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Informal Science Institutions and Learning to Teach: An Examination of Identity, Agency, and Affordances

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Abstract: Informal science education institutions play an important in the public understanding of science and, because of this are well-positioned to positively impact science teacher education. Informal science institutions (ISIs) have a range of affordances that could contribute to learner-centered science teacher identity development. This article describes research from a clinical experience in a museum where teacher candidates engaged visitors in learning dialogs around objects on a moveable cart in an exhibit. We describe how working in informal settings and learning to use the affordances of that setting supports aspiring teachers to connect theory to practice in ways that developed Spielraum in that is student-centered, responsive to the needs of learners, and allows for the imagination future selves and classrooms that are conducive to maintaining these identities. This research supports the critical role that ISIs could play in teacher education, especially during the clinical phase where teacher candidates are forming initial notions about their identities, about the self who teaches. © 2015 Wiley Periodicals, Inc. J Res Sci Teach 9999:1–19, 2015.

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Informal science institutions (ISIs) are places that convey complex science ideas and phenomenon through non-traditional and engaging ways. By emphasizing curiosity, excitement and motivation, and leveraging the affective and emotional domains of learning, ISIs are valuable partners for strengthening science teaching and learning associated with schools. ISIs focus on developing and displaying foundational and cutting edge science using compelling exhibits, visuals, displays, and objects. Associated programs are created to engage different audiences in the science on display. Programs designed for educators and students often focus on using the resources available to teach and learn science. As such, ISIs have a long history of working with K-12 education, both for school programs and teacher education (Adams, 2007). In this article, we describe how ISIs become relevant and critical partners for supporting science teacher preparation when teacher candidates are positioned as both learners and teachers who access and appropriate different resources within an ISI to feed their continually transforming teaching identity.

Clinically rich science teacher education emphasize the merging of theory with practice by engaging aspiring teachers in the practices of teaching alongside theoretical coursework early in their program. Realizing the value of having multiple and diverse opportunities to teach while learning how to teach, institutions of higher learning have

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made great strides in weaving practicum experiences into theoretical coursework. For example, race to the top (RTTP) funds supported eight pilot projects in New York State[1] to specifically test clinically rich models of science teacher preparation. This is a welcome trend away from education models where theory is often divorced from practice and affords little opportunities for aspiring teachers to reflect on theory *in* practice while participating in the planning and enactment of teaching (Darling-Hammond, Hammerness, Grossman, Rust, & Shulman, 2005). Using out-of-school setting in teacher education is a growing area of research. Emerging evidence suggests that candidates exposed to these settings develop shifts in understanding children as diverse learners with relevant prior knowledge (Wallace, 2013). Recognizing the value of ISIs as part of the ecosystem and partners for formal institutions of teacher education (Traphagen & Traill, 2014), there has been an upward trend of university-based programs partnering with informal science institutions to design professional learning experiences for teachers. These programs integrate the resources and pedagogy of informal science learning with the content knowledge and classroom-based pedagogy required for teacher preparation and certification. Federal agencies[2] have also supported pilot science teacher preparation projects that are partnerships between higher education institutions and non-school science-rich settings. These all provide compelling examples of sharing and merging resources in the interest of increasing civic capacity of science knowledge, understanding, and participation.

In this article, we focus on an ISI as a site for preservice teacher preparation. Using a framework of agency and identity, we describe the affordances of an informal science institution and how these affordances support teacher candidates in developing greater understandings of how people learn and how to engage diverse learners. A framework of identity allows us to focus on the teacher candidate as learner; getting a "feel" for how one learns to teach in different contexts with different affordances (Varelas, 2012). Affordances are described both in terms of the objects or environment within which one is situated and the opportunities available for a person to act (Gibson, 1977). Connected to the definition of affordance is the notion of possibility as this allows a person to bricoleur of sorts, that is one who takes a given object or resource and creates something new—new way of learning, interacting, or mediating learning with the object. The affordances in an informal institution allow for particular ways of teaching and learning to teach and also allow for possibility of learning how to teach in a transformative ways. We examine the experiences of teacher candidates to demonstrate how learning to teach in informal spaces affords positive science teaching identity development with dispositions that could lead to core science teaching practices that privilege concepts such as learning about student understanding, eliciting student thinking during interactive teaching, and anticipating student responses (Grossman, Hammerness, & McDonald, 2009). Such teachers are able to create student-centered environments, engage students in minds-on and hands-on activities, are aware of and responsive to the needs of diverse learners and issues of equity, and able to leverage the cultural and linguistic resources of students in their classrooms (Barton, Rubel, Furman, & Lopez-Freeman, 2009; Luehmann, 2007).

Science centers, natural history museums, zoos, aquaria, or arboreta, all examples of ISIs, are places with specific structures that characterize them as science-rich environments. In these environments, the personal, physical, and sociocultural contexts all intersect and influence the kinds of learning and interactions that people have in these places (Falk & Dierking, 2000). In other words, the structures of these places shape and enable a particular type of science learning and corresponding identity development. These contexts can be even more impactful for those who learn to teach in these settings as they have the opportunity to learn to use these structures to mediate science learning interactions of visitors, many of them school-aged children. These

settings afford people studying to be teachers opportunities to experience multiple ways of interacting with objects, phenomena, and others in ways that are not afforded in more formal or school-like settings (Rowe, 2002). In prior work, we analyzed three ISI partnerships for teacher learning uncovered some initial patterns that relate the affordances of learning to teach to teacher identity development. In each of the sites, teacher candidates spent a substantial number of hours engaged in teaching activities that allowed them to interact with diverse visitors. We learned that learning to teach afforded the following: (1) the opportunity to teach the same topic to different audiences over and over each time revising, refining, and testing strategies; (2) opportunities to try the same strategies on different and diverse learners thereby developing an intuitive understanding of what works for whom; (3) learning alongside museum staff and seeing different styles of teaching, different approaches, and borrowing strategies from these different experts; and (4) having opportunities for self-reflection in between the instances of teaching allowing the candidate to identify areas of weakness and strengths and focusing on those each time the science experience is iterated (Gupta & Adams, 2012). From this work, we developed a standpoint that teacher candidates need to be supported to develop the awareness and associated practices that allow them to develop identities to create learning environments that position students at the center, invite relevant and engaging experiences, and account for issues of equity. We build on this work by merging the notion of affordances with identity and providing a close examination of one kind of informal science teaching act in terms of affordances and identity.

