

Science
Education

Challenging Beliefs, Practices, and Content: How Museum Educators Change

LAUREN B. ALLEN, KEVIN J. CROWLEY

University of Pittsburgh Center for Learning in Out-of-School Environments, Learning Research & Development Center, University of Pittsburgh, Pittsburgh, PA 15213, USA

Received 21 December 2012; accepted 17 October 2013

DOI 10.1002/sce.21093

Published online 25 November 2013 in Wiley Online Library (wileyonlinelibrary.com).

ABSTRACT: Educators in informal settings can be a key part of the learning experience, yet they are often poorly supported as professionals. This study followed the professional development of museum educators who participated in iterative implementation of a new school trip program focused on climate change. The learner-centered pedagogy, inquiry format, and controversial content of this program all presented challenges to the educators' existing models of learning and teaching in the museum. We offer four case studies that explore how part-time museum docents engaged in reflective practice through iterative implementation and how their approaches to learning and teaching in the museum changed, or failed to change. Findings have implications for addressing the challenge of effective professional development for informal educators, particularly in content areas that may be scientifically challenging or socially controversial. © 2013 Wiley Periodicals, Inc. *Sci Ed* 98:84–105, 2014

INTRODUCTION

We present a group of museum educators—docents in a natural history museum (NHM)—who confronted their own notions of learning in the museum as a result of participating in a 5-month iterative implementation of a completely new school trip, which was different in both format and content from previous school trips that the docents had facilitated. Docents in the United States are usually volunteers or part-time, low-paid educators

Correspondence to: Lauren B. Allen; e-mail: lba8@pitt.edu

who come to the museum because of their own knowledge and passion for the collections and/or their desire to share that knowledge and passion with the public (Cox-Petersen, Marsh, Kisiel, & Melber, 2003; Grenier, 2006; Jones, 2012). They are often retired and well educated, and see the role of docent as a way to continue their own lifelong learning and give back to society (Abu-Shumays & Leinhardt, 2002). Docents are most often found in collections-based institutions such as natural history museums, zoos, botanical gardens, aquaria, and nature centers or parks.

Docents are often the only point of human contact for visitors to museums. This is especially true for school trips, where docents routinely guide groups of students through exhibitions (Cox-Petersen et al., 2003). Although informal learning settings expand the possibilities for science learning beyond those offered in schools (Bartels, Semper, & Bevan, 2010; Bell, Lewenstein, Shouse, & Feder, 2009; Bevan et al., 2010; Falk, & Shepard, 2006), school trips rarely take advantage of the unique affordances of museums, tending to look more like formal learning enacted in an informal setting (Cox-Petersen et al., 2003; DeWitt & Storksdieck, 2008; Kisiel, 2005a; Kisiel, 2005b). We assert that a major reason for this has to do with the ways that docents and other kinds of museum educators conceptualize and enact models of learning in the museum. Museum educators tend to rely on familiar epistemologies and pedagogies, which are often rooted in their own personal learning experiences in formal settings (Bevan & Xanthoudaki, 2008; Castle, 2006; Cox-Petersen et al., 2003; Grenier, 2005).

Confronting and changing embedded assumptions about learning and teaching is a major challenge for informal and formal educators alike. Stein, Smith, and Silver (1999), for example, argue that teacher preparation programs should provide deep-seated reexamination, ongoing experimentation, and critical reflection through scaffolded and intensively analyzed apprenticeships informed by discussions of the latest research on teaching and learning. Rather than viewing teaching as a skill to be trained, teachers develop as part of an evolving community of practice where newcomers may begin on the periphery, but over time move toward the center and become resources for helping new members make progress in becoming members of the community (Abu-Shumays & Leinhardt, 2002; Castle, 2006).

Most professional development for museum educators does not yet follow this model. Docent-specific training conventionally consists of occasional lectures from other members of the museum staff, readings, and perhaps briefly shadowing more experienced docents giving visitor tours (Abu-Shumays & Leinhardt, 2002; Castle, 2006; Grenier, 2005, 2009; Grenier, & Sheckley, 2008). Grenier (2005) explored a paradoxical discrepancy between the participatory theories of learning espoused by docent trainers (usually full-time museum educators or staff members) and the transmission, or acquisition-based, “theories-in-use” during actual docent trainings. “Without training reflective of engaging programs that encourage questioning, interaction and experimentation, docents will likely continue to lead tours in a manner that mirrors their prior learning experiences in schools and in docent training” (Grenier, 2005, p. 6).

Ash and colleagues have recently conducted research with museum educators, finding reflective practice and a design-based scaffolding framework can result in changes in museum educators’ practice toward less didactic, more learner-centered interactions with visitors (Ash & Lombana, 2012; Ash, Lombana, & Alcala, 2012). Tran (2006) conducted an in-depth study of museum educators’ practices and learning goals for school trip students. She found that museum educators expected students to apply prior knowledge, make connections to real-world situations, and most importantly have a positive experience that sparked enthusiasm for learning in museum environments. Yet, in spite of ontologically different priorities, museum educators demonstrated limited strategies for affectively engaging school-trip students, and, as a result, their educational practice appeared very much

like that of formal classroom teachers. Tran advocates that museum educators develop a shared professional language and appropriate pedagogy to support the top priority, affective and student-centered learning objectives museums are uniquely suited to serve.

Castle's (2006) research on how docents conceptualize their own learning in regard to their professional practice further elucidates the need to recognize the chasm between inquiry-based pedagogies museum educators are expected to employ and the types of professional development they are offered. She provides evidence that docents benefit from a community of practice emphasizing reflection and support from their institution, much like formal educators (e.g., Horn, 2010). Museum educators, like classroom teachers, are often isolated in their practice, with few opportunities to discuss the details and generalities of their work with knowledgeable colleagues. Several researchers have recommended training for museum educators that includes adequate support for reflection (Bevan & Xanthoudaki, 2008; Castle, 2006). Grenier, Castle, and colleagues have called for a more experiential, practice-based, and participatory approach to docent training (Castle, 2006; Grenier, 2005, 2006, 2009, 2010; Grenier & Sheckley, 2008).

One of the major challenges faced by formal and informal educators alike is dealing with what Sfard (1998) describes as the two main metaphors of learning: the acquisition metaphor, wherein learning is conceptualized as the absorption of transmitted knowledge; and the participation metaphor, wherein learning is conceptualized as an active process. Many museum educators begin with the notion that learning is primarily the acquisition of knowledge, a property to be transmitted from a more knowledgeable person to a less knowledgeable person (Bevan & Xanthoudaki, 2008). The acquisition metaphor, however, fails to recognize learning that happens through experience and interaction. Current ideas about powerful learning in informal settings tend to be built from the participation metaphor, phrasing knowledge as action and making learning inseparable from context and process (Bell et al., 2009). Cox-Petersen and colleagues (2003) found that traditional, didactic, docent-led tours in a NHM failed to educate on the level of twenty-first century science standards and that student learning gains were negligible. Our project strived to design and iteratively implement a school trip that encouraged student learning with active scaffolding using research-based principles for inquiry. Neither the acquisition nor the participation metaphor alone can accurately characterize human learning (Sfard, 1998) or usefully inform educational practice. An understanding of the strengths and weaknesses of each is what we hoped our docents could achieve by participating in this experience.

This study examines how NHM docents' educational practice and conceptions of learning evolved through professional experience. Docents participated in the iterative implementation of a new school-trip program that encouraged student-centered, inquiry-based learning and asked them to critically examine traditional teacher-centered learning models. We hypothesized that participation in the iterative implementation of an inquiry-based school trip would support natural history docents in developing professionally by adopting a pedagogy of inquiry not previously part of their training or practice in the museum. We address two main research questions: How do docents at a NHM think and talk about learning in the museum? And, how (if at all) does involvement in iterative implementation of a new, inquiry-based school trip program about climate change influence the way docents think and talk about learning in the museum?

