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ELEMENTARY SCIENCE TEACHER EDUCATION

Developing a Reform-Minded Science Teaching Identity: The Role of Informal Science Environments

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Abstract Recommendations for reform in science education around the world set high goals for beginning elementary teachers. Concurrently, existing literature indicates a number of challenges that beginning elementary teachers face. In this paper an argument is put forward about the integration of informal science environments in elementary teacher preparation, as a means for supporting beginning elementary teachers develop reform-minded science teaching identities. Essentially, the purpose of this paper is to explore the links between teacher identity, reform recommendations, and informal science environments. In doing so, a discussion of the theoretical construct of teacher identity in conjunction with reform recommendations is offered, followed by a summary of existing literature about the challenges that beginning elementary teachers face. Subsequently, the advantages and unique opportunities that informal science environments offer for teacher learning and development are discussed through a review of related literature. Following this review, a set of theoretical and methodological limitations of existing literature are identified. Based on these limitations, a research agenda is framed to address the theoretical, methodological and research implications that the idea of integrating informal science environments and approaches to elementary teacher preparation holds.

Keywords Informal science · Beginning teachers · Teacher identity · Reform recommendations

Introduction

In the past decade reform recommendations around the world have called for a reconstruction and redefinition of what it means to understand and teach science with

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special emphasis on scientific inquiry (Australian College of Education, 2001; Duschl, Schweingruber, & Shouse, 2007; Millar & Osborne, 1998; National Research Council [NRC], 1996, 2000, 2012). More recently, the *Framework for K-12 Science Education* has been published in North America, as the basis for the development of new standards in K-12 science education (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).

Moreover, reform recommendations place an emphasis on scientific inquiry and propose that one of the principal goals of science education is to "cultivate students' scientific habits of mind, develop their capability to engage in scientific inquiry, and teach them how to reason in a scientific context" (NRC, 2012, p. 41). It is obvious that the above overarching goal covers a wide and demanding range of scientific knowledge, knowledge about the nature of science, skills, and attitudes towards science that are developed not only in school but also in out-of-school settings. 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, such as outside the school classroom, in order to achieve this goal. A review of the literature provides evidence that beginning elementary teachers (the term is used to refer to both preservice and early-career teachers) are often reluctant to teach science because they lack relevant disciplinary and/or pedagogical expertise and confidence required to promote learning outcomes in the field effectively (Avraamidou, 2013a; Davis, Petish, & Smithey, 2006). Consequently, there is an emergent need for high quality, content- and context-rich teacher preparation and professional development programs for science teachers. Such programs should aim at the development of teachers' pedagogical content knowledge and skills that will enable them to embrace and enact reform recommendations and teach science within the context of a range of environments—both formal and informal.

In this paper the idea of supporting elementary teacher learning and development (framed within the construct of 'identity') in informal science environments as a means for addressing current reform recommendations in science education calling for an emphasis on scientific inquiry and context-rich experiences is explored. McKinnon and Lamberts (2014) argued that informal settings are well positioned to help with reform recommendation calls because they highlight the relevance of science to everyday life, and they emphasize hands-on activities, which have the potential to enhance elementary teachers' self-efficacy. Likewise, other researchers argued about the importance of forming relationships between the formal and the informal sector in order to address existing problems (e.g., low interest in science) and to move science education forward (e.g., Bell, Lewenstein, Shouse, & Feder, 2009; Fallik, Rosenfeld, & Eylon, 2013; Osborne & Dillon, 2007; Stocklmayer,

Rennie, & Gilbert, 2010). In a review paper, Fallik et al. (2013) argued for creating collaborations between informal science organizations and schools for the purpose of increasing student motivation for learning, expanding student conceptions of learning and knowledge and supporting students in developing new skills and abilities.

The purpose of this paper is to explore the links between teacher identity, reform recommendations, and informal science environments. In the sections that follow, a discussion of the theoretical construct of teacher identity in conjunction with reform recommendations is offered, followed by a summary of existing literature about the challenges that beginning elementary teachers face. Subsequently, the advantages and unique opportunities that informal science environments offer for teacher learning and development are discussed through a review of related literature. Following this review a set of theoretical and methodological limitations of existing literature are identified. Based on these limitations a research agenda is framed to address the theoretical, methodological and research implications that the idea of integrating informal science environments to elementary teacher preparation holds.

Teacher Identity and Reform Recommendations

The theoretical underpinnings of the argument put forward in this paper are rooted in the assumption that learning is essentially socially situated within specific sociocultural contexts and bounded by individuals' interactions (Vygotsky, 1978). In agreement with Lave and Wenger's (1991) view that "one way to think of learning is as the historical production, transformation, and change of persons" (pp. 51–52) the term 'learning' is used to refer to 'the construction of identities'. Gee (2000) referred to identity as being recognized as a certain kind of person within a given context. Beijaard, Meijer, and Verloop (2004) suggested that identity can also be seen as an answer to the questions: *who am I at this moment*, and *who do I want to become?* To frame teacher identity, Lave and Wenger's (1991) social theory is used in this paper. This theory views identity as a part of a social practice, and not just an individual and isolated project. Central in this theory is the process of becoming or the construction of identities. Therefore, teacher learning and development are viewed as a process of identity construction through social participation, and emphasis is placed on the 'communities of practice' that beginning teachers form (Lave & Wenger, 1991; Wenger, 1998) in both formal and informal science settings. The conceptualization of beginning elementary teachers' participation in various informal science sub-contexts as learners and future teachers of science is built upon Wenger's (1998) definition of participation which "refers not just to local events of engagement in certain activities with certain people, but to a more encompassing process of being active participants in the practices of social communities and constructing identities in relation to these communities" (p. 4). The nature and characteristics of such participation in the practices of the social communities formed within the various informal contexts of learning-to-teach science is the point of interest in this paper.