Theoretical Framing

Learning to teach is an ongoing process of developing, maintaining, and re-creating a professional identity. Aspiring teachers come to a teacher education program with preexisting notions of what it means to be a teacher. Beginning with teacher preparation, they are exposed to different contexts and people begin to re-shape their notion of what it means to be a teacher and initiate a teacher identity. Throughout a teaching career, a teacher creates and re-creates what it means to be a teacher through her pedagogical choices and alignment with like-minded professionals (Deneroff, 2013), through ongoing professional learning experiences, interactions with students and other educators, actual teaching, reflections on self-as-learner; an ecology of learning interactions and experiences that continuously shape their identity as an educator. A teacher preparation program is a prime space for examining science teaching identity development—learning how teacher preparation experiences could shape initial teaching identities and form a foundation on which to continuously build and evolve an identity that corresponds with inquiry and equity-based teaching practice.

We describe a framework of identity in relation to agency because agency, or the power to act (Schwartz, 1997), describes how one accesses and appropriates affordances in a given field, and this learning is identity development. A teacher candidate *learns* how to adapt and use a variety of resources to meet curricular goals thus affording a sense of *agency* in science teaching and developing an *identity* in relation to the context (or field) and affordances. In informal science institutions, people have particular science learning interactions that are more personalized and self-directed. This allows a teacher candidate to learn how to interact with a variety of people and use selected resources to engage them in science learning conversations. When a teacher candidate is engaged in learning-to-teach activities in an informal science institution, she is able to access these resources and reflect on learning in ways that connect to education theory and pedagogy and also allows her to imagine how what she is learning will play out in the classroom, thus, she begins to imagine a teacher identity for herself.

Identity development has been receiving more attention as a construct in science teaching and learning (Varelas, 2012). A succinct and theoretically grounded definition of reform-minding science teacher identity is "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, 2014, p. 826). This supports our standpoint and we add that informal science experiences provide teacher candidates with opportunities to facilitate hands-on experiences with diverse audiences while developing student-centered dispositions, sensitivities to diversity, and positive attitudes about STEM teaching and learning, all of which contribute to a reform-minded science teacher identity (Gupta & Adams, 2012). A framework of identity allows us to think beyond what is learned and to focus on the learner as situated in the contexts within which she learns (Beauchamp & Thomas, 2011). In teacher education, it allows us to situate teacher candidates as new members of a professional community and ascribe them a sense of agency in constructing who they are in relation to this community.

This begs the questions of *who am I as a teacher and what does this identity mean in terms of the way I teach?* (Beauchamp & Thomas, 2011) and for teacher candidates, "what kind of teacher would I like to become?" Actually, in both cases—it is a process of becoming because identity is an ongoing process rather than an end product; it is an ongoing process of learning to teach and teaching enactment in different contexts, with different people and with different resources (Beauchamp & Thomas, 2011). In other words, as Anna Stetsenko (2008) describes, identity develops in relation to others; becoming a kind of teacher means situating oneself among other educators and learning how to contribute to the continuous flow of the social practices of teaching and learning, "identities are the part of self that are defined by the different positions we hold in society" (Varelas, 2012, p. 3) and how we locate ourselves amongst others.

Identity and Agency

Agency and identity develop interdependently and as an ongoing process of learning not only who is the self who teaches, but also who is the self in relation to others who teach, learn, and learn to teach science. Identity is also responsive to the contexts or fields in which one learns to teach and teaches. Agency is belief that the self is capable of making the right instructional decisions, knows how to acquire and use resources to teach, and confidence about constructing and maintaining a safe and effective learning environment. For science teachers, it also means confidence in content knowledge and ability to motivate and sustain science learning in students. When one gains agency in a given context, one begins to develop an identity associated with that field.

As affordances of a given field include the people who are present and engaged in activities, the interactions between people are important in identity construction. Agency occurs as a process of learning how to *be* in a given field, with the *to be* not connoting passivity but to the active response of saying, "*I am*" in response to the question of the self who teaches. This means knowing how to maneuver in a field, with field being a site of cultural production and transformation that are organized around particular affordances, also called schema and resources (Schwartz, 1997). Science education could be considered a larger field within which smaller fields are nested. Classrooms and informal institutions are nested within the field of science education and are often bounded by space and defined by the physical elements that define them. However, affordances could extend beyond these bounded spaces and also include networks of professionals, associations, or learning practices with which one associates. Also available are the social practices that guide the learning interactions that happen in a field. These practices are often shaped by ideologies, missions, and mandates that influence the culture of a field and also influences how one uses the affordances available. Agency allows one to transform how one uses affordances within a field and across settings thus transforming the learning opportunities available.