Project Background

Our study takes place in the context of a large NHM in a midsized rust belt city that embarked on a 4-year collaboration to develop a curriculum-connected, climate science learning experience for middle school students from the local public school district (PSD).

PSD is a typical urban school district with a diverse student body, over half of whom qualify for free or reduced lunch. A multidisciplinary and multiinstitutional team of staff from the museum, the school district, and a university research group designed the inquiry framework and format that were iteratively implemented by the docents, facilitated and supported by a science educator from NHM and a learning scientist (Allen) from the university research group. The new school trip in this study used National Aeronautics and Space Administration (NASA) satellite data and the museum collection to engage students in learning about climate change and its connection to biomes. Table 1 shows our driving questions and learning objectives, which were arrived at by connecting the required school curriculum with the affordances of the museum collections.

While the present study is primarily about changes toward learner-centered practice that docents made, we emphasize that the context of the difficult-to-learn and politically controversial scientific content of climate change (Grotzer & Lincoln, 2007; Moser, 2010) is an important facet of these practice-based changes. Climate change is an important issue for museums to address because it is not undertaken in many school curricula (Abbasi, 2006; Cameron, Hodge, & Salazar, 2013). Researchers of social responses to climate change have found that science content knowledge alone is not sufficient to induce feelings of concern and responsibility for climate change adaptation and mitigation (Kahan et al., 2012; Roeser, 2012). Educational researchers and climate scientists agree that climate literacy must include a sense of concern for the environment and responsibility to adapt and change (Crowell & Schunn, 2013; van Kerhoff & Lebel, 2006). We designed the new school trip to provide a balance of scaffolding and free-choice learning. Iterative implementation improved and refined the design and supported docents in their professional development and growth as reflective practitioners of science education.

To understand the professional development of the docents who iteratively implemented the new school-trip content and format, we first describe briefly what the traditional school trips and docent training at NHM look like. We then explain the new school-trip format and inquiry framework that docents implemented in contrast to traditional school trips. Finally, we present four docent case studies, followed by an analysis and discussion of these findings and their implications.

Traditional School Trip Format. The traditional school trip to NHM consisted of docents leading tours of 6–12 students to areas of the museum. Docents selected exhibits and explained their significance to fit a designated theme, chosen ahead of time by the teacher or the school’s trip coordinator. Traditional school trip themes included a comparison of three cultures, the Mesozoic, and in-depth explorations of specific areas of focus, such as Egyptian artifacts and culture. Docents would engage in back-and-forth questions and answers with students, sometimes checking for understanding or answering questions about exhibits or the museum’s role in acquiring artifacts or specimens on display. Docents at this NHM underwent in-depth content training on the permanent exhibits when they joined the museum and attended sporadic lectures from the museum’s staff or guest scientists regarding temporary exhibits or new research findings. Attentive to the needs and interests of students, docents would ask questions at the beginning of tours to ascertain students’ levels of understanding of the topics and concepts central to their tour. Early in the development of the new school trip about climate change (December 2011, before the new design), docents were encouraged to talk about climate change and NASA satellite data on their traditional tours, but were not provided training on climate change content, NASA satellite data, or how to address potentially uncomfortable topics.

TABLE 1
Learning Objectives and Driving Questions Matrix

Driving Questions	Learning Objectives		
	Knowledge	Skills	Disposition and Participation
How are climate and biomes connected and what happens when they change?			
What are biomes?	I can describe in my own words earth's biomes, using features such as precipitation, temperature, and vegetation.	I can utilize NASA data to identify and describe different biomes.	I will explore weather, climate, and biome data based on my own interests.
What's the difference between climate and weather?	the differences and connections between weather, climate, and climate change.	identify and use scientific evidence (maps, fossils, photographs, etc.) to describe current and past climate change.	have conversations about biomes, climate change, observations and evidence with peers and adults.
Do climate and biomes really change?			
How will humans respond?	why it is important for people to understand climate science.	ask questions and connect experiences to my own life.	identify the parts of my school trip that are of personal interest to me.
How do scientists study change?	how my school trip site is part of climate science research and education.	access scientific evidence and learn through authentic objects, data, and living collections on my school trip.	recognize my school trip destination as a valuable part of my city—a place where I can visit, learn, have fun, volunteer, and find a job.
What does NASA have to do with this?			

TABLE 2
Project Timeline

Date	Description	Participating Case Docents
16-Dec-11	First meeting	Elizabeth, Steve, Paul
26-Jan-12	Training: Guiding principles, learning objectives, and big questions, format introduced	All
3-Feb-12	School trip: ~160 students, 15 chaperones	All
8-Feb-12	Debrief for 3 February school trip	Lucy, Paul
10-Feb-12	School trip: ~20 students, nine chaperones (special education academy)	Elizabeth, Steve
10-Feb-12	Debrief for 10 February school trip	Elizabeth, Steve
14-Mar-12	Docent training: On the floor; principles in practice	All
18-Mar-12 to 22-Mar-12	Online survey on docent training: Satisfaction, perceived effectiveness	Elizabeth, Steve, Paul
23-Mar-12	School trip: ~180 students, 18 chaperones	All
28-Mar-12	Debrief for 23 March school trip	All
18-Apr-12	School trip: ~30 students, two chaperones	Paul
18-Apr-12	Debrief for 18 April school trip	Paul
26-Apr-12	School trip: ~45 students, four chaperones	All
7-May-12	Debrief for 26 April school trip	Lucy, Paul, Steve
13-Jun-12 to 15-Jun-12	Interviews	All

New School Trip Format. The pedagogical design of the new school trip had three main elements: driving content questions, learning objectives, and guiding principles for inquiry-based learning. Docents iteratively implemented this new school trip design with students from PSD between January and May 2012 (see Table 2 for project timeline). In this section, we first describe the structure and format of the new school trip, as it contrasts with the traditional tour, followed by an explanation of the theoretical underpinnings for the guiding inquiry principles docents implemented and the overall framework of iterative implementation within a community of practice.

The new school trip, unlike traditional tours, included a one-class-period visit by a science educator from NHM to the school a day or two before the museum visit. None of the traditional school trips include an in-school component, which means that docents rarely have in-depth understanding of student preparation. The pretrip component was intended to enhance student learning and engagement (Gennaro, 1981; Orion & Hofstein, 1994). Sturm and Bogner (2010) argue that adequate preparation and clear objectives for connecting class material to school-trip material make school trips much more beneficial to student learning. The goal of the school visit was to introduce and activate students' resources for learning about the connections between climate, biomes, and the animals and plants inhabiting those biomes (Hammer, Elby, Scherr, & Redish, 2005) while also framing those resources as useful for the pending school trip (Engle, 2006). The pretrip component established the main driving question of the experience: *How are climate and biomes connected and what happens when they change?* (Table 1) and introduced the use of observations of real data and specimens as evidence in conversations about biomes, climate, and change. The March 14 docent training included the full pre-field trip component of the

program, so that docents had a clear understanding of exactly what students experienced in school immediately before visiting the NHM.

During the new school trip, the only structural similarity to traditional tours was the group structure: each docent was assigned a group of 10–15 students and at least one chaperone from the school. Rather than leading to various parts of the museum and explaining and describing exhibits of the docents' choosing, docents began the new school trips by briefly modeling scientific observation at a single exhibit as an introduction to an area of the NHM: analyzing the interactions between biotic and abiotic features of the diorama and discussing connections between adaptations of the organisms and the climatic features of the biome represented. Students were then encouraged to document their own observations and analyses of exhibits in that same area consisting of six to a dozen related dioramas using field notebooks introduced in the pretrip component. During this time, docents would circulate, engaging students in small conversations, answering questions, and scaffolding engagement with the driving questions (Table 1). Traditional NHM tours allowed few opportunities for students to choose which of the many exhibits they would spend time observing and discussing. By encouraging students to think about climate change as an ongoing process that has happened in the past and will continue to happen in the future, docents were able to more easily facilitate and engage in conversations about this controversial topic.