Science teacher identity is used in this paper to refer to *the ways in which a teacher represents herself through her views, orientations, attitudes, emotions, understandings, and knowledge and beliefs about science teaching and learning* (Avraamidou, 2014a). Teacher identity is conceptualized as a sociocultural, comprehensive and multidimensional construct (e.g., Avraamidou, 2014b; Connelly & Clandinin, 1999; Gee, 2000; Varelas, 2012). A review of the literature about science teacher identity and identity development illustrates the significance of adopting an identity lens for framing teacher development given that it goes beyond knowledge and skills (Luehmann, 2007). The ways in which teacher identity has been conceptualized by various researchers around the world point to different characteristics and dimensions of teacher identity. In terms of its nature, it is well documented in the literature that teacher identity is social and multidimensional, tentative, and always in a process of formation and re-formation (Beijaard et al., 2004; Lee, 2012; Luehmann, 2007; Settlage, Southerland, Smith, & Ceglie, 2009). In terms of its structural components, studies about science teacher identities and science identities have illustrated the following: self-confidence and view of self as a science teacher (Pedretti, Bencze, Hewitt, Romkey, & Jivraj, 2008), sense of collegiality with colleagues and recognition by others (Carlone & Johnson, 2007), subject matter knowledge (Helms, 1998), personal histories (Avraamidou, 2014a; Volkmann & Anderson, 1998), views and beliefs about science teaching and emotions (Rivera-Maulucci, 2013; Zembylas, 2005) and, social markers such as race, gender and ethnicity (Moore, 2008). Another set of studies in the literature on science teacher identity has explored approaches and ways to support teacher identity development. These have ranged from the use of specially designed methods courses and field experiences (Danielowich, 2012; Siry & Lara, 2012) to the use of afterschool programs and science internships (Katz et al., 2011; Luehmann & Markowitz, 2011; Varelas, House, & Wenzel, 2005) the use of technology applications such as blogging (Hanuscin, Cheng, Rebello, Sinha, & Muslu, 2014; Luehmann, 2008), and the use of specially designed curricular materials (Forbes & Davis, 2008).

In this paper the term 'reform-minded science teaching identity' is used to refer to the ways in which a teacher's identity is informed by reform recommendations, in other words, a teacher views herself and is recognized by others as a reform-minded teacher. Saka, Southerland, Kittleson, and Hunter (2013) used the term 'reform-minded' to highlight the ways in which teachers' thoughts about and approaches to instruction are central to efforts for reform in science education. They summarized these efforts in the following main ideas:

- The goal of science education is to foster scientific literacy in students.
- Scientific literacy requires that students form a deep understanding of a limited number of foundational concepts as opposed to a superficial recognition of a wide range of scientific facts.
- Science concepts should be learned in relation to students' everyday experiences so they can learn to apply their knowledge in those contexts.
- Science teachers must understand the knowledge students bring with them into the classroom and build from this knowledge.

- Inquiry is central to reform. Students should understand how scientific inquiries are conducted and how these processes shape the knowledge produced (p. 1222).

The question then becomes one of how do these efforts translate in practice? According to the *Framework for K-12 Science Education* (NRC, 2012), the following eight practices are essential for learning science: (a) Asking questions and defining problems; (b) Developing and using models; (c) Planning and carrying out investigations; (d) Analyzing and interpreting data; (e) Using mathematics and computational thinking; (f) Constructing explanations; (g) Engaging in argument from evidence; and, (h) Obtaining, evaluating, and communicating information (p. 42). In other words, a reform-minded teacher ought to be able to enact such practices. It becomes then important to explore questions such as how do beginning elementary teachers interpret reform recommendations? How do they work through expectations, how do they negotiate understandings, and more importantly, what kind of support do they need in order to develop reform-minded science teaching identities? In this paper an argument is constructed to suggest that such support can be provided through the integration of informal science environments in elementary teacher preparation. This proposition comes as a response to calls for reform as well as the need for addressing challenges that beginning elementary teachers face, which are summarized in the next section.

Challenges Beginning Teachers Face

As discussed in the introduction, reform recommendations pose great challenges for science teacher preparation. At the same time, a review of the literature shows that beginning teachers, especially at the elementary education context, face a number of difficulties when it comes to science teaching. In a comprehensive review of the literature, Davis et al. (2006) summarized the challenges that new teachers face in the following: (a) challenges related to understanding the content and disciplines of science; (b) challenges related to understanding learners' needs; (c) challenges related to understanding instruction; (d) challenges related to understanding learning environments; and, (e) challenges related to understanding professionalism. Similar problems were summarized in a related review study by Mikeska, Anderson, and Schwarz (2009) who identified three common problems of practice that all elementary science teachers face: engaging in science, organizing instruction and resources, and understanding students. In examining the difficulties beginning elementary teachers face, other researchers identified the lack of content knowledge, lack of confidence in teaching science, and negative attitudes towards science and science teaching (Abell & Roth, 1992; Avraamidou, 2013a; Davis et al., 2006; Loughran, 1994). As described in previous research, beginning elementary teachers do not have many memories of science learning experiences except from a few ones that involved experimentation and their memories of science teachers involve stereotypical images of strict and eccentric middle-age men (Avraamidou, 2013a). Beginning teachers, especially females, grow up not liking science, considering it particularly difficult when compared to other subjects and hence tending to avoid