Agency and Spielraum

A part of having agency and a related identity is a having a feeling of fluency in the practices of a field. This having of an embodied sense of practice that allows one to move from one interaction to another all while maintaining Spielraum, which is the ability to maneuver; to develop practices that are anticipatory, timely, and appropriate to given situations (Roth, Lawless, & Masciotra, 2001). In learning to teach, the notion can be used to think about teaching that allow a teacher candidate to be prepared to take advantage of teachable moments and contradictory events in the moment as social life unfolds with little time for immediate reflection and planning. This way of being in the classroom is learned through the practice and experience of teaching and having a forum to reflect on the experiences in a transformative way so that they become a part of the embodied practice of teaching. A challenge of preservice teacher education in a traditional classroom is the lack of opportunities for successful teaching interactions in relatively low-stakes environments (Luehmann, 2007); these are environments where student outcomes do not determine student grade advancement, career trajectories, or school funding. Because ISIs are not bound by formal top-down assessments of learning and visitors enter with individual learning and/or entertainment goals, these are prime contexts for teacher candidates to develop Spielraum in science teaching.

We develop identities based on the fields in which we learn and enact culture. When we develop Spielraum, we develop agency in a given field. We can extend the relationship to say agency and identity are dialectically related, such that our power to act, within certain structures and corresponding affordances, mediates our identity development. As our identity evolves, it mediates our agency and dialectically, the structures of a given field. The field has porous boundaries, which means that the agency developed in one field could contribute to agency in another field. For example, a teacher who develops agency in teaching from the affordances in a museum field could enact that agency in a classroom; s/he could use the affordances available to create new ways of teaching and learning. This precise skill, the fluidity, ultimately contributes to the ever-lasting project of learning to teach science in ways that are engaging, approachable, and successful for diverse learners.

Context and Methods

The context for this article is a Masters of Arts in Teaching (MAT) Earth Science that is based at the American Museum of Natural History (AMNH). People with undergraduate degrees in earth science/astronomy or closely related topic can apply with the intention of becoming certified to teach Earth Science in New York State. Launched in 2012 as a state-funded pilot project, the program expects 50 graduates as of September 2015. These teacher candidates undergo a 15-month intensive program that consists of two museum residencies and two school residencies. The candidates also complete 36 credits of science and education courses, which are co-taught by science and education faculty. The museum residencies are in the first summer (right at the beginning of the 15 months) and the second summer (right at the end of the 15 months). In the first museum residency, teacher candidates rotate through three major activities that scaffold on one another. Each activity builds pedagogically on the next with the ultimate goal of getting the teacher candidates to have a more refined understanding of diverse learners, engagement strategies, and using the museum's multiple and rich resources for teaching science.

For the first rotation, candidates work in small teams with interactive carts in the museum halls. They learn how to engage visitors in learning conversations around the objects on the cart and in connection to the objects in the permanent exhibitions. During the second rotation, candidates get an in-depth experience observing and co-teaching with master museum educators

working with middle and high school youth who participate in week-long and month-long museum programs. In the third rotation, the candidates have the opportunity to design and teach their own lessons for high school youth who are invited for a summer science institute. While they do rotations, they also take a class called *Applied Research in Science Learning in Informal Environments*, where they develop theoretical understandings of learning in informal settings. The rotations are a part of credit-bearing courses that also include assignments that are aligned with the learning-to-teach activities.

Two questions guided our inquiry into the teacher candidates' experiences: (1) in what ways do the affordances of learning to teach in an ISI contribute to agency in teaching? (2) what kinds of emerging teaching identities do the teacher candidates appear to develop?

Teacher Candidates

Fifty-seven candidates, divided among three cohorts, have enrolled in the MAT program to date. The first and second cohorts have graduated and are teaching in high-need public schools (defined as schools with at least 70% of students living below poverty levels). The third cohort of 15 Residents is still in the program. The data presented in this article is from cohort 2 and 3. Collectively, these two cohorts ($n = 36$) are 58% female and 42% male and 13% identify as people of color. Fifty-three percent received their bachelors within the last 3 years and 39% are considered career changers.

Cart Rotation

The teacher candidates spend approximately 20 hours over a 2-week period learning to teach using the carts. While practicing, they participate in a series of workshops that focus on (1) the content of the carts, (2) identifying the big ideas around the objects on the cart, (3) questioning strategies to engage learners in the both the big ideas and discrete content, (4) fostering intergenerational conversations, and (5) accessing prior knowledge. We focus on the questioning strategies workshop here because teacher candidates learn specific terminology that they then refer to when they reflect on their interactions at the carts. We articulated three different facilitation styles: Monolog, Initiate-Response-Evaluate and Reflective Discourse with Monologue, being more teacher-centered, and the Reflective Discourse, being completely learner-centered. Having this shared vocabulary allows them to communicate their experiences and advance each other's understanding.

Data Analysis

In this article, we examine data from the first rotation, the experience with the carts. We chose to analyze this activity because this is where the candidates have their first experiences with using the affordances of the museum to teach. The data sources examined and described here include semi-structured conversations with candidates immediately after using the carts, online forum posts, surveys, and field notes from faculty. The 20 hours of cart work were completed over 6 days. At the end of each day, second author (Preeti) met with the candidates to discuss key visitor conversations, successes, and issues. These meetings were designed to take place immediately after working at the carts to capture the candidates' immediate reactions and experiences. The candidates were required to post daily reflections on their experiences with the carts, some of the reflections were prompted while others were open-ended. A total of 994 posts, each approximately 150 words or more, were examined.

An external evaluation of the project was conducted where teacher candidates were required to complete survey responses and semi-structured interviews (Silvernail, Fallona, & Johnson, 2014). Data from the external evaluation were also analyzed as they provided salient reflections on

the teacher candidates' first-year clinical experiences in the museum. Field notes taken by the first author consisted of written documentation of discussions during meetings and observations of candidates at carts. The data were collected during each of the two cohorts' the 3-month summer residency. The evaluation was conducted each year in the early Fall immediately after the summer residency and before the clinical experience.

