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When You See It: Intersections of Formal and Informal Science Learning

Cristina A. Trowbridge

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WHEN YOU SEE IT:
INTERSECTIONS OF FORMAL AND INFORMAL SCIENCE LEARNING

by

CRISTINA A. TROWBRIDGE

A dissertation submitted to the Graduate Faculty in Urban Education in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2018
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Cristina A. Trowbridge

This manuscript has been read and accepted for the Graduate Faculty in Urban Education in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

WHEN YOU SEE IT:

INTERSECTIONS OF FORMAL AND INFORMAL SCIENCE LEARNING

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Cristina A. Trowbridge

Advisor: Kenneth Tobin

In this dissertation, I examine the role of out-of-school learning environments in the development of new science teachers. The context for the research is the American Museum of Natural History (AMNH) Master of Arts in Teaching (MAT) program, specifically; the first two-year post-graduation new teacher induction. This manuscript style dissertation documents various aspects of using the museum and other out-of-school learning experiences in new teacher induction as well as illuminating how graduates of the program use the museum and its resources in their classroom. The first museum teacher residency program in the United States, this study advances our understanding of museum affordances and of out-of-school learning environments to enhance reciprocal development among new science teachers and students.

I begin the dissertation with an Autobiographical chapter that examines formative experiences and provides a context for my work and motivation for this dissertation. I apply teaching and learning frameworks to understand past learning experiences that shaped me as a teacher and researcher.

In chapter 2, Dioramas and Teachers: Looking, Thinking, Drawing and Talking, I reflect on my initial work using the Museum’s natural history dioramas with science teachers. Natural history dioramas are generative of visual stimuli, which afford various entry points for teachers and students to engage in science. A version of this chapter will be published (Fall 2018) in a book,
In chapter 3, *Breaking Dichotomies: Learning to be a Teacher of Science in Formal and Informal Setting*, I examine the nexus of informal and formal learning and leverages the affordances of museum resources in shaping science teacher identity of residents in the Museum’s MAT program. This chapter, which was published in 2016 in *Intersections of Formal and Informal Science*, edited by Lucy Avraamidou and Wolff-Michael Roth, was a co-authored article with AMNH colleagues Preeti Gupta and Maritza Macdonald.

In chapter 4, *Mining Science Capital: Collaboration with a Scientist Enhances Out-of-School Education for New Teachers and their Students*, I provide an example that illustrates the value of integrating informal and formal learning environments to enhance reciprocal development for new teachers and their students. I describe the program Advances in Geosciences – designed in the frame of MAT induction activities – that brings together MAT graduates, some of their students, and an AMNH scientist, as they visit the Museum’s science halls, the scientist’s lab, and an underground zinc mine.

In chapter 5, *Drawing Attention: Notes from the Field*, I investigate the use of silent sketching as a contemplative practice with the new science teachers involved in the MAT induction program. For teachers, contemplation and silence are in short supply in school environments. Natural history museum dioramas lend themselves for looking and contemplating. In 2017 the chapter was published in *Weaving Complementary Knowledge Systems and Mindfulness to Educate a Literate Citizenry for Sustainable and Healthy Lives*, edited by Malgorzata Powietrzyńska and Kenneth Tobin.
In chapter 6, *Out of the Museum into the Classroom (and Back Again)*, I examine experiences of a recent MAT graduate as he integrates the Museum’s resources in his Earth Science teaching to illuminate his students’ impressions and learning in a New York City public school.

I close the dissertation with an Epilogue that reflects on the process of writing and formative ontological shifts that have challenged my previous ideas about teaching, learning, and research.
Prologue

This dissertation is centered in my work with graduates of the Master of Arts in Teaching (MAT) program offered at the American Museum of Natural History (AMNH) during the induction component of the program. The initiation of my work in the doctoral program at the Graduate Center coincided with being asked to develop and implement this new component of the program. This confluence set the space and time for me to read, write, and formalize my ideas of what I was observing and learning. Throughout this time, I wrote daily, which was a critical element for and development my ideas. I highlight the evolution and themes across specific chapters as well as provide details when chapters have already been published or are in the publication pipeline. On writing and revising the autobiographical chapter, I realized how writing itself helped me to recognize some of the recurrent themes of teaching and learning, a constellation of interests and values all along my academic and professional trajectories that I was not prepared to identify clearly at the outset of the writing process. Building community, emotions in learning: embodied learning; use of informal resources, reflection, and immersive experiences in learning outside of school are some of those themes I looked to frame throughout the chapters of this dissertation. An introductory paragraph was added to each chapter to contextualize the circumstances that drove me to write it in the development of the dissertation.
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I sincerely appreciate colleagues, friends, and family that have provided support, friendship and understanding during the past five years. I know I could not have taken on this endeavor without you and I am thankful for having you in my life.