The areas visited during the new school trips were those that most closely related to the themes of biomes, climate, and how they might change. For docents, this meant connecting areas of the museum not traditionally presented together during a tour—for example, there is evidence of changing climate in the Mesozoic exhibits, as well as in the contemporary depictions of wildlife in their habitats from around the world. The content portion of the new school trip is outlined in Table 1 in the form of driving questions and learning objectives, which docents reviewed and referred to throughout implementation. Content foci for this school trip are the connections between the PSD middle school science curriculum, visualizable satellite data from NASA, and conceptual learning about climate change.

Guiding Principles for Inquiry. The new school trips were pedagogically founded on three guiding principles for inquiry-based learning from learning science and educational psychology research: learner autonomy, conversation and reflection, and deep investigation. These principles were established by the project's leadership, based on feedback and reflections from docents following an early attempt to modify the traditional tour to fit the climate change learning goals of the project. Specifically, docents had been frustrated that students did not hold still and listen to their lectures about docent-chosen exhibits, that students were talking among themselves at different exhibits than the docents wanted to focus on, and that there was not enough time to cover as many areas of the museum as they desired. We chose these guiding principles for inquiry to directly respond to docents' frustrations, reframing students' behaviors as positive for an inquiry-based learning experience, and providing research-based justification for encouraging such types of inquiry. The new format and guiding principles for inquiry were introduced to docents in a 3-hour training following the meeting where these frustrations were voiced. A second training, after two school trips and debrief meetings had been conducted, asked docents to put themselves in the place of the students and experience the principles in practice on the floor of the museum (see Table 2 for full project timeline).

Learner autonomy plays a significant role in student motivation for learning and engagement (Ames, 1992; Linnenbrink, 2007; Pekrun & Linnenbrink-Garcia, 2010; Ryan & Deci, 2000), particularly in informal and museum settings (e.g., Barton & Tan, 2010; Falk & Dierking, 2000). Autonomy is an important part of inquiry-based learning, as it frames the

learner as the decision maker and encourages learner-centered choices on the part of the teacher, facilitator, or (in this case) docent. We chose to use the term “learner autonomy” to encourage educators and docents to foreground learner-centered pedagogical choices, and the advantages of free-choice learning provided by the museum. Traditional docent tours provided little to no opportunity for learner autonomy, and, based on docents’ reports of student behavior at the first project meeting, it was clear that this particular group of students would benefit from more autonomy. We believed it would be a valuable learning tool when scaffolded well by the docents. Second, *conversation and reflection* have both been established as important aspects of museum learning (Ash, 2004; Barron, 2003; Crowley et al., 2001; Leinhardt, Crowley, & Knutson, 2002; Palmquist & Crowley, 2007; Pierroux, 2010). It was important that these two learning behaviors be encouraged during school trips, since both can lead to deeper engagement, especially with challenging content. In addition, students were already engaging in conversation with one another, to the earlier chagrin of docents. As a principle for inquiry, we found it important to encourage budding learning behaviors and give docents a strong foundation upon which to scaffold students learning experiences through their natural exploratory behaviors. And third, *deep investigation* of a few concepts, as opposed to shallow exposure to many facts, was our third principle for inquiry-based learning. This principle is specifically to help educators from feeling pressure to make sure students “see as much as possible” (Bitgood, 1989; DeWitt & Storksdieck, 2008; Kisiel, 2005a; 2005b; Orion & Hofstein, 1994). Throughout this report, we refer to “inquiry” as the incorporation of these three principles into learning experiences.

Iterative Implementation for Professional Development. We hoped to encourage and document the professional development of the docents who worked to iteratively and reflectively implement the new school-trip format. We also hoped to document the evolution of a community of practice among museum staff throughout this process. To achieve these goals, docents were involved in an iterative implementation process where they tested out successive versions of the school trip with students, reflected upon each experience with the project team and the other docents in facilitated “debrief meetings” after every school trip, and discussed changes that would make the next version of the school trip more effective. Changes were incorporated into the next version of the school trip with a new group of students, and docents and project leaders reengaged in the reflection and discussion debrief process. Our research encompasses five successive iterations of the school-trip and follow-up reflection and discussion with docents (Table 2).

We hypothesized that docents would experience success while implementing the three guiding principles, triggering a change in how they conceptualized learning in the museum based on new and different approaches to school trips. Iterative implementation allowed docents to refine the new approaches through the built-in reflection and support in the process. The provision of a safe environment, in which docents felt free to discuss their success and challenges in trying new ideas, was key. These supports were designed to promote the development of a community of practice among the docents. This hypothesis is informed by formal education research, in particular Nunnery’s (1998) study of teachers’ implementation of new classroom methods which revealed that educators do not need to be the sole developers of new approaches, but that they do need to observe successful application of those approaches in context (i.e., in the classroom, or in the case of the docents, on the museum floor). Engaging the docents in the process of iterative implementation allowed us to avoid the “locus of development problem” by including and supporting educators from the inception of the development process, while simultaneously challenging dominant notions of how learning happens on the floor of the museum during school trips.

Informed by literature from informal educator professional development as well as the larger body of research on teacher professional development, the theoretical framework for this study is founded in sociocultural learning theory (e.g., Greeno, 2006) and communities of practice (e.g., Lave & Wenger, 1991). As noted above, informal educators are in need of their own professional language (Tran, 2006) as well as adequate support for reflection on their practice (Bevan & Xanthoudaki, 2008). We developed a research-based inquiry framework, as well as a corresponding school trip format that we hoped would enable docents to actively scaffold student-centered learning experiences about climate change on the floor of the NHM. By implementing this new framework in a supportive, reflective group environment, we hoped that docents would begin to build a community of practice through observing one another on the floor with students, participating in reflective discussions with colleagues, and sharing their on-the-floor strategies. In addition, we hoped a community-of-practice environment would support the challenges particular to learning and facilitating learning about climate change for docents. By documenting the iterative implementation of this new school trip through observations, e-mail correspondence, and reflective debrief meetings after each iteration, we are able to present an example of the inception of a community of practice that works together to challenge dominant notions of learning and grapple with challenging (and for some, controversial) scientific and politicized content.

METHODS

Participants

Eight docents volunteered to participate in this new school trip project in 2010, before research began. These docents are among the most engaged and enthusiastic about their educational practice, all having noted that they almost always sign up for opportunities to try new things on the floor of the museum. All of the participating docents are White, college-educated (some having attended graduate school) retirees or those near retirement age. These docents facilitated all of the observed school trips and participated in debrief meetings (Table 2), and seven of the eight were interviewed at the end of the 5-month period of data collection.

Data Collection

Observations. Throughout the first 4 months of 2012, we observed four of the five school trips that took place at the NHM where our docents were applying the inquiry-based school-trip approach (see Table 2 for project timeline). Allen recorded observations in the form of detailed fieldnotes and wrote reflections within 24 hours of each observation to ensure the general understanding of the school trip was captured. Allen was a participant-observer for the two docent-training sessions (see Table 2) during the first half of the project, after which they also recorded informal reflections.

Debrief Meetings. Part of our iterative implementation process included reflective, facilitated debrief meetings after each school trip. We established a format in these meetings (between four and eight docents attended each meeting) where each docent shared his or her experience with the school trip, including successful strategies to be repeated and challenges they wished to discuss and better address in the future. Allen facilitated these meetings as an active participant and observer, attempting to ensure that all docents were given space to speak and listen. This structure highlighted the importance of reflecting on one's own experiences, receiving feedback, and providing feedback and reflection upon

others' experiences. Debrief meetings were attended by a separate minutes taker who typed detailed minutes used in our analysis. Allen also recorded informal reflections following each debrief meeting.