teaching it (Appleton & Kindt, 2002; Brickhouse, Lowery, & Schultz, 2000). A large body of literature illustrates that many elementary teachers are reluctant to teach science and confess a lack of confidence to teach it (Abell & Roth, 1992; Appleton, 1995). Moreover, researchers have documented that the first years of teaching is particularly difficult, that first-year teachers closely follow the curriculum and they struggle with implementing student-centered inquiry activities (Loughran, 1994) and that their classroom practices differ from their beliefs (Simmons et al., 1999; Van Driel, Beijaard, & Verloop, 2001). Other difficulties that beginning teachers face as illustrated in Davis et al.'s (2006) review, are associated with time management issues and obtaining necessary resources. In addition, as documented in previous studies, preservice elementary teachers and elementary school teachers tend to have negative attitudes towards science (Van Aalderen-Smeets, Walm Van Der Molen, & Asma, 2011). As can be drawn from the above, beginning elementary teachers face various challenges ranging from lack of knowledge to issues related to self-confidence and negative attitudes towards science. The next section is dedicated to exploring the potential of informal science environments in supporting teachers overcome these challenges.

The Role of Informal Science Environment to Teacher Development

The Affordances of Informal Science Environments

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. As she argued, nontraditional experiences (e.g., after-school programs, science days, museum visits) can provide motivating activity structures, opportunities to practice reform-based instructional strategies in safe environments as well as opportunities for co-teaching and small-group teaching. Similarly, Gupta and Adams (2012) argued for the value of informal science institutions serving as partners to university-based teacher preparation programs. As they described, 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. In a historical review of how museums and science centers have developed over the years, Pedretti (2002) illustrated how these settings have moved from hands-on displays and neglecting the processes of scientific practice and the nature of science to more critical exhibitions that consider socio-scientific issues from a variety of perspectives, and address issues associated with the nature of science. As she stated, "science centers and museums are increasingly positioning themselves as socially valuable resources for conveying information to the public about science and technology and its social implications" (p. 34). Luehmann and Markowitz (2011) provided empirical evidence to support the argument that out-of-school settings provide opportunities to engage students in

scientific inquiry and investigations with authentic scientific data. As described in the Standards (NRC, 2000) inquiry teaching and learning have five essential features: engaging in scientifically oriented questions, giving priority to evidence, formulating explanations, evaluating evidence, and communicating and justifying the results of inquiry investigations. It becomes clear in the above that an inquiry-based approach requires allowing students with adequate time to conduct scientific research. Even though the out-of-school experience described in Luehmann and Markowitz's study was only a 1-day class laboratory visit to the university, it was done within the context of an extensive collaboration of one academic year between a science classroom and a university. This is important given reform efforts emphasizing the engagement of students in long-term inquiry-based investigations as well as criticism toward informal science institutions for not offering such opportunities due to the lack of time in one-day school visits and the fact that some of these institutions adopt traditional models of learning (Allen & Crowley, 2014).

It is such arguments that led to the exploration of the idea of integrating informal science programs and activities within elementary teacher preparation programs especially for addressing reform recommendations. This idea is largely unexplored and neglected in science education research particularly within the area of beginning elementary teachers learning and development. A review of related literature indicates that there have been very few studies documenting teacher learning in informal science environments (e.g., Kelly, 2000; Kisiel, 2013; Wallace & Eick, 2012; Wallace, 2013). However, the results from these few studies are positive and favorable of such an approach. When reviewing related literature one thing becomes clear: there exist many studies within informal science environments about museum visits in a thematic area called 'visitors studies' (e.g., Falk & Dierking, 2000) and a set of studies on after-school, family and community programs with young children (e.g., Dadney et al., 2012; Kong, Dadney, & Tai, 2014; Rahm, 2002, 2010; Stocklmayer, Durant, & Cerini, 2011). Fewer studies exist that describe school–museums collaborations (e.g., Anderson, Lawson, & Mayer-Smith, 2006) and even fewer studies exist that describe university–museums collaborations and out-of-school programs for teacher preparation (e.g., Jung & Tonso, 2006; Katz et al., 2011; Kisiel, 2013; Luehmann & Markowitz, 2011; Wallace, 2013; Wallace & Eick, 2012). In the paragraphs that follow a synthesis of the findings of these few studies is offered organized around the main theoretical frameworks in which the studies were bounded: (a) teacher knowledge; (b) self-efficacy and attitudes towards science and science teaching; and, (c) views about science teaching.