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I thank the Museum’s MAT graduate teachers. I have learned with you in your classroom and in the halls of the American Museum of Natural History. Thank you to the teachers and students who participated in the research.

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Dedication

For my Parents
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Chapter 1

Autobiographical Chapter

Chapter 1 is an autobiographical examination that uses vignettes to highlight different teaching and learning experiences that have influenced my development as an informal educator, classroom teacher, teacher of teachers, and researcher. Some of the themes, values, and interests that seem to be recurrent throughout this life history, reappear in a formalized theoretical framework in the following chapters.

Becoming a Teacher | Researcher

My development as an educator has unfolded over the course of my life, through lived experience. The present autobiographical chapter examines the influence of my work in museums and with science teachers on my evolution as a doctoral student and novice researcher. Over the past five years in the doctoral urban education program, I have gained awareness of how the two roles of teacher and researcher are braided in my work. The interrelatedness of these two identities has led me to use the Sheffer stroke identifier of teacher | researcher (Alexakos, 2015) to indicate a dialectical relationship. Though I now embrace the role of teacher | researcher, getting to this point has been a process of questioning my values (axiology) and shifting my understanding of what is knowledge (epistemology).

In writing this chapter, I’ve used vignettes, which appear in italics to describe life experiences to illustrate my narrative. At times, I struggled with my decisions about what to leave in and what to omit. In the hermeneutic process (Tobin, 2014), I have reflected on certain parts of the whole, at the same time leaving out elements that no doubt shaped my development. The recursive nature of reflecting and writing brings an awareness of what I am illuminating
while obscuring (Tobin, 2014). I hope this chapter provides a context for the path that I have taken in becoming a teacher | researcher – and to the remaining chapters of the dissertation.

*Early Museum Experience and Views of Teachers*

When I told by my sister I was writing an autobiographical dissertation chapter, she spontaneously replied, “I think you should write about how much you disliked working with teachers when you were in New Mexico.” I was surprised. The time she recalled was almost 30 years in the past, when I had worked for ten years to establish a small natural history museum located in a shopping mall in Las Cruces, New Mexico. My sister’s recollection was similar to my own memory of the time. It wasn’t teachers that I disliked, but rather the practice of classroom teaching that I found off putting. Teachers often asked museum staff to visit their classes, but I would always respond, “No, that is not what we do.” I didn’t like it when teachers wanted museum staff to come to schools with the museum’s animals to do a show and tell. It was stressful for the animals, and I questioned the value of such visits. I did not think going to visit teachers’ classrooms was effective. I didn’t want to meet the teachers where they were; I insisted they come to visit the museum. I wanted teachers to bring their classes to the museum and see their students outside of the classroom. I wanted teachers to be comfortable with not knowing the answers: to explore alongside their students the live snakes, lizards and animals native to the Chihuahuan desert. I wanted teachers to join their students to make animal tracks in the sand; to ask why do I appear upside down and distorted when I look into a twelve-foot concave mirror I wanted teachers to bring their students to listen to the stories of La Llorona on the Rio Grande while observing the constellations in the night sky and looking through a telescope to see the M80 galaxy.
In retrospect, I see that my dualistic view of informal and formal learning created a
division and, for a time, prevented me from developing ways of learning with teachers and
schools. I believed that teachers needed to embrace informal learning experiences in
environments that were more open than classrooms, and shifted the power dynamics between
teacher and students in ways that allowed for discovery. I believed that the strength of the
museum, lay in out-of-school learning, and I was afraid that strength would be consumed by
schools. It would take many years before I started to shift my view, to believe that learning is
learning regardless of environment. I can now see how a binary view of learning science
prevented me from imagining what Lucy Avraamidou and Wolff-Michael Roth advocate: formal
and informal science forming symbiotic relationships or communities (2016). I have changed a
lot since I worked in the natural history museum in New Mexico, but in one regard I’ve stayed
the same: I still want teachers to bring their students outside of the classroom.