Interviews. In June of 2012, Allen interviewed seven of the eight most involved docents on the project, in an attempt to document their background, prior experiences that informed their work as docents, and experience of being a docent up to and throughout the course of the project. Interview questions included: "What are the moments that make you feel a school trip has been really effective?," "Can you talk a little bit about how museum learning is different from or similar to learning that happens in school?," and "Please describe the evolution of this project, from your point of view, since you first began working on it." These semistructured interviews were audio recorded, transcribed, and verified.

Data Analysis

Our earliest data were minutes from the December 2011 debrief meeting pertaining to the traditional school trip (Table 2). This meeting generated a lot of the initial ideas for the new school trip structure and informed the decision to use guiding principles from learning-science research to support and structure the change. Over two training sessions, five school trips, six debrief meetings, and various informal interactions, we observed distinct moments indicating that docents were changing how they interacted with students and how they talked about learning.

RESULTS

We present individual case studies of four docents representing a broad range of experiences, reflections, and responses to the process of iterative development. These cases serve as examples of how educators perceive changes in their own practice, or how they assimilate new ideas into existing cognitive frameworks. We close this section with a brief explanation of the docents' emergent community of practice, including the challenges faced when addressing controversial content and unfamiliar pedagogy.

Steve's Case: Reflective Change

I think the debriefings after each tour were absolutely invaluable . . . when a docent begins to have an individual approach within the framework that has been established, that is a very, very positive sign. (Steve, interview, 13 June 2012)

Steve is a retired geography lecturer and environmental planner for engineering firms, married, without children. He joined the NHM docents after retiring at age 63, in 1998, in an effort to "keep my brain from turning to sauerkraut" (Steve, interview, 13 June 2012), in other words, to continue to learn new things and be around a group of people who were also interested in natural sciences. He is a self-identified curmudgeon and has found his experience as a docent working with younger children to be the most challenging part of the job: "Below fourth grade, I am not very comfortable, and below second grade, I simply will not do the tour" (Steve, interview, 13 June 2012). Steve expressed low expectations for the target audience, which may have influenced some of his early attitudes: "[PSD] kids are not getting as much of a quality education as they deserve . . . I don't blame this on the

school system, I blame it on the parents because the parents are not demanding” (Steve, interview, 13 June 2012). He specifically reflected on the differences between the target audience for this project (urban public school students) and audiences from other nearby schools with more resources and different demographic compositions:

We are teaching a way to learn. I am not going to do that, well I would like to avoid doing that for older groups. To be honest, I think it’s sort of demeaning. [R: But not for middle schoolers?] Middle schoolers are on the line—it depends on the group. If the middle school is [Nearby Catholic] or [Affluent Suburb], same thing. Their preparation is better, and not just the preparation for the tour, but their overall preparation is one of inquiry. (Steve, interview, 13 June 2012)

Steve’s doctoral degree in geography and his experience as a lecturer at a university afford him a much deeper background in natural sciences than the majority of the NHM docents. He appreciates the rationality, logic, and intellectual stimulation that come with the natural history experience. The content of climate and biomes was what attracted Steve to volunteer for the project, given his deep knowledge of physical geography. His early reticence to changing how he interacted with students may be related to his primary interest in sharing his knowledge in his field of expertise. In particular, he was apprehensive about allowing students autonomy on the floor of the museum. During the first school trip under the new format, he ignored that guiding principle, leading his group through the museum as a traditional tour (Observations, 3 February 2011).

Steve developed a particular strategy for addressing the controversial topic of climate change during the project:

Climate change I generally kept away from, because with older groups it is politicized. I think the key to it is really explaining that climate change is all the time . . . once they understand that the climate is changing, irrespective of the debate about it changing, that tends to de-politicize it, and I keep away from the causes of it. (Steve, interview, 13 June 2012)

The tendency to avoid potentially uncomfortable or political topics was a strategy that many docents employed during the project.

On the second school trip (10 February 2012), Steve was stationed as a “roaming expert” with whom other docents’ groups could engage during their explorations at the museum. The opportunity to observe students engaging with the museum in a different way allowed him to reflect on his earlier apprehension:

This is how it was put to us [in training]: you show them, you model the behavior, and then you turn them loose. And when you turn them loose, horrors! You know, oh my God! What are you doing? I’ve gotten a little bit beyond that, a smidgeon . . . I recognize that in certain environments and circumstances, given the objectives of this tour, you have to accommodate [autonomy] to some extent. (Steve, interview, 13 June 2012)

Steve more readily embraced the principle of learning through conversation. He maintained that he must start a school trip with a short formal lecture, but noted that he knows a trip is really effective

when I see kids finding things on their own, commenting about them and raising intelligent questions . . . every once in a while you get a really good question that indicates the person

understands what he's seeing, not just looking at it, that's the light bulb going off and that's when I say AHA! We got something going here, I like it. (Steve, interview, 13 June 2012)

As he became more aware of the positive aspects of students' conversations and sharing observations among one another and with him, Steve began to more enthusiastically embrace the process of iteratively improving how he and other docents approached these new experiences. He differentiated this approach from both his other techniques on the floor of the museum and his own experiences in museums as a middle school student:

The approach we took in [this project] did not exist when I made my annual sixth or fifth grade museum trip. We went and looked at the things to look at, we were told what to think about it, we were told, if we were lucky, what it really meant, so to that extent, museum trips are better learning experiences now than they were. (Steve, interview, 13 June 2012)

Steve was able to reflect on the process of his own changing feelings regarding this project, and especially found value in the in-class preparation students received before visiting the museum, as well as the opportunities to share and reflect on all the docents' experiences after each school trip:

There was a point at which we realized that the in class preparation the kids were getting actually made a difference. We were not talking to people who simply looked at us like, 'what are you talking about?' That made a difference . . . the docents were getting more comfortable with the idea that they were getting better at [the new format] . . . (Steve, interview, 13 June 2012).

The experience and the changes that Steve had throughout this process inspired him to redesign one of the existing traditional tours offered to school groups at NHM with the principles of inquiry from our project. He presented the 12-page document of the redesigned tour to Allen at the end of our interview in June with a genuine enthusiasm that so contradicted his curmudgeonly nature he almost seemed embarrassed.

Elizabeth's Case: Struggle and Change

I am still quite frustrated at the shallow amount of information that can be obtained by the students. Where does the guidance to proper conclusions come from in so brief a time? I can effectively guide an entire tour group through exploration to collectively learn. (Elizabeth, interview, 14 June 2012)

Elizabeth is a former elementary school teacher—a position she left to become a full-time mother in the late 1970s. She emphasized her identity as a mother and teacher and noted that part of the reason she became a docent after her children had grown was because they encouraged her to seek an activity that would allow her to use her inquisitive nature in a constructive way. She identified her father's observations of nature on their family farm as part of the draw to the NHM in particular. Elizabeth makes a concerted effort to bring other disciplines into her tours of the natural history museum, quoting ancient texts, naturalists, and talking about relationships between nature and culture. She had almost the opposite view of Steve's perception of parents, noting, "the parents are far too involved in what goes on in a classroom. I don't think we need that much parent involvement. To me it suffocates the teacher" (Elizabeth, interview 14 June 2012). To identify and define learning both in

her former elementary classroom and on the floor of the museum, Elizabeth's predominant references were to vocabulary. She also repeatedly described learning in terms of quantity: "I had a lot of important information for them before we even started," "this child was thrilled to have learned so much," and "I was really surprised . . . how little opportunity there was to learn enough" (Elizabeth, interview, 14 June 2012).

