context of this study situated within elementary teacher preparation. In related work I review existing research to construct an argument about the significant role of informal science environments to teacher preparation. The outcomes of that work illustrate how informal science environments:

> - Offer motivating structures for learning to teach and provide opportunities to practice science teaching in 'safe' environments;
> - Offer opportunities for learning to teach science through inquiry-based activities in environments that are rich in resources;
> - Offer unique opportunities for developing content and pedagogical knowledge for science teaching;
> - Can support teachers in developing understandings about the nature of science, the relationship of science to society, scientific inquiry and the work of scientists. (Avraamidou, 2014b)

Grounded within these outcomes, this study explores the idea of integrating informal science approaches to elementary teacher preparation and examines the impact of an innovative elementary methods course that incorporates informal science approaches on a group of 12 pre-service elementary teachers' learning and development. The next section summarizes existing research findings about the role of informal science environments to teacher preparation.

Empirical Underpinnings

Luehmann (2007) argued that traditional school settings provide only limited opportunities for meaningful apprenticeship in inquiry-based science teaching, while out-of-school contexts can offer prospective teachers' opportunities to experience reform-based practices. Likewise, Gupta and Adams (2012) argued about the value of informal science institutions serving as partners to university-based teacher preparation programs. In their words, these institutions offer unique learning opportunities that support prospective teachers in their own professional development and growth. Specifically, they advocated that these settings offer opportunities to teachers to practice their teaching in environments that are rich in resources, to work with diverse learners, and to learn alongside museum staff. Similarly, McKinnon and Lamberts (2014) argued that informal learning settings are well positioned to help with reform recommendation calls because they highlight the relevance of science to everyday life.

As reported elsewhere (Avraamidou, 2014b) a review of the literature shows an increasing interest in the past few years on the role of informal science environments to teacher preparation (e.g. Katz et al., 2011; Kisiel, 2013; Wallace, 2013). A set of studies offer empirical evidence of how participation in informal science education internships and learning-to-teach experiences within museum contexts support teachers in developing scientific content knowledge (Chin, 2004; Ferry, 1995; Jung & Tonso, 2006). A few studies have explored the use of informal science environments in practicum experiences and showed positive outcomes. For example, a study conducted by Anderson, Lawson, and Mayer-Smith's (2006) showed that a 3-week teaching practicum at an aquarium improved pre-service secondary science teachers' self-efficacy and self-confidence in teaching science. Similarly, Jung and Tonso (2006) who examined the use of a museum and a nature center as contexts of a group of pre-service teachers' practicum experience showed that the participants exhibited less nervousness about science teaching. Another study, which examined a group of pre-service teachers' experiences within the context of a practicum experience, developed as a partnership between a university and an aquarium, illustrated that the participants gained self-efficacy and expanded their thinking about education in various contexts (Anderson et al., 2006).

Other studies support the claim that when prospective teachers participate in out-of-school science learning experiences (i.e. science program of kids, exploration station at a local museum, and physics open house) they develop understandings of the characteristics of young learners, pedagogical knowledge as well as content knowledge (Kisiel, 2013). In a study with 230 prospective elementary teachers, Kelly (2000) showed that a combination of teaching a methods course in the university classroom and a local museum of science and history supported the participants to develop positive attitudes toward science and science teaching and enhanced their confidence in their abilities to teach science. Similarly, Kisiel (2013) showed how a group of pre-service elementary teachers enrolled in a science methods class who participated in a semester-long assignment, which required participation in their choice of activities and events (workshops, field trips, and family day activities), strengthened their perspectives about informal science education institutions as more than places for field trips and hands-on experiences. Moreover, a study conducted by Luehmann and Markowitz (2007), which explored how eight urban secondary science teachers evaluated a year-long, out-of-school science enrichment program (i.e. half-day laboratory experiences for the students), showed a positive impact of the program on the participants' appreciation of science, including scientific inquiry. Riedninger, Marbach-Ad, McGinnis, Hestness, and Pease (2011) reported similar findings in a study investigating the impact of an innovative elementary science methods course that included aspects of informal science education (i.e. informal science educator guest speakers, a live animal demonstration, and a virtual field trip) on the participants' attitudes toward science and science teaching. The findings of this study showed that almost all candidates in the treatment group finished the course with positive attitudes toward science and viewed the inclusion of informal science learning in their classrooms as a means to provide novel learning experiences for students, to access current resources, and to excite students.

As the findings of the above studies illustrate, informal science environments hold a great potential for teacher preparation for various reasons. In this study, I explore this idea through an empirical investigation of the impact of an innovative elementary methods course on a group of 12 pre-service elementary teachers' learning and development. Similar to Riedninger's et al. (2011) study, in this study I aim to explore the impact of a series of informal science approaches (i.e. interaction with a scientist, field trip, and a science fair) on the participants' views about science teaching and learning as well as their understandings about the role of informal science environments in science teaching and learning.

Methods

Context

A teacher preparation program of a private university in a Southern European country defined the context of this study. Students enrolled in this program are required to take three science content courses (developed and offered through the College of Education) during the first 3 years of their preparation and an elementary science methods course in the first semester of their last year of studies. During the second and third years of their studies, prospective teachers are enrolled in a field experience course where they have the opportunity to observe various lessons and to also teach about 5 hours each week. In the last semester of their fourth year of studies, prospective teachers are placed in local schools as part of their field experience and are required to teach full days for 3 months (Avraamidou, 2014a).