Teacher Knowledge

A growing number of studies provide evidence that engagement in informal science education activities supports the development of teachers' science content knowledge (Ferry, 1995; Jung & Tonso, 2006). Jung and Tonso (2006) reported that preservice teachers gained scientific content knowledge through participation in an informal science education internship, which contributed to the formation of their identities as competent teachers of science. As part of their internships, preservice teachers received lesson plans as well as training from museum and nature center

staff, and taught lessons to visiting classes. Moving beyond an examination of content knowledge development, other researchers have investigated the impact of informal science opportunities on beginning teachers' pedagogical content knowledge. For example, Wissehr and Hanuscin (2008) examined the nature of the opportunities informal environments afford prospective teachers to participate in the teaching/learning process and the ways in which the experience informs prospective teachers' pedagogical content knowledge for teaching science. Throughout a semester, prospective teachers enrolled in a content course and participated in out-of-school science learning experiences. These experiences, as the researchers described, included facilitating activities for students at Physics Open House, volunteering at the university's Saturday Science Program for Kids, or volunteering at a local hands-on museum of science, health and technology. Typical activities included offering explanations to children about exhibits, demonstrating how exhibits work, guiding children's explorations as well as interacting with adults and staff. Analysis of survey data indicated three major findings: (a) participants developed a deeper understanding of the affective, cognitive, and behavioral characteristics of young learners; (b) participants increased their pedagogical knowledge for teaching science to children, particularly concerning instructional methods and strategies; (c) most participants felt that this experience increased their preparedness to teach science by deepening their understanding of scientific concepts as well as boosting their confidence in their ability to teach science to children. These findings become of great importance when viewed in light of existing literature documenting beginning elementary teachers' low self-efficacy and confidence in teaching science (e.g., Avraamidou, 2013a; Davis et al., 2006).

Self-efficacy and Attitudes Toward Science and Science Teaching

A few researchers have examined the impact of informal experiences on teachers' development of positive attitudes toward science and gaining confidence in teaching science (Jung & Tonso, 2006; Kelly, 2000). For example, Kelly (2000) examined the impact of a constructivist-based elementary science methods course had on prospective teachers' knowledge and understanding of science and their attitudes science and teaching science. The methods course was conducted in two different locations: the university classroom and the hands-on science site of the local Museum of Science and History. Prospective teachers visited the museum four times, and each visit lasted for 3 h. In the first visit prospective teachers were given presentations and a tour of the museum, while in the second and third visit they were paired with elementary students and engaged in inquiry-based science investigations. In the last visit prospective teachers field-tested their investigations with groups of elementary students from area schools. The analysis of the pre- and post-surveys from the 230 prospective elementary teachers who participated in this study, indicated that most of them expressed more positive attitudes towards science and science teaching as well as greater confidence in their ability to teach science.

Similar findings were produced in a study conducted by Anderson et al. study (2006) that showed that the 3-week teaching practicum at an aquarium improved pre-service secondary science teachers' self-efficacy and self-confidence in teaching

science. During this practicum preservice teachers were involved in observing the Aquarium staff as they taught school programs, teaching on their own, and developing materials for school programs for students from pre-school to grade eleven. In doing so, they collaborated with the Aquarium education staff members as well as their university advisors on weekly basis. Several participants stated that the aquarium practicum enabled them to overcome professional and personal struggles they had experienced in their classroom practicum. In providing a new environment for science education, the informal aquarium setting helped restore pre-service teachers' interest in the teaching profession and confidence in their own teaching abilities. Similar findings were reported in Jung and Tonso's (2006) study, which used a museum and a nature center as contexts of a group of pre-service teachers' practicum experience. The findings of this study showed that a sequence of experiences such as hands-on lessons, practice of teaching and repeating of lessons reduced pre-service teachers nervousness about science teaching.

Riedinger, Marbach-Ad, McGinnis, Hestness, and Pease (2010) reported similar results in a study investigating the impact of an innovative elementary science methods course that included aspects of informal science education. As part of this course, informal educators were invited to share their perspectives on science education and demonstrated how to incorporate resources from informal science education to enhance science lessons. One of these speakers, for example, brought a live owl to the classroom while another one used activity calendars from an afterschool program in which students engaged in science investigations with their families. In addition, preservice teachers explored a museum's exhibit through a virtual field trip to study global climate change. The findings of this study showed that almost all candidates in the treatment group finished the course with positive attitudes towards science, and that they 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. Summing up, the findings of these studies provide evidence that informal science environments have the potential to improve teachers' attitudes towards science, motivation, interest and engagement.

Teachers' Views About Science Teaching

Another set of studies have explored the impact of informal programs on teachers' views and understandings about science teaching. For example, Anderson et al. (2006) examined pre-service teachers' experiences within the context of a practicum experience developed through a partnership between a teacher education program and the Vancouver Aquarium Marine Science Centre, as described earlier. Analysis of a set of qualitative data (i.e., videos of focus group discussions, observations and field notes, reflective papers) showed that through this experience prospective teachers expanded their thinking about education to other contexts, they enhanced their understandings of constructivism, developed their skills in flexible pedagogy, gained a sense of autonomy in trying different pedagogical techniques, self-confidence and self-efficacy as teachers. Wallace and Eick (2012) reported