Recognizing our own subjectivity in the research process, we used a constructivist approach to the data analysis (Charmaz, 2014). The first author (Jenn) was a classroom science teacher, worked in a museum where she planned and facilitated teacher-learning experiences, and is now in a university setting and involved in teacher learning and research. The second author (Preeti) designed, planned, and enacted teacher-learning experiences in a science center and is now in a natural history museum where she facilitates authentic teacher learning experiences in conjunction with the youth programs. As informal science educators, both authors brought their pre-existing identities and understandings of learning to teach in a museum to the analysis process. This allowed us to look beyond the physical structures of the museum and look to learning interactions with others and generate themes about how those interactions contributed to a teaching identity to the data analysis process. Jenn's prior experience as a classroom teacher also allowed us to draw conjectures about what our emerging themes mean for becoming a classroom teacher. We also engaged another museum educator, one who worked closely with the teacher candidates and who was also a classroom teacher and is thinking about induction, to contribute to the descriptions of the emerging themes. We recognize ourselves as a part of the teaching context and possibly and affordance to the teacher candidates in the museum. We also recognized our agency in being able to shape the teacher candidates' learning experiences and this notion allowed us to examine the data from the position of looking at how the designed teacher-learning activity shaped and enabled the kinds of learning interactions that happened. With these in mind, we first used an open-coding approach were we looked for keywords and phrases within and across data sources that pointed toward affordances in the museum, learning to teach, and emerging teacher identities (Saldana, 2013). We then grouped the keywords and phrases to describe several salient themes and subthemes that we describe below. Some of the themes are overlapping and some of the events and vignettes spoke to several themes. We then re-examined all of the data with the chosen themes at the forefront in order to organize the lived experiences of both the candidates and ourselves as teacher educators. We chose specific vignettes within the data to illustrate themes and associated findings.

Findings

The Affordance of Visitors

The carts were created in conjunction with several of the permanent halls in the museum, with the objects on the cart correlating with the exhibits and tools of science in relations to the exhibits. For example, a cart in the Hall of Minerals and Gems would have samples of rocks and crystals as well as some tools that geologists use for visitors to touch and examine the objects a scientist would. In a given hour, the candidate may interact with numerous visitors—families, couples, students on a field trip, or individual adult visitors.

Engaging Learners. One of the initial goals of the candidates with the carts is to motivate visitors to want to learn about the objects on the cart. Many visitors are initially drawn to the carts because of the array of objects displayed and the possibility of touching them; however, they are free to walk away at anytime and in a museum setting, there are always multiple experiences competing for attention. As we learned in prior research, floor facilitators base successful

interactions on how long a visitor stays engaged along with other body language cues that indicate interest and curiosity (Adams & Gupta, 2013). In the following reflection, a teacher candidate describes how she leveraged children's initial excitement into a learning opportunity:

> During my first rotation at the Ocean Life cart, I had two children extremely excited about finding out about the sperm whale's tooth. Since they were so hyper I sent them down to see the diorama and told them to come back to tell me what they have seen. A few minutes later, they came back but they didn't have the right answer so I asked them if they wanted me to tell them or they wanted to continue their adventure. They decided to go back downstairs to check again. When they came back they were jumping and screaming that it was a sperm whale and a huge squid. But when I asked them to whom the tooth belonged to, the boy said it was a squid's tooth and the girl said that it was the whale's. I had the boy tell me why he told the tooth belonged to the squid and then I had the girl explain to the boy why the tooth belonged to the whale. This interaction was one of the best one thus far mainly because they children were involved and willing to explore the hall.

Through this spontaneous act of engaging the kids in a "scavenger hunt" and having them discuss their inferences with each other, the candidate created an opportunity for self-directed learning that also leveraged the physical excitement brought by the children. It is a rather long staircase that they climbed twice to learn more about the sperm whale tooth, as they were motivated to find the "right" answer. For this candidate, this positive learning interaction enabled her to witness how leveraging children's curiosity energy and shared experiences could lead to a valuable learning event. This small but meaningful act of inquiry teaching allowed the candidate to experience using the objects on the cart, displays in the hall and the children's enthusiasm to motivate learning.

In addition to the objects and exhibits an important affordance of a museum, especially for teacher candidates, are the visitors. Different people enter the museum with different identities and learning goals (Rounds, 2006). Some visit as tourists visiting a new city, others to see a special exhibit while others are frequent visitors to a favorite place. Visitors have various identity-related motivations and as such, the candidates have to be able to engage these visitors without having a clear prior understanding of what might be motivating a visitor to come that day. This provides a unique opportunity for a teacher candidate to use the affordances of diverse visitors coupled with exhibits and objects to engage visitors in science learning dialogs. Over the course of an hour, a candidate might easily have five different interactions with different age ranges, configurations of learners (i.e., family units, peer groups, or unrelated individuals) and with the affordance of being a popular tourist destination, candidates have to negotiate challenges of language and culture during these interactions.

A frequent theme that emerged for all candidates was the idea of being able to quickly assess the group for "where they are at" or prior knowledge. Interacting with visitors afforded the candidates multiple opportunities to "try out" this assessment while both learning how to access learners and adjust approaches in the moment and challenging their assumptions about learners and learning. Another candidate using the same cart in the same hall noted:

> Through reorganizing my thinking, I have found that by making each item on the cart relatable to something in the person's life: whether it's on their own body—such as having students feel their own spine and vertebrae right before we leap into a discussion on the humpback whale vertebrae, or I try to relate the baleen and krill to Finding Nemo, or I have the students look at how many rows of teeth they have vs. how many rows of teeth a shark might have (this involves me making funny faces).

This teacher candidate focused on relating the objects, which may seem foreign to many people, to their own lived-experiences and bodies. In noting that she "reorganized her thinking," she indicates that the cart experiences allowed her to think differently about how people learn and become creative about how she could relate the objects on the cart to her visitors. By bringing awareness to how their bodies are structured, she was able to engage them in learning dialogs about the form and function of a whale's body.