The data for this study were associated with the elementary methods course entitled: *Teaching Science at the Elementary School*, which aims at supporting the development of prospective elementary teachers' pedagogical knowledge for teaching science at the elementary school. This course is designed upon current recommendations for reform in science education emphasizing scientific inquiry and was conducted for 3 hours on a weekly basis through a 13-week long semester. In this course, prospective elementary teachers explore theoretical concepts associated with the nature of science and the work of scientists, scientific inquiry, the role of women in science, and the role of informal science environments in science teaching and learning. As part of the course, prospective teachers engage in activities associated with critical examination (e.g. examine the degree of coherence between the goals and the activities and examine whether the activities are in line with reform recommendations) and modification of science curricula. Their assignments include various reflective tasks, personal philosophy statements related to their views about science teaching and learning, microteaching activities, review and presentation of research articles, and participation in a science fair (Avraamidou, 2013b, 2014a). Three specific meetings and related assignments were of interest to the research presented in this paper. These meetings incorporated informal science approaches: an outdoor field study, an interaction with a herpetologist, and a science fair. The instructional goals of these meetings were associated with the six strands of science learning as described in the introduction.

For the purpose of the outdoor field study, prospective teachers were engaged in an inquiry-based investigation driven by a question related to water quality. In the second informal science experience, prospective teachers were provided with opportunities to interact with a herpetologist who visited the elementary methods course. A limitation in this approach is that the scientist visited the classroom instead of the pre-service teachers visiting the laboratory. However, the visit could not have been made possible because of a lack of funding resources. The scientist was selected based on criteria that contradicted the stereotypical personal characteristics of scientists—although male—in an attempt to support prospective teachers in reconstructing their possibly stereotypical views of scientists. The scientist was young, social, athletic, and wore jeans during his visit, which came in contrast with the stereotypical image of a scientist being a strict, middle-age man, bald, wearing lab coat, and being antisocial (Avraamidou, 2013b). The third informal science activity was a science fair. The purpose of the science fair was to engage young children of different age groups in fun science activities about various topics. Table 1 describes the main activities of each of these experiences and illustrates how they fit into the conceptualization of informal science environments as described earlier (Stocklmayer et al., 2010).

Design, Data Collection, and Analysis

This study follows a qualitative case study approach to the design, data collection, and data analysis, with the case being defined by a group of 12 beginning elementary teachers. As a qualitative study, it focuses on the meaning and understandings the participants make out of their participation in a series of learning-to-teach science experiences situated within different kinds of informal science settings (Creswell, 2007). As a case study, it aims to provide an 'in-depth description and analysis of a bounded system' (Merriam, 2009, p. 43) through 'detailed in-depth collection of data over time involving multiple sources of information' (Creswell, 2007, p. 73).

In order to explore the impact of the three informal science experiences on the participants' ideas for science teaching and their understandings about the role of informal science environments to science education, data were collected in a period of an academic semester through the following sources: 3 journal entries (1–2 pages long) for each of the 3 experiences, a personal teaching philosophy statement (6 pages long), and a 2-hour long semi-structured interview with each of the 12 participants. In the journal entries, the participants were asked to reflect on their experiences, to identify advantages and disadvantages, and to discuss how the experiences influenced their ideas about science teaching and learning. In the personal philosophy statement, which the participants had to develop at the end of the course, they were asked to write their ideas about how children learn science best in the form of a claim-evidence using personal science learning experiences to support their claims. In the interviews that were conducted 2 weeks after the course ended, the participants were asked to respond to questions related to their learning-to-teach science experiences with special emphasis on the ones situated within informal science contexts, as well as their ideas about science teaching and learning. This was used as a way to triangulate the data collected through journal entries as well as the personal philosophy statements for the purpose of establishing internal validity (Creswell, 2007). At the time the study was conducted, the participants were completing the first semester of their fourth year of studies during which they were enrolled in the elementary science methods course. They were all from a white ethnic group and typical beginning elementary teachers in terms of age and background—21 years old with no science specialization background or teaching experience. Nevertheless, as a group, the participants provide a range of interests, abilities, and orientations toward science and science teaching.

In order to analyze the data open coding techniques were used to construct categories and subcategories and eventually to identify emerging themes (Coffey & Atkinson, 1996). For each of the research questions, open codes were identified through multiple readings of the data. Examples of such codes are the following: emotions, engagement, scientists' characteristics, fun science, informal environments, meaningful learning, content knowledge, orientations to science, motivation, career in science, and others. These codes were further developed to form categories and subcategories. Examples of these are the following: nature of the context, understandings about scientists, understandings about the nature of scientists' work, making science learning fun and personally meaningful, inquiry-based science, and others. Table 2 provides a sample of the coding analysis for the third research question. For reliability purposes, an external researcher, familiar with the context, was asked to read and code all the data from the interviews and the journal entries based on the coding scheme. Discrepancies were then discussed and negotiated with the author until consensus was reached.