Informal and Formal Learning: Early Memories

My memories of formal school learning are filled with mixed emotions. I did well in, and liked,
certain subjects such as art, science and math – but felt less affinity with reading and writing. I
was happy in gym and growing plants. I dreaded the end of summer and the return to school
because my natural inclinations were being active, living in my body, and playing sports. When I
think about school experiences in which I was proud of learning, almost all of them took place
outside of school. The week trip to an environmental camp, where I worked with friends to
figure out how to use a stick, string and stopwatch to measure the velocity of the stream was a
happy one. I remember going on a school trip and entering the crown of the Statue of Liberty
without the teachers. I remember my small greenhouse kit that I set up with cactus plants that
seemed so exotic on Long Island.
In my early work as a museum educator, I came across writers whose ideas spoke to my own preferred ways of learning. John Dewey advocated for students to engage in experiences and to learn by doing. Some tenets of Dewey’s education philosophy focused on students’ interests and encouragement of social interactions. Dewey’s ideas about the place of socialization and lived experience in learning in schools resonated with how I learned through playing sports, working with others to figure out the speed of a stream, growing succulent plants in a miniature greenhouse, and climbing up into the crown of the Statue of Liberty. In childhood, it was outside of school that I remember feeling most engaged, physically and emotionally.

Lifelong learning, starting in childhood and continuing throughout life is characterized by observing, trying and doing based on interest. Learning across the life span is lifelong, life-wide and life-deep learning (Banks, Au, Ball, Bell, & Gordon, 2007). In my own life, I found that the learning experiences I had outside of school held more value for me than those inside of school. The kinds of learning experiences I valued in my teenage years continue today, and continue to teach me about learning.

*Raising My Awareness of the Inequities in Education*

Living in New Mexico raised my awareness of inequities in education. My decision to move to New Mexico, resulted from a trip I took with my mom, who is Mexican American, to visit my Mom’s family in the Southwest. I had been to New Mexico only once before, when I was eight years old. I have memories, from that early trip, of my brother and I accidentally flooding my aunt’s yard with a hose, and watching my grandmother roll her own cigarettes. Now it was 1988, and it was liberating to be in a place that felt foreign but was in the United States, and to meet extended family and gain understanding of my mom’s Mexican roots. The trip to New Mexico began the process of understanding my mother’s – and my – heritage and culture. In New
Mexico, educational injustices became visible and I was exposed to multiple perspectives toward school, which differed from my own experience and idealism about education. It affected me profoundly to understand that schools are not experienced as welcoming by all; and could diminish a desire for learning among large portions of the population.

I knew education was a privilege and that it conferred power. This was more clearly evident in southern New Mexico than in anywhere else I had lived. My time in New Mexico brought an awareness of my privilege based on my race, education, and class. Reflecting back, I can see that my habitus (Bourdieu, 2011) carried cultural capital – from having an education to knowing how to maneuver within bureaucratic systems, and owning a car and home. The concepts of cultural capital underscore how societal structures are reinforced and perpetuate themselves (Bourdieu, 2011). Despite significant regional differences, educational issues in southern New Mexico are similar to those in public schools in New York City: high percentages of immigrant students, emerging bilinguals, under resourced classrooms, and low teacher compensation. My work and life in New Mexico shaped subsequent work choices and continue to influence my approach to supporting teachers today.

*The Chihuahuan Desert Times: The Museum and the Classroom Meet*

The Chihuahuan Desert Times, a science newspaper published by the Las Cruces Museum of Natural History, written by and for children, reached a circulation of 12,000 schoolchildren in Las Cruces, New Mexico. Professional journalists from the community participated as editorial advisers. The paper, which appeared in an 8-16 page tabloid format, semi-annually, over a period of eight years, addressed a different science theme in each issue. Astronomy in New Mexico, plants and animals of the desert, dogs – all were covered through first hand reporting and interviews conducted by primary and secondary school students. Students’ research for stories
were steeped in contextual experience. We visited the Very Large Array, the national radio astronomy observatory, the National Solar Observatory, and star gazed in a dark New Mexico sky to research topics on space. Background reporting for the paper’s dog issue included a visit to a ranch to research how dogs protect sheep; interactions with therapy dogs; an investigation into the problem of unwanted cats and dogs in the community; and sketching exercises with canine models. I co-taught classes related to the newspaper’s production with local journalists; organized student reporting trips and interviews; and sold advertisements in the paper.