analogous findings about a study with 23 elementary preservice teachers who were enrolled in a methods course that was implemented in conjunction with children's summer camps. In the context of the methods course, preservice teachers alternated half-day teaching experiences in the camps. The methods course focus on reform-based science teaching strategies and emphasized the 5E learning cycle model. As the researchers described, when conducting instruction at the summer camps preservice teachers worked in pairs to engage groups of 6–8 children with inquiry-based science lessons. The findings of this study showed that by the end of the course the participants had developed advanced ideas about teaching, learning and identity, which included understandings about inquiry, engaging students in open-ended explorations and discussions, and addressing diverse learners' needs. Similarly, the findings of Jung and Tonso's study (2006) showed that preservice teachers felt less inhibited in museum and nature center settings as they were free to develop their own teaching styles. As Ferry (1995) suggested, informal science settings can provide a fun, non-threatening, and supportive environment in which pre-service teachers can experiment with new approaches to science teaching. In examining preservice teachers' views about informal institutions, Kisiel (2013) reported on a study where a group of pre-service elementary teachers enrolled in a science methods class participated in a semester-long assignment which required participation in their choice of activities and events (e.g., workshops, field trips, family day activities, professional development sessions) conducted at local informal science education institutions in California. Examples of these activities are the following: (a) the science center open house where teachers have opportunities to explore scientific phenomena with the help of volunteer explainers and to talk with staff about scheduling programs for schools; (b) the Aquarium lecture series which feature leading scientists speaking on a variety of topics as they aim to promote ocean literacy; and, (c) NASA day on campus, where teachers have opportunities to engage in discussions with NASA educators and to participate in a variety of hands-on learning activities. Analysis of pre- and post-course data showed that this assignment strengthened preservice teachers' perspectives about informal science education institutions as more than places for field trips and hands-on experiences. As Kisiel (2013) summarized, the participants viewed these spaces as institutions that can help them with classroom science instruction, support them in developing content knowledge, and provide them with lesson plans and other learning resources, artifacts and materials. Access to resources was also identified by the participants in Luehmann and Markowitz's (2011) study, which explored how eight urban secondary science teachers evaluated a year-long, out-of-school science enrichment program (i.e., half-day inquiry, laboratory experiences for the students). The purpose of this program, as the researchers described, was to engage students in scientific research, by designing and carrying out investigations drawing conclusions about collection and analysis of authentic data. Other perceptions of the participants about the benefits of the program included positively affecting students' learning of, interest in, and attitudes toward science, providing students with opportunities to assume central roles with scientific inquiry, and also supporting both students and teachers' identity needs with respect to school science.

Summing up, as it becomes evidenced in this review of the literature, there exists a consensus about the significant role of informal science environments in supporting teacher learning and development, as shown in Table 1. Of special interest in this literature is how the use of informal science approaches to teacher preparation has the potential to support elementary teachers overcome certain challenges that they face: constructing science content knowledge, constructing pedagogical knowledge, developing an appreciation of science and its role to society, developing positive attitudes and orientations toward science and science teaching, developing self-confidence as future teachers, developing understandings about scientific inquiry, and developing understandings about the nature of science and the work of scientists. These potential outcomes are not only connected to the challenges that beginning elementary teachers but they are also intertwined with reform recommendations, as illustrated in Fig. 1.

Limitations of Existing Literature

As described above, the examples of embedding informal science approaches to science teacher preparation, especially within the elementary preparation context are limited. However, the few that exist provide sufficient evidence that make a compelling argument for integrating informal science approaches and activities in teacher preparation and specifically within the elementary science methods course. A set of studies provide evidence of the crucial role of informal science programs in supporting teachers develop subject-matter and pedagogical knowledge, another set of studies offer findings that speak to the role of such programs in supporting teachers develop positive attitudes towards science and science teaching, and other studies describe the impact of such programs on teachers' views about science teaching. In summarizing the findings of these studies two limitations become profound: one is associated with the theoretical framing of the studies and one is connected to the methodological approaches adopted.

The researchers of the studies reviewed here have used various theoretical constructs (i.e., knowledge, understandings, beliefs) that emphasize cognitive aspects of development in order to conceptualize and examine teacher learning and development in various informal science contexts. However, given the social nature and culture of informal science environments a sociocultural approach to framing teacher learning and development in these settings is proposed. Such a framing is offered through the construct of teacher identity. Only a couple of studies reviewed here have used the construct of identity to frame teacher learning and development. One study conducted by Katz et al. (2011) explored the ways in which an afterschool informal internship (i.e., science program for elementary students) supported preservice elementary teachers' professional identity development. Identity, in this study, was conceptualized as the ways in which teachers' viewed themselves as teachers of science as well as how they were viewed by others. Preservice teachers participated in an 8-week session of the program, which included inquiry-based activity guides, training prior to each session, and kits of materials for the activities in the guides. As part of the internship, preservice