Significance, Limitations, and Trustworthiness

The unique contribution of this study to the existing literature is that it examines a series of different kinds of informal science approaches and settings, and hence offers a more comprehensive understanding about the impact of a variety of activities and experiences on teacher learning and development. Moreover, this study focuses on the participants' ideas about science teaching and learning as well as their

Table 2. Coding scheme for research question 3

Research question	Category	Subcategory	Codes
How did the inclusion of a set of informal science activities in an elementary science methods course influence the participants' ideas about the role of informal science approaches to science teaching and learning?	Making science fun and personally meaningful	Fun	Fun Motivation Hands-on activities Engaging activities Exciting Trip Enjoyable science
		Personally meaningful	Personal interest Connections between science and everyday life Students' interests Authentic
	Engaging students in inquiry-based science	Engagement in data-driven investigations	Collect data Analyze data Form scientific explanations Design investigations Carry out investigations
		Supporting the development of interest in science	Exciting questions Engaging investigations Supporting low-motive students Student-centered approaches Positive attitudes toward science
	Supporting the development of understandings about the work of scientists	Reconstruct stereotypes about scientists	Wide range of scientific work Scientists' personal characteristics Normal people Nature of scientists' work
		Consider a career in science	Students viewing themselves as scientists Career in science Appreciating the value of science to society Demystification of science

understandings about the role of informal science environments to science education. In this way, it directly addresses reform recommendations about enabling teachers to teach science in a variety of contexts and settings. One of the assumptions of this study is that teachers are a catalyst for change and hence, studying teacher learning and development can provide useful understandings toward attempts to address reform recommendations. By gaining an understanding of teachers' ideas about science teaching and learning in general, and science teaching and learning within informal science environments in particular, a missing link can be provided to address the goal of teaching science in a variety of contexts and connecting science to students' everyday lives. Concurrently, such an exploration will provide valuable insights about the role of informal science environments to teacher preparation.

The main limitation of this study is that it only addresses the participants' ideas about science teaching and learning, and hence leaving a gap of knowledge regarding the participants' practices. It would have been useful to be able to compare these findings with data that examine if and how the participants implement their ideas in practice. Another limitation of the study is connected to its design and the small number of participants, which makes it impossible to form generalizations (Creswell, 2007). However, transferability of the findings is feasible as those might be applicable in similar contexts and informal science settings as well as teacher preparation programs. In order to achieve transferability, as proposed by Lincoln and Guba (1985), detailed descriptions of the context (i.e. elementary methods course) as well as the nature and characteristics of each of the three informal science experiences (i.e. interaction with a scientist, outdoor field study, and science fair) are provided.

Following from the qualitative research paradigm, I, as the researcher of the study, served as the instructor of the course and as the primary instrument of data collection and analysis (Merriam, 2009). I interacted with the participants and I conducted the interviews with them after the course ended in order to avoid possible teacher–student power influences. I tried to become an insider (Creswell, 1998) and to minimize the distance between myself and the participants (Lincoln & Guba, 1985) in order to establish credibility. In order to avoid the impact of the personal bias when interpreting the data I used two techniques: member checks and an external research check. Specifically, I had asked all the participants to review my analysis and interpretations of their journal entries as well as the interview analysis and comment on whether their ideas were interpreted and represented accurately. In addition, I had asked an external researcher, who is familiar with the context of the study, to examine my interpretations using the coding scheme that I developed.

Findings

How Did the Participants Perceive Their Engagement in a Series of Informal Learning-to-Teach Science Experiences?

In order to explore the ways in which the participants perceived their engagement in the three informal science experiences, I analyzed their journal entries where they reflected on the three informal science experiences. The findings showed that all the participants perceived these experiences positively and emphasized different aspects of their engagement: outdoor context, connection with everyday life, fun and engaging, and a sense of freedom and ownership for learning. These are presented next, independently for each experience and alongside authentic quotes from the participants' journals.

Field study. In analyzing the participants' journals about the outdoor field study, emotions of happiness and enjoyment were prevalent. These emotions were associated with the nature of the activities as well as the context of the activities. For example, Mary stated:

> It was a very different lesson because we were outside the classroom. It was unique, interesting and exciting. I will never forget this day because I felt free to explore and learn in such a peaceful and beautiful environment—in nature. We worked through a unit as learners of science, and I now feel ready to teach this unit! (Journal 1)

It is important to note in this participant's words that the emphasis is placed on the nature of the context (i.e. outside the classroom) as well as the sense of freedom for exploration and the sense of confidence as a future science teacher. The freedom to decide what to investigate was also emphasized by another participant:

> I was so happy to be at the park and I enjoyed all the activities and experiments we conducted in our small groups. I really liked the fact that we were given time to explore on our own the setting and decide on our investigation . . . I enjoyed that sense of freedom! (Patricia, Journal 1)

Similar to Mary, another participant emphasized that the context of the experience, being outdoors instead of in the university classroom:

> I really enjoyed the fact that we did not go to university that day but, instead we had out class at the park! I never had such an experience throughout my education. A visit to a park is something we usually do with our families, not with our instructors! (Linda, Journal 1)

Of interest in Linda's words is the fact that she does not associate a visit to a park with formal education, but as a family activity instead. On a similar tone, Elizabeth commented that she would not call it a class:

> The class today was so different, actually I can't even call it a class . . . it was so exciting and fun. We conducted various experiments and learned so many things. I don't even know how time went by . . . when I sit in the classroom I usually just sit and wait for time to go by! (Elizabeth, Journal 1)

Besides the context of the experience as well as the sense of freedom for learning that participants were provided, another component of the experience was emphasized by a few participants—a connection of science with real life. A quote from Jennifer's journal provides a good example of this:

> I enjoyed the activity at the botanical garden because I learned a lot about the plants . . . I really enjoy botanic tea but I never knew what is what . . . now I do! (Jennifer, Journal 1)

In summarizing the above, it becomes evident that the participants emphasized three aspects of the field study: the fact that it was held in a park which made it fun and exciting, the fact that the participants were free to decide what they wanted to investigate, and the connections of the activities with everyday life.

Interaction with a scientist. The second informal science experience provided the participants with opportunities to interact with a young herpetologist. The analysis of the participants' journals illustrated positive outcomes related to emotions, content knowledge, and views about scientists and the nature of their work. A quote from a participant's journal illustrates an indicative example of how the experience supported the participants to reconstruct their stereotypical views of scientists:

> Prior to the class I thought that the scientist would be an old, strict man wearing a lab coat and glasses. But, I was wrong! The scientist was young and cool, and had a great sense of humor. I loved listening to him . . . he changed my views of how scientists look like and what they do! (Susan, Journal 2)

Such views were prevalent in most of the participants' journals. Moreover, the participants emphasized the fact that they had never met a real scientist throughout their lives, and that they never studied snakes. A quote from an indicative journal entry follows:

> This was the best science learning experience that I had in my entire life. It was so unique and interesting for two main reasons: the subject and the fact that we had a real scientist with us. We never studied snakes in school and I never met a real scientist. (James, Journal 2)

Similar to James, another participant pointed to the fact that she had never met a scientist and that she developed scientific knowledge about snakes:

> This was such a unique lesson. First of all, I never met a real scientist and second, I never thought that snakes could be so interesting! I did not know that snakes are quick in their reactions and that not all species are poisonous. Also, I did not know that different species of snakes eat different things. I always thought that they all eat just rats! (Linda, Journal 2)

Lisa also reflected on the knowledge she gained about snakes. Her words revealed a sense of confidence in teaching about snakes.

> If I were to teach a lesson about snakes right now I would do it without searching the Internet, because I feel that I learned so much about snakes through this meeting: about their diet, their reproduction, how they shed their skins, how they react to attacks, and how we should react in case they attack us. It was very inspiring to have this field scientist in our classroom because he was so cool and communicative and passionate about snakes! (Lisa, Journal 2)

In conclusion, an analysis of the participants' journals regarding their experience with the scientist illustrated the different aspects of the experience that they highlighted:

developing science content knowledge, meeting a real scientist for the first time and reconstructing their views of scientists' personal characteristics.

Science fair. The ways in which the participants perceived their engagement in the science fair became evident through analysis of their corresponding journals. The analysis of the journals illustrated how all participants emphasized the fun nature of the activities. A representative quote from a participant's journal illustrates this:

> It was one of my best days at the University! I had so much fun with the children, and learned a lot not by preparing my activities. It made me realize that science can be fun, and not just this difficult and boring lesson. (Karen, Journal 3)

Besides the fun nature of the activities, the participants reflected on the fact that they developed content knowledge. A participant stated:

> In my station I had students exploring the concept of gravity. When I was preparing for the science fair I realized that I had a lot of misconceptions about gravity and so I had to study a lot in order to prepare the activities . . . it was an unforgettable experience, I had much fun, and I interacted with children in small groups, which was not intimidating like standing in front of the classroom. (John, Journal 3)

Of interest in this quote is the fact that John's words provide a sense of confidence as a future teacher, which is also evident in other participants' journals. Similar to John, another participant pointed to the fact that she developed content knowledge and a sense of ownership for learning:

> Our experiments were about sinking and floating. We spent a lot of time preparing for this because we did not feel confident in our content knowledge. Even some of the questions that we thought we knew, we did not . . . we had misconceptions. But, it was fun because *we* had to find out on our own and prepare the activities. So, we felt motivated about our own science learning. (Karen, Journal 3)

Similarly, another participant emphasized the fact that he was free to decide what he wanted to investigate, which was motivating:

> In our station we prepared two experiments about pressure, the one with sand and the other one with the needles and the balloon. It's a subject that always fascinated me so I was excited to prepare the activities for the children. It was an amazing experience for me . . . I was motivated because I felt that I was free to decide what I wanted to do. (Robert, Journal 3)

Summing up the above, the participants highlighted three specific aspects of their engagement in the science fair: development of content knowledge, fun nature of activities, and development of a sense of ownership for their learning.

How Did the Inclusion of a Set of Informal Science Activities in a Methods Course Influence the Participants' Ideas about Science Teaching and Learning

In order to explore the ways in which the three informal science activities in the methods course influenced the participants' ideas about science teaching and learning, I conducted a content analysis of their personal philosophies. The findings of the analysis showed that all participants, with no exception, identified teaching in informal settings and adopted informal science approaches as one of the most effective approaches to science teaching and learning for various reasons.