Elizabeth does not hold an advanced degree in science, and often described scientific concepts as "too sophisticated" either for her, or for the students with whom she worked. At our first meeting, she conveyed a mistaken understanding of one of the satellite data parameters used in the pretrip and as a display on the floor during an early version of the school trip. When Allen followed up with her about it, she was happy and eager to learn a new piece of information. Elizabeth pointed out that there was one exhibit in the museum that she felt represented climate change, but that it was not in an area that had been designated as part of the school trips for this project. She noted that the museum exhibits visited during the new school trips did not directly address climate change: "Actually, when you get up into the polar [exhibit] there is nowhere to really address climate change . . . it suggests seasonal change, but not climate change" (Elizabeth, interview, 14 June 2012).

Elizabeth actively resisted the notion that students on school trips would be able to learn on the floor of the museum without the direct guidance and interpretation of a docent throughout the project. When asked how she would describe the project to someone from outside the museum, her terse reply was, "Ongoing." With further prompting, she revealed,

Well, it's a learning style that for the time I don't feel is effective . . . this is what I see as a weakness perhaps based on a lack of information, but then I'm also trying to figure out how I can take what I see the idea of the project to be, and how I can in some way beef it up . . . based on something I really don't like but I would like to make what I don't like a little bit better so this project will work within the scheme of my understanding. (Elizabeth, interview, 14 June 2012)

Her dissatisfaction with the "learning style," that is to say, the inquiry-based format that was implemented, is closely tied to her definition of learning as a quantifiable amount of knowledge or information, and an adherence to her own "scheme of understanding," her personal epistemology of how learning happens in the museum.

On one occasion, Elizabeth used a set of data maps during the school trip, which the students had used in their in-class preparation. Allen observed her use of the maps during the school trip, and when asked about this during our interview, she exclaimed, "That worked out! It was serendipitous . . . I happened to glance down and I saw 'sub-Saharan' and that's when we most effectively used those maps and came up with new vocabulary . . ." (Elizabeth, interview, 14 June 2012). In this case, Elizabeth used the new tools in a way that fit with her original definition of learning, or "scheme of understanding" as she put it. Elizabeth was clear about how engagement in this project had changed her practice:

Through my struggles with this [I] have found . . . I'm even looser with the way I do a tour. But guided and allow them to come up with their own conclusions, with a proper answer though . . . allowing for more observation, more conversation—I'm finding a lot of success with that because if your children are really excited, they go to an exhibit and they start chattering, that's your avenue. (Elizabeth, interview, 14 June 2012)

While Elizabeth found success in "loosening" her tour, she was not entirely comfortable with the school trip format that restructured the docent-student relationship to be more

learner centered. She was clear on her stance that the docent should be in control of the learning:

Keep good, constructive knowledge guided by a docent. Just don't let them run off unless there's a specific reason the teacher wants an investigative tour . . . with guidance limited by the teacher. I think the basic idea of coming to a museum is to have someone teach you. I've had adults of all different professions say, "oh, I'm so glad you're here. We love to have a docent. It's the only way you can really know what you're standing in front of." So to have a docent interpret, that's vital, because we know a lot. (Elizabeth, interview, 14 June 2012)

Here is evidence that Elizabeth's success with adult audiences influences how she structures her interactions with children and young adults. She was eager to reflect on her practice throughout the project, even though she disagreed with some of the pedagogical decisions that had been made for the new school trips. She regularly responded to notes from observations with questions about how she could improve her explanations of various concepts and a desire to sound more "sophisticated" (e-mail communication, 10 May 2012). She noted early in our interview, "I have key points that through experimentation I have found light up children, make adults more interested or connect" (Elizabeth, interview 14 June 2012) indicating that she recognizes differences in the interests in different groups of visitors, particularly groups with varying age compositions. In general, Elizabeth seemed to base her assessment of the quality of a school trip on how much information she was able to transmit to students, with feedback from their reactions to those ideas and information. Steve, in contrast, seemed to base his judgment of a successful school trip on the conversations and questions students raised during their visit, rather than the information he was able to talk about.

Paul's Case: Embracing Pedagogy to Fit the Learner

I mean conversation is where it's at. A tour like this, if you're not talking, or you're not conversing, both of you, I mean the students and the leader, if you're not doing that, it's not going to go anywhere. (Paul, interview, 15 June 2012)

Paul is a White, retired schoolteacher, widower, and proud grandfather. He retired from teaching in the early 1990s. His docent experience began in 1999, when he initially attempted to become a docent at the art museum that shares a building with NHM, but switched to natural history when he realized "I never would have fit in over there" (Paul, interview 15 June 2012). He is a docent primarily because he loves kids, loves talking, and loves sharing knowledge with other people; and he finds great satisfaction in engaging with visitors, especially when visitors express their own interests and excitement about being involved with the museum. His attitude toward museum learning was well aligned with the guiding principles of the project from early on: "Rather than trying to impart knowledge, our aim is to have them like their experience here, as well as at least pick up some of the things that they can" (Meeting minutes, 16 December 2011). He noted early on that he would like to see a similar pedagogy applied to the other school trips facilitated by the docents, and that docents who did not work on the project should be exposed to this new format, even if they said they did not like it at first. He differentiated himself from other docents who were less comfortable with change, identifying as open to change and happy to try new things, even if they were unfamiliar. Paul had a very positive opinion of the students

who attended the school trips during the project: “I’ve had the pleasure of meeting these kids at their best or their finest or whatever, because the kids have all been great” (Paul, interview, 15 June 2012). He connected this to his experience with junior high students on school trips in the 1970s, noting that no matter how poorly they behaved in the classroom, students were always very well behaved in settings outside of school.

Paul’s experience as a middle school science teacher in the 1970s seemed to afford him a much higher comfort level with the students in this project. In contrast, his experience with the curriculum during that time period contributed to a tension regarding the climate change content of the school trip: “I got burned once and I won’t be burned again like that, when the scientists predicted we’re going to have an ice age, and I was teaching that . . . I got sucked in on the ice age thing, and went whole hog for that, well I won’t do that again” (Paul, interview 15 June 2012). The heavily publicized “debate” among political and economic stakeholders regarding the science of climate change did not help Paul to reconcile the feeling of being “duped” by science—he expressed suspicion toward scientists and politicians who make decisions about funding for scientific research, noting “I think Al Gore’s a total jackass” (Paul, interview 15 June 2012). At the same time, Paul maintained that it is appropriate for the NHM to address climate change, because “it’s real, it’s always been there, we maybe never discussed it, but it’s always been there. It’s just something that’s an ongoing thing” (Paul, interview 15 June 2012).

Paul’s prior experience with middle school students on school trips likely allowed him to feel more comfortable giving students autonomy on the floor of the museum, where other docents were apprehensive about allowing students to explore on their own, for fear that students would misbehave. He discussed his own process of reflection and refining how he conducts a school trip, mostly realizing when he spent too much time talking: “I can’t ever seem to get this in and I can’t ever seem to get that in because I talk too much here and I talk too much there. As I’ve adjusted, I read through the [driving] questions again, and that’s why I’ve seen it evolve” (Paul, interview 15 June 2012). Paul specifically differentiated between the traditional school trip tours and our focal project:

I try to teach factual and identifiable things about the different dinosaurs, and review their knowledge by asking and asking and asking. But that’s very different from working through a bigger concept—one thing about [these school trips] that’s a bigger concept, what we’re trying to do with biomes, working in a different way. I’m asking questions over here, over here I’m presenting areas, and I am facilitating them doing something. (Paul, interview, 15 June 2012)

Not only did Paul identify differences between the traditional tours and the different format to meet project objectives, he stressed that the format was particularly successful with the specific age group of the project. When asked whether he felt that the new format was more effective than the traditional tours, he responded: “For seventh graders? I’m going to tell you it’s much more effective” (Paul, interview, 15 June 2012). Paul’s easy adaptation to new on-the-floor pedagogy in the NHM seemed to be fueled by his trust and experience with middle school aged students in the past, and his genuine desire to spend quality time with young people as one of his primary motivations for working as a docent. His opinions about climate change surprisingly did not affect his ability to engage with the ideas and concepts of the school trip centered on climate, perhaps in part because he so readily embraced the inquiry format, putting students in charge of their own learning.