Table 1 Potentials of formal–informal institutions partnerships

Issues and challenges beginning elementary teachers face	Potential solution through formal and informal institutions partnerships
Lack of confidence in teaching science and difficulties in understanding instruction	Informal science environments can provide safe environments where teachers could teach small groups of young learners, for example through participation in informal science institutions internships where they have opportunities to teach young learners and enhance their confidence and self-efficacy (Anderson et al., 2006; Gupta & Adams, 2012; Kelly, 2000; Luehmann, 2007)
Negatives attitudes towards science	Teachers can be supported in reconstructing any negative attitudes towards science through exciting and fun activities in informal settings that exemplify the connections of science to everyday life (e.g., interactive tours to space, exhibits about the human body, energy, sounds and light etc.) (Anderson et al., 2006; Riedinger et al., 2010)
Challenges related to content knowledge/understanding the content of science	Teachers can be supported in constructing scientific knowledge through various means, modes of communication, and activities that cover a wide range of learning styles (e.g., science cafes, hands-on activities, audiovisual materials, use of interactive technology devices, working with scientists, interactive exhibits, photographic images, field-trips etc.) (Jung & Tonso, 2006)
Not adequate understandings of the nature of science and the work of scientists	Teachers can be supported in developing understandings of the nature of science and the work of scientists through specially designed exhibits related to the nature, history and philosophy of science, as well as scientists' biographies and through science apprenticeships (e.g., Alexander Fleming Museum, working with scientists, visits to scientists' laboratories) (Gupta & Adams, 2012; Katz et al., 2011; Stocklmayer et al., 2010)
Difficulty in embracing reform recommendations, especially in developing understandings about scientific inquiry	Provide teachers with opportunities to experience inquiry-based science through engaging in investigations with authentic data in context-specific settings that are rich in resources (e.g., investigations about dinosaurs in a natural history museum) (Katz et al., 2013; Luehmann & Markowitz, 2011; Wallace & Eick, 2012)
Challenges related to instruction, pedagogical knowledge and understanding students' needs	Provide teachers with opportunities to work with diverse learners through internships in informal science institutions and field-experience placements (Anderson et al., 2006; Wissehr & Hanuscin, 2008)
Issues related to obtaining necessary resources and managing materials	Informal science settings and institutions provide spaces that are rich in resources and materials where beginning teachers can learn alongside museum staff and informal science educators how to manage those and design for learning (Kisiel, 2013; Luehmann & Markowitz, 2011)
Challenges in understanding learning environments	Provide teachers with opportunities to learn-to-teach science in a variety of contexts and settings such as museums, after-school settings, scientists' laboratories (Kelly, 2000; Kisiel, 2013; Wallace, 2013)

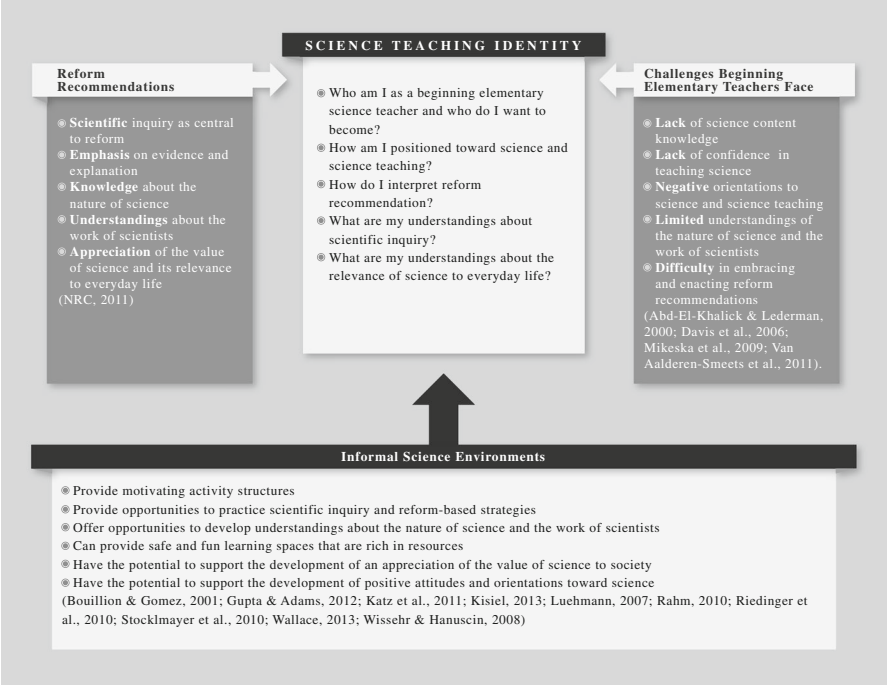

Fig. 1 Challenges teachers face, reform recommendations and the role of informal science environments

teachers engaged children in investigation of scientific questions with the use of authentic data. Analysis of research data on four selected participants showed that after completion of the internship the participants were able to see themselves as enacting key reform recommendations including sensitivity to diversity, facilitating hands-on science, inquiry and collaborative work. Another study, conducted by Katz, McGinnis, Riedinger, Marbach-Ad, and Dai (2013) explored how the inclusion of an informal science internship in a teacher preparation program influenced two beginning teachers' science teaching identity development. This 3-month internship occurred prior to the science methods course. As part of this internship, participants had opportunities for co-teaching young children with informal science teachers. The methods course included sessions devoted to informal science education and included informal educators visits as guest speakers as well as a virtual field trip to a museum. The outcomes of this study illustrated that the informal science experiences contributed in positive ways to the development of the participants' identities. In agreement with Katz et al.'s conceptualization, the point of interest in this paper is the ways in which beginning elementary teachers view themselves as science teachers. However, the argument put forward in this paper goes a step further than Katz et al.'s work (2011, 2013) to make a direct link between how teachers view themselves as science teachers particularly in relation to reform recommendations—in order words, to explore the construct of *reform-minded science teaching identity* and the role of informal science environments in supporting its development.

A methodological limitation found in existing literature on informal science education is that the majority of empirical studies are short in duration ranging from a few days/experiences embedded in a course (Riedinger et al., 2010), to a semester (e.g., Kisiel, 2013) or a year (e.g., Luehmann & Markowitz, 2011). What's missing is a set of longitudinal and biographical approaches to studying science teacher identity, which would shed light on the various experiences that teachers have throughout their lives and in a variety of contexts (e.g., everyday life contexts, informal institutions contexts, out-of-school contexts) and which are critical to the development of their science teaching identities. In light of reform recommendations, the argument put forward in this paper proposes that researchers turn their attention to the role of informal science environments to the development of beginning elementary teachers' reform-minded identities for science teaching, which has been largely neglected in existing research on elementary teacher development within informal science environments. To examine this empirically the use of longitudinal and biographical methods, which have not been adopted in existing research is suggested. The following sections offer recommendations for future research directions based on the theoretical, methodological and research implications that the argument put forward in this paper holds.