The nature of the context. As exemplified in the analysis of the participants' personal philosophies, one of the key aspects of informal science approaches to science teaching and learning is the nature of the learning context, and specifically being outdoors, in natural settings. For example, one participant emphasized how such approaches can highlight the connection of science to everyday life:

> There are so many advantages in teaching science outside the classroom. It's like connecting real life with science . . . everything that we learned was so practical and useful. It's exciting and motivating and students can really see the value and importance of science to their lives. (Jennifer, Personal philosophy)

In addition to connecting science to everyday life, the participant described such approaches as exciting and motivating. Linda stated:

> Teaching science outdoors is very exciting. The fact that children will be out of the classroom is motivating. These settings offer great opportunities for hands-on science, for connecting science with everyday life, and for supporting students in developing positive attitudes towards science. (Linda, Personal philosophy)

It is important to notice in the above quote how the participant views teaching science in outdoor settings as a means to supporting student engagement with science and developing positive attitudes toward science. Likewise, another participant highlighted the significance of the context:

> Teaching science outside the classroom is probably the best approach to teaching science. It has so many advantages: it provides a real-place for studying nature, it's real life, it's interesting and fun because it's practical . . . it's not theoretical knowledge that students have to memorize from a book. (Susan, Personal philosophy)

It is interesting to notice how the participant draws a connection between the nature of the context and the nature of the gained knowledge, as being practical. John, another participant, also made a reference to the practical nature of knowledge as well as the fact that this knowledge is connected to the students' everyday lives.

> I believe that students learn better, easier and quicker in such settings because they experience learning through hands-on activities! Moreover, students get to see the connections of science to their every day lives. (John, Personal philosophy)

The prevailing emphasis from the above data indicates that the participants stress the nature of the context as a means for promoting engagement with science, but also as a way of making connections between science and everyday life.

Understanding about scientists and the nature of their work. When analyzing the participants' personal philosophies it became apparent that almost all of them (10 out of 12) elaborated on their experience of working with the scientist. These 10 participants discussed the importance of introducing scientists to young students mostly as a way to support them in reconstructing their stereotypical views of scientists. For example, Patricia stated:

> I believe that this approach is a great way to support students to reconstruct their stereotypical views about scientists and to learn more about the nature of their work . . . to learn that there are different kinds of scientists, and they don't all work in laboratories. (Patricia, Personal philosophy)

Patricia's quote also illustrates a developing understanding of the nature of scientists' work with the reference that not all scientists work in laboratories. Similarly with Patricia, another participant stated:

> I believe that providing children with opportunities to meet a scientist has many advantages. First, it shows them that not all scientists work in labs and that they can be normal people. Second, students can learn about the various scientific tools that scientists use for their work, which is very exciting! (Susan, Personal philosophy)

Likewise, Robert argued that such an approach can support students to develop positive attitudes toward science, and even perhaps decide to follow a career in science:

> It is very important to provide young students with opportunities to meet scientists . . . cool scientists. Because, this may help them develop positive attitudes towards science, to realize the many different scientific fields, and to consider following a career in science. (Robert, Personal philosophy)

Along similar lines, Helen pointed to the importance of providing students with opportunities to work with scientists who could perhaps serve as role models for them.

> I believe that it is important to provide students with authentic science experiences, such as working with scientists, to illustrate the various aspects of science and scientific jobs, and to provide them with opportunities to interact with scientists that could serve as inspiration or even as role models for them. (Helen, Personal philosophy)

The above quotes provide a representative picture of the participants' views that working with scientists is a very beneficial approach to science teaching and learning for the following reasons: it supports students to reconstruct their stereotypical views of scientists and the nature of their work, and it supports students to develop positive attitudes toward science, and could potentially inspire them to choose a science career.

Fun and relevant science. A major theme that was evident throughout the participants' personal philosophies was making science learning fun, and connecting scientific knowledge with everyday life. The participants' views seemed to have been impacted mostly by their participation in the science fair. For example, John stated:

> For me, one of the most important aspects of science teaching is to make science learning fun. I learned this through my engagement in the science fair . . . students were free to explore various concepts and to stay longer in any station they wanted to . . . I believe

> that some of the students felt the same way that I felt as a teacher, free to explore whatever interests me, which is motivating. (John, Personal philosophy)

Likewise, Susan argued for making science learning fun and drawing connections between science and everyday life:

> This experience [science fair] influenced my thinking about science teaching and learning as I realized the importance of making science learning fun and making connections between science and everyday life. The children were all engaged in activities, they were very excited and enthusiastic ... it was like a mini science museum! (Susan, Personal philosophy)

Another participant also pointed to the fun nature of learning, but he also emphasized the study of a variety of scientific concepts, an opportunity that was provided to students through their engagement with the science fair:

> Informal science experiences, like the science fair, offer students with opportunities to explore scientific concepts with hands-on and fun activities. A major advantage of the science fair, in my view, is that students get to explore so many different scientific concepts ... and most importantly they *choose* what to investigate ... unlike in the classroom where each lesson is about one specific scientific concept. (John, Personal philosophy)

Similar to John, another participant emphasized the importance of providing students with opportunities to experience science in fun ways. Susan referred to the science fair as an example of such a fun approach:

> It's important to engage students in fun activities ... just like the science fair where students can see and touch things ... they can play and learn at the same time. Another important aspect of the science fair is that it happens outside the classroom, which makes it more playful and enjoyable. Even the fact that the students can walk around, instead of sitting all the time, makes a difference. (Susan, Personal philosophy)

These representative quotes from the participants' personal philosophies illustrate the emphasis they placed on making science learning fun and engaging students in hands-on activities. To support these claims, the participants used their participation in the science fair.