Lucy's Case: Evidence-Based Education

Because skepticism is so important in science, should there be some way to make that point to the students? Could there be some way to encourage skeptical thinking, or questioning of students' or others' interpretations? (Lucy, interview, 14 June 2012)

Lucy is a former nurse and biology laboratory technician and currently a part-time freelance consultant and writer, and mother. Her interest in science and her love for museums attracted her to the docent role at NHM, which she began in 1996. To Lucy, the museum is a place where scientific thinking is encouraged: "the museum is a more welcoming place where you can come and you can doubt and you can say, 'I'm not sure if I believe that,' or 'what's the evidence,' and you're not going to get shut down for that" (Lucy, interview, 14, June 2012). Lucy's passion for and background in science appear to have instilled in her a strong tendency toward concrete, evidence-based knowledge. She was very hesitant to speculate on the learning that takes place on the floor of the museum, but expressed several times during our interview a desire for a more tangible understanding of what is learned in the museum:

I'm really interested in taking the things people are most mistaken about even when people think they know . . . and having some kind of evidence for whether the museum's doing a good job helping people to understand those things. But the other part of that would have to be also making sure it's not something they knew before they came here. (Lucy, interview, 14 June 2012)

This drive to make decisions based on evidence, including controlling for confounding variables such as visitors' prior knowledge, may have helped Lucy to justify her use of the guiding principles over the course of the project. Even late in the process, she expressed discomfort with the inquiry-based format, voicing that she did not consider the practicing of previously learned skills or applying prior knowledge to be true learning and that she wanted to "push students further, into new knowledge" (Debrief Minutes, 7 May 2012). However, as she witnessed students' motivation to engage with the opportunities presented during the school trip under the guiding principles of autonomy and conversation, Allen observed her using these strategies on the floor more and more consistently. Her reflection on the process indicated that she had made a similar observation, as well as an indication that she defines her own learning similarly to the way she defines it for students in the museum:

I think every time I worked on a tour, I did it a little bit differently. So I feel like I have a better idea of being able to model more clearly and send them off to do whatever they're going to do . . . And my learning of the material itself . . . I have a long way to go. (Lucy, interview 14 June 2012)

Unlike Steve and Paul, who explicitly differentiated between age group and demographics of the target audience for this project, Lucy drew distinctions between the environments that students are being or may be exposed to. Lucy considers the museum an advantageous learning environment, in part because it is different from the day-to-day classroom learning experience, because in the classroom students are

socialized to act in a certain way and think in a certain way . . . the museum is a good fit for conversation with small groups, or one on one . . . also because the docent or the leader is usually someone they've never met, and probably their impression is they'll never meet

you again, you're like really a total stranger, so it's a different conversation than they would have at school with their teacher. (Lucy, interview 14 June 2012)

Lucy dealt with several tensions while working on this project. The first was between what she understands to be true learning (acquisition of new content knowledge) and the more motivation and affect-oriented objectives of the project. The second tension was her apprehension with the topic of climate change:

I find it really hard to talk about it with other people, because it immediately becomes political, so I have mixed feelings about climate change. I think it's a really important issue . . . museums should be able to [address], but they have to stay very close to the science and the evidence . . . None of the students took it up as a political argument. I was a little surprised. (Lucy, interview, 14 June 2012)

Lucy's apprehension about discussing climate change may have enabled her to embrace the inquiry-based format. Allowing students' interests to guide conversations, and finding that none of them took it as a political issue, could have made the strategy more valuable to Lucy when addressing potentially volatile topics. Overall, Lucy's case demonstrates that an individual educator can utilize pedagogical strategies that range from teacher- to learner-centered as well and from acquisition- to participation-based models of learning.

An Emergent Community of Practice

The four docents whose cases are described above worked together with three other highly involved docents on our iterative implementation project. They participated in inquiry-based training and practice with one another, observed each other with students on the floor, and had in-depth debrief discussions after each school trip implementation. A pivotal moment for the group occurred during a debrief meeting approximately halfway through the 6-month project period, when one docent remarked that the students attending the school trips were "getting better and better." One of the NHM educational leaders responded, "maybe you all are getting better" (Debrief Meeting, 28 March 2012). The docents considered this proposition and were visibly invigorated throughout the ensuing discussion, pinpointing strategies they felt were helping them to connect with students and have success. Throughout the iterative implementation process, docents spent the bulk of their reflective discussions sharing examples of how to scaffold student learning using the principles for inquiry that guided our project. Addressing climate change was difficult for the group, who separately devised the strategy of not talking about causes of climate change, but focusing on making sure students understood it as an ongoing phenomenon.

DISCUSSION

Experts in learning and education are now looking to the promise of collaborative relationships between schools and museums to "close the gap" of access to high-quality science education in the United States (Bevan et al., 2010). Museums and schools alike face the challenge of changing educational practice away from traditional, didactic, teacher-centered methods and toward inquiry-based, participatory, engaging strategies for learning. This study followed museum educators as they took up this challenge by iteratively implementing a new school-trip design, which was generated through collaboration between a natural history museum, a PSD, and a university-based research group.

As part of the iterative implementation process, all four educators engaged in extended reflection on their own learning in regard to the new school-trip format and its challenging content: climate change. Steve's self reflection included acknowledgement that he'd changed how he thinks about learning, allowing him to recognize the value of a new approach and take it upon himself to apply that approach to an existing traditional tour at the museum. Paul also found value in the inquiry format, comparing it to an educator's academic freedom to try new things and adjust practice as it evolved. Lucy's focus on evidence shaped her reflections, prompting her to indicate that she appreciates having another "tool" or "method" to use on the floor, while maintaining that it would not be a good idea to constrain or limit the different ways that educators engage with visitors. Elizabeth's reflections allowed her to engage in reimagining her practice to be oriented toward the observations and interests of the students "so that they come out knowing something based on what they're really interested in" (Elizabeth, interview, 14 June 2012).

Each of the four educators had different opinions about and experiences with the target audience for this project, which influenced their expectations and how they interacted with the students. Steve's opinion that the students attending these trips needed an opportunity to "learn how to learn" was based on a deficit model, wherein urban public school students are not as well prepared or supported by their families as students from private or suburban schools. Paul's prior positive experiences with urban middle school students on field trips allowed him to be comfortable with the students and adapt easily to the format that gave students more autonomy. Lucy, like Paul, drew a distinction between school and the museum as learning environments, focusing on the advantages of the museum as a new and different place where students would behave differently. Elizabeth used evidence from tours she'd conducted with adults to justify her pedagogical choices with other age groups in the museum, while also acknowledging that different groups have different interests that can be used to engage them with content.

Informal educators are in need of a community of practice and a professional vocabulary and pedagogy that acknowledges and capitalizes on the unique affordances of learning in informal settings, especially for audiences that are underserved in formal educational settings (Bell et al., 2009; Bevan, & Xanthoudaki, 2008; Castle, 2006). This community can help practitioners to challenge dominant notions of teaching and learning together, differentiate practices and strategies for engaging different kinds of audiences, and support ongoing professional development through conversation and reflective practice. Our study demonstrates what the beginnings of such a community of practice might look like, and what steps were taken to initiate reflective practice and shared communication among informal educators in a natural history museum. The educators in this study began to develop a community of practice among themselves, supported by the structured iterative process of implementation that encouraged reflection and conversation about practice. By taking into consideration the needs of educators for an open and encouraging process, this project succeeded in sparking change in practice, even for those who struggled with difficult scientific content, politicized topics, and challenging new pedagogical approaches to learning.