Moving Forward

The following recommendations are offered with the recognition that certain challenges and constraints in attempting to achieve greater complementarity between teacher preparation and informal science institutions exist and that policy changes and strategic planning ought to be made. These challenges are associated with issues of accreditation and teacher licensure, university policies, financial resources, as well as institutional cultural differences between informal science institutions and universities. Factors to be considered in attempting to reconceptualize teacher preparation to integrate informal science institutions are national education goals and policies, teacher preparation and accreditation, informal science institutions' accreditation and informal educators' professional development, systems of professional development, and ways of teacher assessment (Allen & Crowley, 2014; Bell et al., 2009; Bevan et al., 2010; Fallik et al., 2013; Stocklmayer et al., 2010). Equally important is a reconceptualization of the science methods course in terms of its development, structure and implementation as well as evaluation (Kelly, 2000). Such changes require the development of symbiotic relationships between formal and informal institutions and productive collaborations between formal educators and museum staff or informal educators (Allen & Crowley, 2014; Fallik et al., 2013). Fallik et al. (2013) offered a model for bridging formal and informal education, which includes four different aspects: (a) mutual recognition of the importance of bridging by both educational staff groups; (b) mutual acquaintances with the two curricula by both staff groups; (c) preparation of students to reduce the novelty space regarding the informal contexts; and (d) ongoing dialogue between both staff groups. This model also includes three design principles (i.e., organizational, cognitive, affective and social environmental)

as well as practical steps (e.g., presenting activities to students by both educational staff groups, defining the roles of each staff member in the dialogue etc.) towards this goal. In describing models for building relationships between the formal and informal sectors, Stocklmayer et al. (2010) identified an ideal model where the "formal sector integrates the capabilities of the informal sector into its everyday working, thus creating a third space for science education" (p. 29). This model of relationships holds theoretical and methodological as well as research implications that are described next.

Theoretical and Methodological Implications

One of the main implications of the argument put forward in this paper is to view teaching learning and development, especially within informal science environments, through the lens of identity. In this paper, as described earlier, identity is viewed as a comprehensive construct that encompasses several aspects and dimensions of teacher learning and development that have been described in the review of the literature: knowledge, understandings, attitudes, self-efficacy, emotions, views, and orientations to science and science teaching (Avraamidou, 2014a). The justification for this decision is grounded within literature pointing to how these dimensions of teacher learning and development are interrelated and intertwined to form an identity (e.g., Avraamidou, 2014a; Beauchamp & Thomas, 2009; Kelly, 2000; Kisiel, 2013; Moore, 2008) and is based on propositions for examining teacher growth using an identity development perspective (Avraamidou, 2014b; Luehmann, 2007; Settlage et al., 2009). The interaction and combination of these constructs contributes to how a teacher views herself and is recognized by others. One would speculate, for example, that when a teacher is confident in her subject-matter knowledge she would probably have positive attitudes towards science and science teaching as well. Moreover, one would imagine that how a teacher positions herself regarding gender and racial orders has consequences on how her identity is being developed. One also would expect that if a teacher has been developing contemporary understandings about science teaching based on reform recommendations, she would probably view herself as a reform-minded science teacher. A review of literature on science teacher identity illustrates a range of theoretical frameworks that have been used to conceptualize and study science teacher identity, as described earlier. Missing in these conceptualizations remains a view of science teacher identity through the lens of reform recommendations in science education. Put differently, the field lacks a clear and concrete definition of science teacher identity connected to reform ideas. Saka et al.'s (2013) work provide a starting place to conceptualizing *reform-minded science identity* and exemplifying its unique characteristics. A deeper examination of science teacher identity in light of reform movements that would provide researchers with a conceptual framework to study reform-minded science teacher identity is warranted.

Another major implication of the argument put forward in this paper is associated with the methodological considerations that the idea of integrating informal science education approaches to elementary teacher preparation holds. Given a lack of longitudinal empirical studies in the field of informal science education, researchers

could examine the kinds of informal science experiences teachers have throughout their lives and the ways in which those impact the development of their science teaching identities, particularly in relation to reform recommendations. Gaining an insight into the informal experiences that science teachers have throughout their lives can be useful in our attempts to understand the processes of their science teaching identities development. Several researchers have argued about the value of studying teachers' biographies and life histories (e.g., Avraamidou, 2014b; Flores & Day, 2006; Knowles, 1992). Knowles (1992) described the following as relevant biographical categories: early childhood experiences, early teacher role models, previous teaching experiences, and significant or important people and significant prior experiences. Likewise, Flores and Day (2006) argued about the significance of studying teachers' life histories and emphasized the importance of examining the various context of teaching and subcomponents of those, which influence teacher development. A related longitudinal study with a beginning elementary teacher, recognized as a reform-minded teacher, provides evidence of the impact of different informal science experiences within various contexts (family visit to a park, interaction with a scientist, outdoors environmental study) on her development of identity for science teaching (Avraamidou, 2014a). In a follow-up study currently in development I aim to examine the impact of a set of informal science experiences (i.e., interacting with a scientist, engaging in a science fair, conducting a field study) situated in the context of an elementary science course, on a group of 25 prospective elementary teachers' development of reform-minded science teaching identities.