How Did the Inclusion of a Set of Informal Science Activities in an Elementary Science Methods Course Influence the Participants' Ideas about the Role of Informal Science Approaches to Science Teaching and Learning?

In order to explore the ways in which the participants' engagement in the three informal science approaches impacted their ideas about the role of informal science approaches to science teaching and learning, data were collected through interviews. In these interviews, the participants were asked to further elaborate on their science teaching philosophies, to reflect on the informal science experiences they had in the methods course, and to share their ideas about the role of such approaches to science teaching and learning and whether they would use such approaches in their practices as future teachers. All of the participants shared ideas that illustrated the significant and positive impact of these approaches to their own learning and development. They all expressed different ideas connected to the various advantages that such approaches have: making science learning fun, connecting science to everyday life, engaging students in inquiry-based science, and supporting the development of content knowledge as well as knowledge about the work of scientists. These are presented next alongside representative quotes from the participants' interviews.

Making science learning fun and personally meaningful. The analysis of the participants' interviews illustrated that all of them commented on the fact that informal science approaches have the potential to make science learning fun for various reasons. A participant commented on how these experiences are fun and personally meaningful:

> These informal science experiences made me love science even more because they were much fun and personally meaningful. For example, at the park I chose to study the birds because I am a hunter so I had a personal interest. Similarly, at the science fair I chose to study 'speed' because I participate in car races, and I was really interested in that. (Robert, Interview)

Similarly to Robert, another participant pointed to the idea of making connections between science learning and students' interests:

> The informal science experiences I had in my methods course made me realize the importance of making science fun, enjoyable and meaningful by making connections between the activities and the students' interests and by exploring science in our everyday lives ... for example, questions like why does it rain, questions of gravity, energy, pollution, sound. (Elizabeth, Interview)

Similarly, John argued that such approaches are motivating because they offer authentic and hands-on learning experiences to students:

> I would argue that the significant role of informal science experiences in science teaching and learning is motivating, student-centered, engaging and exciting ... of course, it all depends on how the teacher is going to design for learning in informal science environments ... informal science experiences such as field trips or visits to museums offer authentic and hands-on experiences that are motivating. (John, Interview)

Another participant pointed to the nature of the context of such approaches, which has the potential to make science learning fun:

> I will definitely use informal science approaches as a future teacher because I believe that they have a great potential in supporting student science learning because they are engaging ... students are actively engaged in activities because they are excited ... some students might be excited just by the fact that they are outside the school classroom or that they don't sit on the chairs, they feel that they are on a trip or something ... but it words! I've seen it worked in all the informal science experiences I had either as a learner or as a teacher of science. (Patricia, Interview)

The above quotes provide an overview of the ideas that all participants shared in the interviews and illustrate how they viewed informal science approaches as valuable approaches to science teaching and learning, especially in terms of making science learning fun and meaningful.

Engaging students in inquiry-based science. Ten out of the 12 participants commented on how such approaches can promote scientific inquiry. One of these participants stated:

> Informal science approaches offer great ways to engage students in inquiry-based science through authentic investigations ... especially the low-motive ones or the ones who are usually excluded ... because group dynamics are different and because the students are provided with opportunities to engage in scientific inquiry ... to explore questions with the use of data. (Linda, Interview)

Likewise, another participant pointed to inquiry-based science and placed emphasis on the collection of authentic data:

> I believe that informal science environments such as the park that we visited, or museums and scientists laboratories offer great opportunities for students to engage in inquiry-based science ... to collect authentic data and analyze them to form scientific explanations, the same way we did at the park when we studied the quality of the air. (Donna, Interview)

Similar to Donna, another participant emphasized the engagement with authentic data as well as communication of explanations:

> Informal science environments offer great spaces for modeling scientific inquiry, because they provide opportunities for teachers to structure inquiry-based investigations ... to engage students in collecting data, in examining and analyzing data, and forming explanations ... the communication of these explanations is also important and informal science approaches are ideal for that because students can communicate their explanations in various ways and forms ... such as an exhibit that they develop. (Linda, Interview).

Another participant argued that such approaches promote student engagement in scientific inquiry, which could influence students' orientations toward science:

> I believe that informal science approaches to science teaching can have a critical impact on students' orientations to science and consequently on their decisions about following careers in science, because they offer opportunities to engage in scientific inquiry, and to develop an understanding of how scientists work and how fun and exciting that can be. (Carol, Interview)

It is clear from the above quotes that a few participants viewed informal science approaches as means to engage students in inquiry-based science, which in turn might motivate students to engage in activities and positively influence their attitudes toward science.