For both candidates, the interactions between people, the cart objects and exhibits demonstrates how the physical affordances and affordances of people allowed engage and motivate visitors in ways were learner-centered and to experience how different people learn. They learned to utilize identities and intellectual affordances that visitors brought into the museum (energy and curiosity for candidate 1 and some understanding of the body's structure for candidate 2) to instantaneously create meaningful learning experiences. This is the beginning of developing Spielraum in teaching—the ability to maneuver, and meet the needs of learners as the learning event unfolds. Through ongoing practice with the carts, the candidates learn to take advantage of teachable moments in real time without needing or even having the time to step back and reflect on the next step to take in the moment. Spielraum comes from experience; however, having opportunities to reflect on these experiences allows the emerging practices to become more conscious when the candidates reflect on theory of learning in relation to how learning unfolds in lived teaching experiences.

Improvisation With Affordances. The affordances of both visitors and objects provide a wide range of possibilities for teacher candidates to learn to be creative about how to teach in the moment as well as provide material for reflection on teaching:

> I think the wonderful thing that separates any old teacher from a successful teacher is their improv ability. Understanding that at any point the class may raise a question that you may not have been prepared for and being able to address that situation properly makes for a great teacher. In the case of the carts, I have found my best bet is to get a feel for the background knowledge a group or individual may come with and play my "shpeal" *(sic)* in that direction. In some instances (especially in groups) this is more difficult. . ....I found that if you have a group and you can recognize one person who's starting to slip back it may be easiest to hand them a sample of something while you talk to them or to the group as a whole to reel them back in. Also, as we've stated before, being prepared to say "I don't know" and "lets think that through" or "lets look that up together" is always beneficial.

This candidate specifically speaks to Spielraum when she relates the ability to "improv" to being a successful teacher. In this reflection, she recognizes the complexity of the classroom and the sometime uncertainty it brings. In relating this to the carts, her anecdote is "getting a feel" for the group (this speaks to the embodiment and intuition that comes from multiple direct teaching experiences with different people) and tailoring her interactions to meet the needs of the group at hand. She also described maintaining an awareness of all learners present and being able to recognize when someone is not engaged and act on reengaging them in the activity. For her, this is all a part of the "improv" or Spielraum that will shape her identity as a teacher for whom engaging all learners is important and central to her practice. Several other candidates note similar experiences in their practice:

> When a large group accumulates around the cart, it takes much more awareness on the part of the educator to keep everyone involved and engaged. I am far from mastering this skill, but so far have found that passing the cart objects around the group and getting everyone

> involved in brainstorming answers to a more difficult question help maintain the large group interactions.
>
> At this point in the museum residency I am just beginning to explore what techniques and resources I find most effective in certain context (e.g. different age groups, cultures, group sizes). I have walked away from this past week's discussions, readings and observation of cart use with a better understanding of the importance of object-based learning and the role that questions can play in creating a more engaging and open learning experience. As we prepare to start our carts experiences this coming week, I would like to keep the following two goals at the forefront of my mind: 1. Ask questions that allow learners to engage and discover information for themselves, and 2. Try to meet people "where they are at", as a gateway to peeking their interests.

In the last reflection, the candidate described the how he would approach learning how to use the objects on the cart while interacting with visitors. He also identified two guiding questions for himself that would help him to focus on keeping the learner at the center of the interaction. The exploration he describes is a necessary component of learning to teach—being able to try new and different ways of engaging learners in a given topic and a key affordance of the museum is having this space for the exploration of possibilities in learning.

In the following reflection, the same candidate later describes what he learned from his exploration:

> In addition to the salt rock I have also had a lot of success with the schist, marble and fossil pieces on the NYS Environments cart. I think the first two work extremely well because of the relevance to the NYC setting and peoples' every day lives. They are also very captivating samples that people tend to pick up right away because of the mica "sparkles". It is nice to then be able to explore these items further with visitors, discussing how they can be found around the city, what makes them shiny, etc. I also like that both of these items can be explored on multiple levels. For example, with working with younger audience looking at the schist I tend to focus on investigating properties and the Central Park connection. For those interested in more information, it is interesting to explore the process of formation, and compare it to other rocks such as gneiss and slate. The Devonian fossil samples are also really great to use because visitors seem to be drawn in by getting to touch a fossil and from there a lot of different aspects can also be explored.

His explorations lead not only developing Spielraum in using objects, but also to the realization of the range of possibilities with one group of objects. The visual characteristics initially draws the visitors to the rock samples and then, in this case, either the connection to the local or the past keeps them engaged. These affordances are not only important in developing teaching practices but are also foundational to an ongoing teacher identity development that places the learner at the center of practice.

Another candidate describes his developing Spielraum in the following reflection:

> I feel as though there is a time and place for each of these techniques. Depending on the visitor's questions, you may be able to relate some of your explanations in terms that they would more readily understand and sometimes you just have to give them the information. If you get to the point where they are asking for more information than you get at through IRE or reflective discourse in a few minutes, I feel as though you've already done a great job - they have clearly been engaged and are curious to know more, which is the entire point of the carts.

By reflecting on his experiences using pedagogical language and tools, he brings consciousness to his emerging Spielraum. He is also developing notions of successful teaching—what does it look like to experience success as well as define what a successful learning interaction means in this context. Since this is among his first teaching experiences, he is beginning to develop a notion of what it means to be a successful teacher, as he clearly articulates what doing a great job looks like.