Research Implications

A review of the literature provides evidence of the advantages that informal science environments offer to teacher preparation. In light of reform recommendations emphasizing scientific inquiry the question becomes one of examining the ways in which the use of informal science environments could support beginning teachers in developing reform-minded ideas about science teaching and learning. Research findings provide evidence that beginning elementary teachers can be enabled to apply reform-minded practices such as teaching science as inquiry, emphasizing argumentation and the role of evidence and explanation in science, and making adaptations to curriculum materials (Avraamidou & Zembal-Saul, 2005, 2010; Davis & Krajcik, 2005; Davis & Smithey, 2009; Schwarz, 2009; Zembal-Saul, 2009). In order to be able to teach science as inquiry, as these studies have shown, beginning teachers ought to be provided with multiple opportunities to learn science as inquiry during their preparation. Such opportunities to engage in scientific inquiry can be situated within informal science environments given their unique contextual characteristics and affordances, the fact that they are rich in resources, that they offer motivating structures for engaging in investigations with authentic data, and that they are well-positioned to exemplify the nature of science and the work of scientists (Gupta & Adams, 2012; Katz et al., 2011; Luehmann, 2007; Stocklmayer et al., 2010). A related research area that deserves further attention is an exploration of the ways in which informal science environments could be used to support the development of teachers' understandings about the history of science, the practice

of science, the culture of science and the nature of scientists' work—all central to reform recommendations. Examples of approaches that support the development of understandings about the practice of science and the work of scientists are found in literature within the contexts of secondary and high school documenting the impact of school-scientists partnerships on students' views of scientists and the nature of their work (Avraamidou, 2013b; Bodzin & Gehringer, 2001; Bouillion & Gomez, 2001; Richmond & Kurth, 1999). These studies offer examples of short-term partnerships of schools with scientists, scientists visiting classrooms and students visiting laboratories, doing internships and attending summer school research programs with scientists. The findings of these studies illustrate how the out-of-classroom experiences and the interaction with scientists could support students in reconstructing their stereotypical views about scientists and developing understandings about the practice of science. In describing ethnographic research of three after-school science programs (i.e., girls-only science afterschool program, gardening and science program at a botanic garden, and a mentoring program affiliated with the science division of a university) Rahm (2002, 2010) described how young people's prior knowledge of science that comes from school-based experiences tends to be narrow and scripted. As she argued, youth need to acculturate to a new culture, that of the community of scientists. Such learning, as she described, involves practice and engagement in the process of making science along with relationships with scientists and the scientific community. These approaches offer examples of learning apprenticeships and participation in communities of practice, through which individuals construct their identities, as conceptualized by Lave and Wenger (1991). Such approaches could be useful at the teacher preparation level as well given research that shows teachers' limited understandings of the nature of science (Abd-El-Khalick & Lederman, 2000). Indicative questions to be answered are the following: *In what ways can teachers be supported in developing reform-minded science teaching identities in the context of informal science environments? What kinds of informal science approaches and activities support teachers embrace reform recommendations? In what ways could informal science environments be used to support teachers to develop understandings about the nature of science and the work of scientists?*

Conclusions

The purpose of this paper was to explore links between teacher identity, informal science environments and reform recommendations in science education. Essentially, the idea proposed in this paper is an exploration of the potential of informal science environments in supporting beginning elementary teachers' development of reform-minded science teaching identities. Interestingly, while there are a few studies documenting the benefits of universities and informal science environments/institutions collaborations in supporting teacher learning and development very few of these studies address explicitly these benefits in light of reform recommendations. The idea of using informal science institutions as partners in teacher preparation to address reform recommendations remains a largely unexplored research area. This is, in fact, the main contribution of this paper, which proposes the integration of

informal science environments in elementary teacher preparation for the purpose of supporting elementary teachers in overcoming challenges they face and developing reform-minded science teaching identities. The basis of this argument lies in the fact that informal science environments are particularly well-positioned to address specific dimensions of a reform-minded teacher identity: affective dimensions, self-efficacy and attitudes dimensions, science content knowledge, understandings of the nature of science, scientific inquiry, and the work of scientists. Researchers have examined these dimensions separately, but not collectively and/or in interaction through a more comprehensive approach: a reform-minded identity lens. Essentially, this argument rests on four separate arguments. One is that informal science environments offer motivating structures for learning to teach and provide opportunities to practice science teaching in 'safe' environments, which, in turn, supports teachers' self-efficacy. Second is that informal learning environments offer opportunities for learning to teach science through inquiry-based activities in environments that are rich in resources. Third is that informal science environments offer unique opportunities for developing content and pedagogical knowledge for science teaching. Last and perhaps more weighty is that informal environments can support teachers in developing understandings about the nature of science, the relationship of science to society, scientific inquiry and the work of scientists. As attention is being paid to teacher identity and in light of calls for reform in science education, the role of informal science environments to elementary teacher preparation and how they need to be considered becomes salient. This paper aims to provide the basis for conversations aligned with the evolving role of informal science environments in the society, and visions for reform in science education among policy makers, curricular developers, researchers, teacher educators, staff and educators in informal science institutions, and science teachers.

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