Sociocultural learning theory (e.g., Greeno, 2006) and theory specific to communities of practice (Lave & Wenger, 1991) supports the development of communities of learning and practice among students (e.g., Boaler, 2008; Engle, 2006), teachers (e.g., Horn, 2010), museum educators (e.g., Bevan, & Xanthoudaki, 2008; Castle, 2006), and project developers. Communities of practice are rooted in the participatory model of learning, an important aspect of inquiry. The development of a community of practice achieves the goal set by Castle (2006) and Bevan and Xanthoudaki (2008) of eliminating the disconnection between pedagogy for educator learning, and pedagogy museum educators are expected to employ by

incorporating the principles for learning that museum educators utilized with students into the process of their own learning. By engaging in the reflective, iterative implementation process laid out during this project, museum educators were able to connect what they'd learned in one setting to the other work they do on the floor. The most prominent example of this sort of change and connection is Steve's decision to redesign an existing traditional tour to further utilize the inquiry format. All of the participating museum educators talked about the value of the experience to their own practice.

Beyond the general implications for professional development of informal educators, our findings also have implications for developing communities of practice for the teaching and learning of difficult, controversial, and important scientific content. The particular school trip we designed, implemented, and studied was focused on climate change, which emerged as the central topic and conflict for the emergent community of practice. While each of the educators had very different backgrounds and experiences with science and science education, all of them engaged in a similar strategy of avoiding the controversial aspects of climate change. All four emphasized the importance of depoliticizing the issue of climate change by framing it as an "ongoing process," and none attempted or approached conversations about the causes of climate change. Part of the reason docents took this path through the challenge of climate change was because within their nascent community of practice, the issue was controversial. The docents expressed their own desire to avoid conflict about the issue because it was politically charged. Paul's opinions and feelings about climate change were definitely a driver for these sentiments. Paul's persistent belief that climate change is not caused by human actions is a testament to the well-documented phenomenon that political affiliation is the strongest determinant to people's opinions about this issue (Borick & Rabe, 2010; Hart & Nisbet, 2011). Because both the content and the pedagogy implemented in this project were new and challenging, the docents' emerging community of practice focused more on how to facilitate inquiry than on the topic of climate change, though both of these facets of the project were controversial for this particular group.

Museums are uniquely positioned to function as "agents of climate change governance" (Cameron, 2011b) since the public generally trusts museums to present information free from political influence (Cameron, 2011a; Cameron et al., 2013). Cameron and colleagues argue that museums can move the climate change conversation beyond the restricted frame of ecological modernization to facilitate community discussions and innovations outside the realms of corporate and government mitigation, or lack thereof (Cameron, 2011a, 2011b; Cameron, & Deslandes, 2011). This idea blends nicely with the sociocultural view of learning that emphasizes agency and identity (Greeno, 2006; Hull & Greeno, 2006) and has been specifically explored in informal science learning by Barton and Tan (2010) who take the position that agency and identity are important factors in science learning and cultivating lifelong interest and engagement with science. To capitalize on the benefits of discourse in learning about these difficult issues, science educators in museums will require supportive communities where conversation about challenging topics is validated and participants feel their voices are heard, even if there is disagreement among community members. Future research should focus on how learning about socioscientific issues such as climate change happens in informal learning settings, and how it can be improved and expanded to reach key populations who will be impacted by a changing climate.

Our goal was to support educators' reflection and build a community of practice through iteratively implementing a new, inquiry-based school trip about climate change. We studied this process to gauge whether docents' educational practice and perceptions of learning changed as they iteratively implemented a new way to facilitate learning new content and concepts on the floor of the museum. As informal science education becomes an

increasingly prominent part of the science education infrastructure, professional development for informal educators is emerging as an important and high-impact arena for change. Informal educators exist in myriad contexts—not just museums, but also community organizations, after-school programs, and NGOs. Formal education has long worked to change dated and dominant paradigms that persist in the collective understanding of how teaching and learning happen (e.g., Cuban, 1984; Tyack & Tobin, 1994). Dedication, reflection, and support from other educators and experts in content and pedagogy are all necessary for real and sustainable change (Coburn, 2004; Cohen, 1990; Smith, 2000). Connecting what we know about professional development through communities of practice in formal and informal education is an important first step toward broadening the opportunities for high-quality science education for all, particularly when facing important and controversial science issues such as climate change.

REFERENCES

- Abbasi, D. (2006). *Americans and climate change: Closing the gap between science and action*. New Haven, CT: Yale School of Forestry & Environmental Studies.
- Abu-Shumays, M., & Leinhardt, G. (2002). Two docents in three museums: Central and peripheral participation. In G. Leinhardt, K. Crowley, & K. Knutson (Eds.), *Learning conversations in museums* (pp. 45–80). Mahwah, NJ: Erlbaum.
- Ames, C. (1992). Classrooms: Goals, structures and student motivation. *Journal of Educational Psychology*, 84(3), 261–271.
- Ash, D. (2004). How families use questions at dioramas: Ideas for exhibit design. *Curator: The Museum Journal*, 47(1), 84–100.
- Ash, D., & Lombana, J. (2012). Methodologies for reflective practice and museum educator research: The role of noticing and responding. In D. Ash, J. Rahm, & L. M. Melber (Eds.), *Putting theory into practice: Tools for research in informal settings* (Vol. 25, pp. 29–52). Rotterdam, The Netherlands: SensePublisher.
- Ash, D., Lombana, J., & Alcalá, L. (2012). Changing practices, changing identities as museum educators: From didactic telling to scaffolding in the zpd. In E. Davidsson & A. Jakobsson (Eds.), *Understanding interactions at science centers and museums* (pp. 23–44). Rotterdam, The Netherlands: SensePublishers.
- Barron, B. (2003). When smart groups fail. *Journal of the Learning Sciences*, 12(3), 307–359.
- Bartels, D., Semper, R., & Bevan, B. (2010). Critical questions at a critical time: Reflections on the contributions of LSIE to museum practices. *Curator: The Museum Journal*, 53(2), 163–179.
- Barton, A. C., & Tan, E. (2010). We be burnin’! Agency, identity and science learning. *Journal of the Learning Sciences*, 19(2), 187–229.
- Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning science in informal environments: People, places, and pursuits* (Vol. 1). Washington, DC: National Academies Press.
- Bevan, B., Dillon, J., Hein, G. E., Macdonald, M., Michalchik, V., Miller, D. et al. (2010). *Making science matter: Collaborations between informal science education organizations and schools*. Washington, DC: Center for Advancement of Informal Science Education.
- Bevan, B., & Xanthoudaki, M. (2008). Professional development for museum educators: Underpinning the underpinnings. *Journal of Museum Education*, 33(2), 107–119.
- Bitgood, S. (1989). School field trips: An overview. *Visitor Behavior*, 4(2), 3–6.
- Boaler, J. (2008). Promoting “relational equity” and high mathematics achievement through an innovative mixed ability approach. *British Educational Research Journal*, 34(2), 167–194.
- Borick, C. P., & Rabe, B.G. (2010). A reason to believe: Examining the factors that determine individual views on global warming. *Social Science Quarterly*, 91(3), 777–800.
- Cameron, F. (2011a). From mitigation to creativity: The agency of museums and science centres and the means to govern climate change. *Museum and Society*, 9(2), 90–106.
- Cameron, F. (2011b). Climate change as a complex phenomenon and the problem of cultural governance. *Museum and Society*, 9(2), 84–89.
- Cameron, F., & Deslandes, A. (2011). Museums and science centres as sites for deliberative democracy on climate change. *Museum and Society*, 9(2), 136–153.
- Cameron, F., Hodge, B., & Salazar, J. F. (2013). Representing climate change in museum space and places. *WIREs Climate Change*, 4, 9–21.