Learning From and With Diverse Learners. As articulated in earlier studies (Gupta & Adams, 2012), the theme of learning from working with diverse learners resonated with the candidates managing the carts in on the museum floor:

> During the last two days on the carts, I have realized how important it is tailor the lesson to the group that is standing in front of the cart. If it is a group of elementary age children that walk up, the questions I ask them will be slightly different than if I am talking to a group of adults. The same over-arching theme applies to both, but getting there in different ways requires a quick assessment of prior knowledge, staying tuned-in to whether or not their attention is being held, and careful use of words/phrases that are age appropriate.

Having both successful and unsuccessful interactions offer important lessons about diversity in teaching and learning. Both interactions contribute to Spielraum as they allow a candidate to understand which approaches work well and with whom, as well as developing a practice of shifting as unexpected events arise. Showing a merging of theory with practice, in the following reflection another candidate layers a multiple intelligences framework on her cart-work reflection:

> Every individual has different learning needs. Some people are visual learners, some are auditory, and many are tactile-kinesthetic, learning best through hands-on activity. The effectiveness of different museum elements and their incorporation into teaching therefore depends not only on age, but also largely on the individual. Just as we discussed the generalizations across age groups the other day, younger audiences are often better suited to a more hands-on approach like the carts. While we might assume that older audiences function well with transmission-style interactions like guided tours (older folks tend to be more outwardly tolerant of transmission-style learning, maybe due to how they were educated?), they too often benefit from more interactive experiences but can prove more difficult to engage as compared to young folks.

She reflects on developmental aspects of learning through her experiences with the carts while also questioning what she believes are common assumptions about learning. This again points to having the affordance of practicing teaching with diverse groups of people across the age and learning style spectrum. Through having learning interactions with multiple and diverse people, the candidates begin to develop identities and corresponding practices that lend to reflecting on and meeting the needs of the diverse learners in front of them, while not making assumptions about who can (or cannot) learn science.

Shifting Ontologies

In the prior section, we saw a teacher candidate reflect on her assumptions about learners and learning. A salient aspect of working with the carts is that the candidates not only begin to challenge their own assumptions about learners and learning, but also begin to shift their assumptions about the self who teaches. These ontological shifts provide foundational markers for ongoing teaching identity development. The candidates often reflected on the importance of accessing prior knowledge as a way of knowing who your learners are:

> I think age is the first thing that determines how I go about my lesson at the cart. But this is not always the best approach, because regardless of age, people have different levels of knowledge. I have learned that assessing prior knowledge is the most important factor in altering my approach at the cart. The earlier on I can figure out what they know, the better the interaction generally goes. Doing this at the carts can be a bit challenging due to the short duration of most interactions.

This candidate describes his assumptions about age and learning but has realized that it is not a given in all situations. This allowed him to shift his approach from looking at external markers like age to internal markers like experience when assessing the learners in front of him. This is an important shift in using markers beyond those that physically define learners to a more nuanced approach.

In many reflections, the candidates often focused on the experience of the learner. In the following reflection, the candidate describes his own shift as he interacted with a group of learners:

> ...the quicker I could assess prior knowledge the better the experience was for myself and the people I was interacting with. This worked really well in African mammals, however, I found myself making certain assumptions in African people – many had limited knowledge or none at all about the objects on the cart. Therefore, I was caught off guard when I was visited by a couple who not only had significant prior knowledge, but certainly knew more than I did. They were an elderly couple from India who informed me that at home and in many of the rural villages around them, people stilled used the same water resource practices. While I knew these practices existed today, I just assumed no one that I would be talking to utilized the exact same tools (many people could relate how we use the similar simple machine methods in America). This interaction was a nice reminder that we all have different experiences, especially students in NYC. This interaction served as a reminder that you never know what anyone's life is really like...and that as teachers it will be helpful to learn as much as we can about our students. The more we know, the better we can relate to, teach and help them.

First, he reflected on what would make the learning interaction both meaningful to him and to his audience. While accessing prior knowledge was important—knowing that visitors enter with different life experiences—this candidate still had the notion that as "one who teaches" he would have more knowledge than anyone, especially in an anthropological "people" hall where the objects and practices often seem to come from a different time and place. However, his interactions with the elder couple from India not only challenged his assumptions, but also allowed him to extend his reflection to his future audience of NYC students, and the kind of teacher he would like to become, one who learns about his students in order to create relevant learning experiences.

Imagination. Based on her first informal teaching and learning experience, the following candidate describes the learning environment she would set up in her classroom:

> Obviously the school is a formal learning environment but if you could turn certain classes or lab periods into more of an informal learning experience would the kids be able to let go of the formality of school and participate as if they were at an informal learning center. A possibility for creating an informal leaning environment during a class could be to have inquiry stations set up around the room, touch carts and experiments. Each student might not have to do each station they could possibly choose a few and then have to present what they learned to the class, this could be done in groups and the group could perform the experiment or explain the touch cart at the end.

Emerging as an important aspect of identity development is imagination, imagining a future self and, therefore, being able to situate oneself in experiences that will lead towards that image of a future self. In these instances, the candidates begin to imagine their future selves situated in a classroom with students. Their initial informal learning to teach experiences helps them to form their imaginations. The candidate in the prior reflection imagines a classroom with learning stations and student choice; and another candidate, in the following reflection, begins to imagine her approach to developing lessons and learning experiences:

> I think in the classroom, assessing prior knowledge will be a bit easier and more thorough, yet no less important. And again, I would assume that this is one of the first things you do for each student, each year. The difficult thing in the classroom is then, tailoring lessons so that kids with different levels of understanding, or different learning abilities can all keep up, while still keeping pace with what has to be accomplished. It seems analogous to air traffic control. As a teacher you need to constantly be aware of the speed and altitude of each student. There will be those students who have the ability to stay above all the other plains so you don't have to worry about them as much, but at the same time you cannot forget about them. Everyone has to land safely! Then there will be students who fly a bit slower or a bit lower, and require more attention to keep them on course. I expect this to be one of the more challenging aspects of the classroom.