Supporting the development of understandings about the work of scientists. As shown in the analysis of the interviews, nine participants pointed to the role of informal science approaches to supporting students in reconstructing their stereotypical views of scientists and developing understandings about the nature of their work. Quotes from the interviews are presented below in order to support this claim. One participant emphasized how such approaches can support students in thinking of themselves as scientists by providing them with opportunities to better understand what scientists do and where they work:

> I believe that informal science approaches have the potential to support students in thinking about themselves as scientists, and perhaps consider a career in science in the future. By meeting scientists they are offered with opportunities to realize the different disciplines, for example, being a field scientist, a laboratory scientist . . . not just someone who does theoretical physics. The informal science environments offer opportunities to students to experience science learning in a fun environment, but also to better understand where scientists work . . . for example, a laboratory, or a park where scientists conduct environmental studies. (Susan, Interview)

Similarly, another participant emphasized how such approaches provide multiple images of scientific work:

> I believe that informal science approaches to science teaching can have a critical impact on students' orientations to science and consequently on their decisions about following careers in science, because they can see the many different 'faces' of science, the wide range of things that scientists study! (Carol, Interview)

Michelle commented on how such approaches have the potential to support students in reconstructing their stereotypical views of scientists:

> Each of these approaches to science teaching and learning is unique and offers specific advantages. These experiences had a great impact on my thinking about science teaching and learning and various approaches and strategies that are really innovative. For example, I would use collaborations with scientists in order to support students to reconstruct their stereotypical views of scientists and to better understand the nature of their work. (Michelle, Interview)

Likewise, another participant argued that such approaches have the potential to demystify science:

> These experiences changed my views about science teaching and learning, because I experienced science differently. Throughout my schooling years I never had any informal science experiences, except from a visit to the Science Museum in London with my parents. I believe that these settings offer great advantages because they make science learning fun, and make students appreciate science and the work of scientists . . . they kind of de-mystify science, making it more humane. (Scott, Interview)

Summing up the above it is important to address how the participants valued the role of informal science approaches and perceived the various advantages they have to offer to science teaching and learning.

Discussion and Implications

In the preceding section I offered a set of authentic quotes from the data to support the claims constructed from the analysis in order to respond to the research questions. As illustrated in the above, the findings of this study suggest that the inclusion of informal science experiences in the context of teacher preparation supported the participants in developing contemporary ideas about science teaching and learning. These ideas include inquiry-based science, understandings about the nature of scientific work and the work of scientists, connecting science with everyday life, and making science fun and personally meaningful. In analyzing the participants' reflections about the three informal science experiences it became clear how positively they all perceived these experiences. These findings are discussed next alongside implications for policy, teacher preparation, and research under these themes: (a) addressing reform recommendations; (b) developing positive orientations toward science and science teaching; and (c) constructing understandings about scientists' work.

Addressing Reform Recommendations

As shown earlier, the participants' words conveyed a sense of developing understandings about reform recommendations, particularly teaching science as inquiry and the nature of the work of scientists. Even though there are no data in this study to help us understand how sophisticated these understandings are or to examine the ways (if any) the participants enacted these understandings, this finding is significant given research evidence illustrating that beginning teachers have difficulties in interpreting and enacting reform recommendations (Avraamidou, 2013b). Researchers in science education have been calling for substantial reforms in learning environments, focusing on teaching and learning science as inquiry, and supporting students in developing an understanding about the nature of science and the work of scientists (AAAS, 1993; Duschl et al., 2007; Millar and Osborne, 1998; NRC, 1996, 2000, 2012).

From a policy perspective, it is important to address the overlap between the various out-of-school contexts and the curriculum if we are to take advantage of the unique opportunities for learning that such contexts offer to formal education (Fallik et al., 2013; Luehmann, 2007; Osborne & Dillon, 2007; Pedretti, 2002; Stocklmayer et al., 2010). Additionally, from a research perspective, it is important to examine the role of informal science environments to teacher preparation especially in light of reform recommendations. A review of the literature (Avraamidou, 2014b) shows that a number of studies at the teacher preparation level provide evidence of the impact of informal science approaches on teachers' development of content knowledge, pedagogical knowledge, development of positive attitudes toward science, development of self-confidence and self-efficacy, development of an appreciation for science and its value to society, and science teaching identity development (Anderson et al., 2006; Katz, McGinnis, Riedinger, Marbach-Ad & Dai, 2013; Kisiel, 2013; Luehmann & Markowitz, 2007; Wallace & Eick, 2012). However, there exists a gap in the literature: there are no studies that directly address the question of the role of informal science environments in addressing reform recommendations. I hence propose that future research be directed toward examining this largely unexplored area. Important questions that remain unanswered are the followings: *In what ways can informal science environments be used in teacher preparation to address reform recommendations? What kinds of informal science approaches and activities can be used in the context of the elementary science methods course in response to calls for reform?*

Developing Positive Orientations Towards Science and Science Teaching

The findings of this study provide evidence that the participants developed positive orientations toward science and science teaching through their engagement in the informal learning-to-teach experiences. In the participants' words, these experiences illustrated the fun aspect of science learning and supported them in developing positive orientations toward science. The fun aspect of science learning was associated mostly with the experiential nature of the activities, the nature of the contexts, and the fact that they felt responsible for their own learning. These findings are in agreement with Wallace's (2013) study, which investigated the influence of an integrated experiential learning and action research project on pre-service science teachers' ideas about science teaching and learning. Similar to the science fair study reported in this paper, Wallace (2013) also argued for the importance of experiential learning and the freedom provided to pre-service teachers to decide upon their investigations.