- Castle, M. C. (2006). Blending pedagogy and content: A new curriculum for museum teachers. *Journal of Museum Education*, 31(2), 123–132.
- Coburn, C. E. (2004). Beyond decoupling: Rethinking the relationship between the institutional environment and the classroom. *Sociology of Education*, 77, 211–244.
- Cohen, D. K. (1990). A revolution in one classroom: The case of Mrs. Oublier. *Educational Evaluation and Policy Analysis*, 12(13), 311–329.
- Cox-Petersen, A. M., Marsh, D. D., Kisiel, J., & Melber, L. M. (2003). Investigation of guided school tours, student learning, and science reform recommendations at a museum of natural history. *Journal of Research in Science Teaching*, 40(2), 200–218.
- Crowell, A., & Schunn, C. (2013). The context-specificity of scientifically literate action. *Public Understanding of Science*, pp. 1–16 [online].
- Crowley, K., Callanan, M. A., Jipson, J. L., Galco, J., Topping, K., & Shrager, J. (2001). Shared scientific thinking in everyday parent-child activity. *Science Education*, 85, 712–732.
- Cuban, L. (1984). *How teachers taught: constancy and change in American classrooms, 1890–1980*. New York: Longman.
- DeWitt, J., & Storksdieck, M. (2008). A short review of school field trips: Key findings from the past and implications for the future. *Visitor Studies*, 11(2), 181–197.
- Engle, R. A. (2006). Framing interactions to foster generative learning: A situative explanation of transfer in a community of learners classroom. *Journal of the Learning Sciences*, 15(4), 451–498.
- Falk, J. H., & Dierking, L. M. (2000). *Learning from museums: Visitor experiences and the making of meaning*. Lanham, MD: AltaMira Press.
- Falk, J. H., & Shepard, B. (2006). *Thriving in the knowledge age: New business models for museums and other cultural institutions*. Lanham, MD: Rowman Altamira.
- Gennaro, E. D. (1981). The effectiveness of using previsit instructional materials on learning for a museum field trip experience. *Journal of Research in Science Teaching*, 18(3), 275–279.
- Greeno, J. G. (2006). Theoretical and practical advances through research on learning. In J. L. Green, G. Camilli, & P. B. Elmore (Eds.), *Handbook of complementary methods in education research* (pp. 795–822). New York: Routledge.
- Grenier, R. S. (2005). Do as I say, not as I do: A case study of two museum docent training programs. Paper presented at the 46th Annual Adult Education Research Conference, Athens, GA.
- Grenier, R. S. (2006). The role of learning experiences in the development of expertise. Paper presented at the 47th Annual Adult Education Research Conference, University of Connecticut.
- Grenier, R. S. (2009). The role of learning in the development of expertise in museum docents. *Adult Education Quarterly*, 59(2), 142–157.
- Grenier, R. S. (2010). “Now this is what I call learning!” A case study of museum-iterated professional development for teachers. *Adult Education Quarterly*, 60(5), 499–516.
- Grenier, R. S., & Sheckley, B. (2008). Out on the floor: Experiential learning and the implications for the preparation of docents. *Journal of Museum Education*, 33(1), 79–93.
- Grotzer, T., & Lincoln, R. (2007). Education for “intelligent environmental action” in an age of global warming. In S. C. Moser & Dilling, L. (Eds.), *Creating a climate for change: Communicating climate change and facilitating social change* (pp. 266–280). New York: Cambridge University Press.
- Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. In J. P. Mestre (Eds.), *Transfer of learning from a modern multidisciplinary perspective* (pp. 89–119). Charlotte, NC: Information Age.
- Hart, P. S., & Nisbet, E. C. (2011). Boomerang effects in science communication: How motivated reasoning and identity cues amplify opinion polarization about climate mitigation policies. *Communication Policies*, 39(6), 701–723.
- Horn, I. S. (2010). Teaching replays, rehearsals and revisions. *Teachers College Record*, 112(1), 225–259.
- Hull, G. A., & Greeno, J. G. (2006). Identity and agency in nonschool and school worlds. In Z. Bekerman, N. C. Burbules, & D. S. Keller (Eds.), *Learning in places: The informal education reader* (Vol. 249, pp. 75–97). New York: Peter Lang.
- Jones, C. A. (2012). *Docent remix: Profiles of art museum docents in the modern museum*. Unpublished master’s thesis, University of Washington, Seattle.
- Kahan, D. M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L. L., Braman, D. et al. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nature Climate Change*, 2, 732–735.
- Kisiel, J. (2005a). An examination of fieldtrip strategies and their implementation within a natural history museum. *Science Education*, 90(3), 434–452.
- Kisiel, J. (2005b). Understanding elementary teacher motivations for science fieldtrips. *Science Education*, 89(6), 936–955.

- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, England: Cambridge University Press.
- Leinhardt, G., Crowley, K., & Knutson, K. (Eds.). (2002). *Learning conversations in museums*. Mahwah, NJ: Erlbaum.
- Linnenbrink, E. A. (2007). The role of affect in student learning: A multi-dimensional approach to considering the interaction of affect, motivation and engagement. In P. S. Chutz & R. Pekrun (Eds.), *Emotions in education* (pp. 107–124). New York: Academic Press.
- Moser, S. C. (2010). Communicating climate change: History, challenges, process and future directions. *Wiley Interdisciplinary Reviews: Climate Change*, 1(1), 31–53.
- Nerb, J., Spada, H., & Lay, K. (2001). Environmental risk in the media: Modelling the reactions of the audience. In G. Bohm, J. Nerb, T. McDaniels, & H. Spada (Eds.), *Environmental risks: Perception, evaluation and management*. Bingley, England: Emerald.
- Nunnery, J. A. (1998). Reform ideology and the locus of development problem in educational restructuring: Enduring lessons from studies of educational innovation. *Education and Urban Society*, 30(3), 277–295.
- Orion, N., & Hofstein, A. (1994). Factors that influence learning during a scientific field trip in a natural environment. *Journal of Research in Science Teaching*, 31(10), 1097–1119.
- Palmquist, S., & Crowley, K. (2007). From teachers to testers: How parents talk to novice and expert children in a natural history museum. *Science Education*, 91(5), 783–804.
- Pekrun, R., & Linnenbrink-Garcia, L. (2010). Academic emotions and student engagement. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *The Handbook of research on student engagement* (pp. 259–282). New York: Springer.
- Pierroux, P. (2010). Guided meaning on guided tours: Narratives of art and learning in museums. In A. Morrison (Ed.), *Inside multimodal composition* (pp. 417–450). New York: Hampton Press.
- Roeser, S. (2012). Risk communication, public engagement, and climate change: A role for emotions. *Risk Analysis*, 32, 1033–1040.
- Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1), 68–78.
- Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher*, 27(2), 4–13.
- Smith, M. S. (2000). Balancing old and new: An experienced middle-school teacher's learning in the context of mathematics instructional reform. *Elementary School Journal*, 100(4), 351–375.
- Stein, M. K., Smith, M. S., & Silver, E. A. (1999). The development of professional developers: Learning to assist teachers in new settings in new ways. *Harvard Educational Review*, 69(3), 237–269.
- Sturm, H., & Bogner, F. X. (2010). Learning at workstations in two different environments: A museum and a classroom. *Studies in Educational Evaluation*, 36, 14–19.
- Tran, L. U. (2006). Teaching science in museums: The pedagogy and goals of museum educators. *Science Education*, 91(2), 278–297.
- Tyack, D., & Tobin, W. (1994). The “grammar” of schooling: Why has it been so hard to change? *American Educational Research Journal*, 31(3), 453–479.
- van Kerhoff, L., & Lebel, L. (2006). Linking knowledge and action for sustainable development. *Annual Review of Environmental Resources*, 31, 445–477.