The analogy she uses is telling, as it is a visual representation of the image of self as teacher. While she recognizes the challenges of meeting the needs of each learner in the classroom, she is also identifying this, for herself, as an important aspect of what it means to be a good teacher. Like someone who is responsible for air safety, this candidate imagines herself as creating a learning environment that is safe, equitable, and engages all learners regardless of ability.

The following candidate reflects on her experiences both with the cart and prior experiences as a science learner in order to imagine her teaching self:

> I also really don't think that cart-based learning is all that different from a lot of stuff that is done in classrooms. For example, in a number of science classes I have been in, hands-on, interactive activities have played a primary part - especially my high school earth science class. In my college paleontology classes for which I took and then TA'd, Fun Fridays occurred just about every week. Specimen would be brought out and 50 minutes would be spent walking around the classroom touching, drawing, answering some questions, but mostly conversing with each other and the professor. Now, with our curriculum, I don't expect to have "Fun Fridays" every week. But it is totally something I want to incorporate into the year, perhaps one for each chapter or a hands on experience to prepare the students for the lab they will have to do. This is where our creativity as teachers comes in. We have to use these experiences in whatever ways we can, hopefully for the benefit of the students and our careers.

Her past and current experiences converge in her imagined future teacher-self. The carts invoked her prior positive science learning experiences. For her, the carts are not too far removed from what she encountered in formal settings and for her, she imagines a classroom that is formal, yet maintains the fun of learning. Yet, candidates are realistic about the differences of teaching on a cart and teaching in a formal classroom:

> What I have always appreciated about most good museums and learning centers, is their ability to cater to all types of learners and reach people in a variety of ways. This is something I myself hope to improve on as an educator and I hope to be able to bring some of these

> lessons learnt with me into the classroom come fall. I imagine it is quite difficult when you have 30 plus students, who are at different learning levels and who have different learning styles.

When candidates can have opportunities to challenge their assumptions and develop greater sensitivities to the complexity of learners, it contributes to their always-transforming identity as teachers. They can imagine, but they can also base those imagined scenarios in reality, understanding how the fields of formal and informal learning offer different and unique opportunities and challenges. That said, they also develop their abilities to carry the resources from one field into the other, in this case from the museum into the classroom field.

Discussion

Affordances

The affordances of an ISI contributed to agency in teaching in the following ways. First, we were able to describe the ways in which the visitors provided a key affordance. Through learning how to engage visitors as science learners, the teacher candidates began to learn how to use the other museum affordances, like the objects and exhibits, in fluid ways. The diversity of learners that they encountered helped to shape their views about learners and change their orientations toward learners from being the one who "held" all of the knowledge to one who recognized and leveraged visitors' knowledge in the learning interactions. The multiple learning interactions with diverse visitors challenged their assumptions about science teaching and learning in ways that allowed them to experience ontological shifts in their identities and roles as teachers. This afforded a space for pedagogical imaginaries to emerge where teacher candidates "try out new ways of knowing, being, and becoming" (Gutiérrez & Barton, 2015, p. 575) teachers of science. They began to view themselves as a part of a professional community and construct their future selves in the classroom. As learning contexts shape learners (Beauchamp & Thomas, 2011), the context of learning in the museum and the affordances accessed and the imagined context of the classroom shaped their emerging teaching identities.

Interactions with others are an important part of a learning context as our identities are shaped by our interactions with and positioning in relation to others in a given context (Stetsenko, 2008). The data analyzed in this article points to teacher candidates beginning to develop reform-minded identities (Avraamidou, 2014; Luehmann, 2007) in their positioning vis-à-vis the visitors in that recognized their responsibility to equitable teaching as they became aware of and responsive to the needs of diverse learners. In their reflective narratives, their pedagogical imaginaries described developing student-centered, minds-on, hands-on learning environments in their classrooms, thus, they were already defining themselves in relation to a community of educators with these characteristics. The structured interactions with visitors helped to shape teacher candidates' early career notions about teaching and learning and what it means to be a teacher. By positioning themselves as teachers in this setting, they enacted a sense of responsibility in being able to engage all visitors who approached their carts. Since the candidates were also enrolled in a teacher education course, they were able to reflect on their learning interactions vis-à-vis education theory, science teaching pedagogy, and their own prior experiences with teaching and learning. Through these interactions with visitors, with teach others, and with teacher educators, they began to position themselves within the educator community and articulate their contributions to teaching

The cart experiences mediated positive changes in their understandings of how people learn with particular attention to how each learner is unique. They saw the value in privileging the learner's knowledge, in leveraging the learner's interest, and becoming more aware of the self as a social being who will naturally make assumptions about learners. They realized the importance of

recognizing when those assumptions arise and to have strategies in place to aim for more equitable, safe, and participatory learning experiences. This small ecology of learning, practice, and reflection provided spaces for the candidates to learn with and from each other, from faculty and most important, from visitors about the self who teaches.

Revisiting Spielraum

Daugbjerg, de Freitas, and Valero (2015) note, "the lived and living bodies of teachers in classrooms are partially shaped by past experiences, but are also acting in the moment and in response to situations in ways that are not entirely scripted by these past experiences" (p. 22). This speaks to the agency of teachers; that Spielraum allows past and present experiences instantaneously inform how to react in the moment.

Teaching science is challenging and requires great effort to learn how to do it well. However, positive teaching interactions affirm a teacher candidate's emerging skills making the activity more rewarding and allows for deep learning. This is in agreement with Csikszentmihalyi's (1990) notion of flow, where a candidate engages in activity that is suitably challenging in a way that allows complete focus and immersion in teaching. In our data, our teacher candidates often reflected on the importance of being able quickly assess prior knowledge and figure out ways to engage learners, all while not loosing the proverbial beat in the activity of teaching. By being able to use the same object to teach the same content but in different says (depending on the learner(s) in front of them), the teacher candidates begin to develop Spielraum in teaching.