In addition, the participants viewed informal science approaches and informal science environments as having a significant role to play in science education. This role, according to the participants' views, is mostly associated with the goal of making science fun and supporting students' development of positive attitudes toward science. This is in agreement with previous research findings that illustrate how such approaches impact beginning teachers' attitudes toward science (e.g. Kelly, 2000; Riedninger et al., 2011). This is significant given the literature indicating that beginning elementary teachers tend to have negative orientations toward science and science teaching (Avraamidou, 2013b) and the need to pay attention to improving the attitudes of pre-service primary teachers toward science (Van Aalderen-Smeets, Walma Van Der Molen, & Asma, 2011). This has implications for both teacher preparation and future research. In terms of teacher preparation, this finding has implications for the design of fun and personally meaningful informal science activities that aim to support beginning elementary teachers to develop positive orientations toward science and science teaching. The findings of this study offer three examples of such approaches: outdoor field study, science fair, and interaction with a scientist. It would be useful to identify other such concrete examples of effective approaches and collaborations between universities and informal science institutions around the world, particularly within the context of elementary teacher preparation. In terms of research, the findings call for future studies aiming at exemplifying the aspects and specific characteristics of informal science approaches that support beginning elementary teachers in enjoying science and developing positive orientations toward science and science teaching. Questions related to the content (i.e. scientific concepts) as well as the context are raised, such as the following: *What specific characteristics of an informal science environment make science fun and enjoyable? What kinds of informal science approaches and what specific aspects (i.e., content, scientific concepts, instructional strategies) of such approaches support teachers in developing positive orientations towards science and science teaching?*

Constructing Understandings about Scientists' Work

The findings of this study illustrated how the participants reconstructed their stereotypical views of scientists and the nature of their work because of the impact of their interaction with the young scientist. Specifically, nine of the participants argued for the importance of providing students with opportunities to interact with scientists in order to reconstruct their stereotypical views of scientists, to motivate them to engage in science activities, and to support them in thinking about following a science career. A review of related literature provides evidence of the impact of specially designed approaches and science apprenticeships to young students' views of scientists (e.g. Avraamidou, 2013a; Bodzin & Gehringer, 2001; Bouillion & Gomez, 2001; Richmond & Kurth, 1999). However, fewer such studies exist at the teacher preparation level. Such studies would be fruitful at the teacher preparation level given that prospective teachers' understandings of scientists influence K-12 students' views of scientists (Finson, Pederson, & Thomas, 2006; Hanuscin & Lee, 2007). In a study with 196 participants, Subramaniam, Harrell, and Wojnowski (2013) examined prospective elementary teachers' images of scientists. The findings of this study showed high stereotypical scores (i.e. scientists as male, Caucasian, wearing lab coats, wearing eyeglasses, and working indoors) and limited knowledge about the role and work of scientists, who were perceived as physical entities devoid of context and societal characteristics. In discussing the implications of the findings, the researchers argued that teacher preparation programs should

> Help prospective teachers to confront and engage with their multidimensional images of scientists, and how these multidimensional images compare and contrast or align with the current trends on perceiving and valuing scientists, their scientific enterprise, and their role and work in generating scientific knowledge. (p. 86)

This is significant especially in light of the fact that the committee for the conceptual framework for new K-12 science education standards in the USA emphasizes the need to support students' development of understanding about the practices of scientists and how their work affects the world we live in (NRC, 2012). Hence, I recommend that future research be addressed toward exploring instructional approaches toward supporting beginning elementary teachers in developing contemporary understandings about scientists and the nature of their work. Possible questions to explore could be: *In what ways could informal science environments be used to support beginning elementary teachers to reconstruct their stereotypical views of scientists? What kinds of informal science approaches have the potential to portray the nature of scientific work?*

Conclusions

In conclusion, the findings of this study indicate that specially designed informal science approaches have the potential to support beginning elementary teachers in developing positive orientations toward science and science teaching, constructing understandings about scientists' work, and developing contemporary ideas about science teaching and learning. As argued elsewhere (Avraamidou, 2014b) and also shown in this study, informal science environments offer a set of advantages that could be of value to teacher preparation. The environments offer sociocultural, exciting, motivating, and free-choice learning spaces that are rich in resources. Additionally, informal science approaches have the potential to connect science to everyday life and support teachers' understandings about the value of science, the nature of scientific work, and the work of scientists. Even though there exists an increasing interest by researchers in exploring the role of such environments and approaches to teacher preparation, many questions still remain unanswered, as described earlier. Existing literature offers useful insights into the role of informal science environments to teacher preparation; however, we do not know much about how such contexts and approaches could be used to address reform recommendations calling for inquiry-based science and supporting students' development of understandings about the nature of science and the work of scientists. For the field to move forward, the critical role of informal science environments and informal science approaches to teacher preparation needs to be further explored in ways that would bring effective reform and radical changes into teacher preparation.

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