In our analysis, we related Spielraum to improvisation as the teachers viewed being able to teach in the moment or improvise as signs of good teaching. Improvisation implies consistent mobility or an ongoing shifts in identity (fluidity) (Deneroff, 2013). It is a creative act where we create new objects or activities by way of forms and process that with which we are already familiar (Douglas, 2013). For the teacher candidates, this is an ongoing re-creation of teaching orientation and actions each building on a prior experience, action, or interaction or, as Douglas (2013) describes, "a perpetual state of responsiveness through movement within a constantly shifting world" (para. 24). In the museum setting, there was a constant flow of visitors with along the unexpectedness of what the encounters would bring. The teacher candidates had to "keep going" within this flow in spite of uncertainty, which afforded the development of Spielraum in teaching; being able to respond to learners in a fluent, fluid, and relevant ways. Spielraum is embodied and can only developing with ongoing practice. The activity of teaching in the museum —the same topic multiple times—provides fertile grounds to see the beginning of a teaching Spielraum that will grow throughout a teaching career.

Imagination, Agency, and Teaching Identity

Maxine Greene (1990) speaks of social imagination in terms of "the capacity to invent what should be and what might be in our deficient society." When we think of the disparities that exist in education, and especially in science education, we need teachers who are able to imagine equitable learning environments that are responsive to the needs of all learners. These are teachers with agency; those with confidence in their abilities to access and appropriate resources at hand (and to acquire or, more often than not, re-create resources that are not immediately available) to meet their needs, as teachers, of teaching diverse learners.

From our data, we saw that as the candidates had more positive interactions with students, their confidence in being able to quickly assess and adjust their teaching style to match the learners in front of them also increased. The also began to reflect on how their learning and new found agency would play out in their imagined classroom. These early teaching experiences contributed both to the imagination of self as teacher and imagination of how a classroom would

be structured in order for them to enact their imagined self as a practicing science teacher—one with an identity that matches attributes of a reform-minded teacher who values learner's knowledges and uses it as building blocks for new ideas, and connects those ideas within learner's everyday experiences so that the learner can apply the new ideas to those contexts (Avraamidou, 2014, p. 826) and a pedagogical imaginary that moves from a deficit view of urban schools and students to one that points towards possibility (Gutiérrez & Barton, 2015).

Implications

Many studies have documented that new teachers have "more sophisticated ideas about instruction than they are able to put into practice" (Davis, Petish, & Smithey, 2006, p. 627). New teachers, being socio-cultural beings, bring beliefs with them about how students learn, ideas about what learning looks like, and what role they need to play in teaching the content into a teaching or learning-to-teach experience. This study acknowledges this reality and presents an approach to supporting aspiring teachers in developing identities as science teachers that are grounded in understandings of how people learn, notions of diverse learners and learning styles, and themselves as socio-cultural beings by engaging visitors in learning interactions in an informal science institution. Using such spaces and environments as learning labs, as sites for testing and re-testing teaching approaches, allows aspiring teachers to access and appropriate museum structures and resources while developing Spielraum that is responsive to teaching diverse learners.

Although we have been describing informal science institutions as a collective identity, we also recognize that individual ISIs differ from one another in missions, resources, institutional policy, and other aspects that shape their individual structures. As such, they each have a slightly unique culture imbued with historical, political, economical, and social structures that shape the teaching and learning activities of each place. This makes it difficult to articulate a model or a program design for teacher preparation that can work across settings. However, we provide insight for how the structures of informal science learning environments mediate change in agency and ultimately contribute to identity development for science educators.

Roughly, there are more than a thousand ISIs spread across the United States comprising science centers, natural history museums, zoos, aquaria, gardens, and national and local parks that have a department or staff that focus on education. Almost all have some type of interpretive activities in conjunction with the exhibits that provide a unique and relatively easy resource to university faculty involved in teacher education. Partnerships between universities and informal science institutions for teacher education are becoming more commonplace and there is research producing evidence of the many ways that an aspiring teacher's practices, and ways of thinking are mediated by either working in a museum (Saxman, Gupta, & Steinberg, 2010), or have in-depth experiences using the affordances of the museum to develop lesson plans (Kisiel, 2014). The findings of this study could advance the ways that those collaborators work together, deepening these types of learning experiences to include opportunities for aspiring teachers to work with multiple groups of visitors, school groups, or other audiences as a part of their field or clinical experiences. We encourage both formal and informal partners to think creatively about how to use their affordances, like the ones described in this article, to expand opportunities and contexts for learning to teach.

Interactions between visitors and teacher candidates are often brief; however, for a teacher candidate, each interaction contributes to developing agency and identity as a science educator. These interactions, as affordances themselves, make them re-think and re-envision themselves as educators, each time improving their skills and learning more about their own epistemologies and ontologies of science teaching and learning. Since human activity is inherently social and when

the activity is authentic and meaningful, the actions of individuals mediate actions of the collective and *vice versa*. When teacher candidates are positioned to meaningfully contribute to science teaching in an ISI, they know that they are transforming as educators while they are also transforming the institution and the practice of teaching science. Because of the dialectical relationships inherent in social life, and in this context, learning to teach realizing the value that ISI structures have for teacher candidate education could be transformative for improving STEM education both in formal and informal settings.

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Notes

[1]http://www2.ed.gov/programs/racetothetop/performance/new-york-year-1.pdf

[2]One of the earliest projects funded was NSF Award #0554262, CLUSTER-Investigating a New Model Partnership for Teacher Preparation and many more projects for alternative certification pilots have been funded since then. Another project can be found at http://sencer-ise.org/supported by the NSF Award #1237463

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