As I worked with the Las Cruces Museum of Natural History to publish a science newspaper by and for children, I felt that a shift had occurred in my relationship with local schools and teachers. The newspaper, delivered in runs of 12,000 to local schools, and was a resource for teachers to use in their classroom. This was how I started to support teachers – with resources.

As a doctoral student, I look back on that experience with the Chihuahuan Desert Times through sociocultural theories of learning. The activity of creating the paper was situated in a social context, with adults facilitating aspects of the work and participating in a community to promote understanding (Vygotsky, 1978). Teachers and students worked side-by-side in an ongoing activity of researching, writing, revising, sketching, and building a newspaper in which students found their voices to advocate for plants, animals and the environment. The newspaper was a resource, which changed the museum’s (and my own) relationship to local schools. William Sewell (2005) identified as “resources” objects, tools, rules, and people. For Sewell, resources exist in a dialectical relationship with people’s schemas (ideas and beliefs). Ideas and beliefs are structures with porous boundaries that are contained in fields where cultural activity occurs and is produced, reproduced and transformed. The newspaper was a resource for the
students and the instructors and was also an activity through which culture was being produced and transformed. The fields of the local schools and the museum exhibited their porous boundaries in ways that allowed for the kinds of learning experiences that I sought for myself and others: learning through doing and in context, and fluidity of power relationships among learners and teachers.

Learning about sociocultural frameworks, views on culture, dialectical thinking, and theory of emotions has afforded me new ways of reflecting on experience and viewing research. I’ve begun to see that many situations which I might once have viewed as “either or” (such as museums and schools, or formal and informal learning, or researcher and subject) were perhaps both at the same time – a dialectical synthesis. Concepts like polysemy (multiple views) and polyphonia (many voices) have influenced my work and desire to ask and seek students’ and teachers’ voices in work and research. This shift has shaped my approach to my work and research with new teachers.

*Learning a Second Language as an Adult*

My move to Montreal to go to college gave me the experience of being a second language learner. Although my courses were taught in English, the city functioned in French and I was determined to try and learn it. In Montreal, I took adult education classes with recent immigrants to learn French. I progressed slowly but I stayed with it. French language learning was supported by French language dominance in the city, but it still was a major challenge because my social and school worlds operated predominately in English. I noticed how quickly others in my classes learned and became fluent.

My circumstances in learning French were very different than those of most recent immigrants to Quebec. However, I believe that this immersion in the experience of having to
figure out meaning from context and trying to express myself with limited language skill has made me sensitive to the meaning of being an emerging bilingual. Situated learning, theorized by Lave and Wenger (1991), proposes that learning is contextualized; happens with others who shared one’s focus; and that it is through experiences that we move from being novices to experts. This theory helps elucidate my own experience of language learning in the context of a Francophone city, and around more experienced speakers who supported my learning. In this case, theory applied to a past experience also gives me insight in new situations, guiding my work with teachers and students in New York City schools.

_Becoming a Public School Teacher_

In 2003, after twenty years of museum work, I became a public high school science teacher in New York City. Teaching biology in a classroom was new to me. The non-regents school that had hired me encouraged trips and science investigations, which allowed me to engage in pedagogy that had many of the attributes of my previous museum work in New Mexico. The Hudson River was a ten-minute walk from the school, and I made the river the focus of a course. I remember walking to the river to sample water, wearing a bulky red lifejacket, and a student eagerly asking to wear the jacket. It took some coaxing to get students to participate in a New York City survey of street trees, in their neighborhoods and outside school, but they took part and later shared how doing so had made them notice trees. On a ferry boat ride to Fire Island, I remember the students with their big frame sun glasses taking pictures and posing like movie stars, but once we got to the island they also seined, picked up and analyzed beach garbage, and completed a silent walk through the maritime forest. A planned rowboat outing in Central Park shifted from excitement to fear when students saw the rowboats. It was almost a complete
mutiny until three brave young women got into a rowboat and their infectious enjoyment helped others to take the risk of boarding rowboats for the first time.

Emotions were a part of these field trips. Emotions are everywhere in the classroom (Tobin & Ritchie, 2012) and because they are everywhere it is difficult to tease them out and to make sense of what is going on. I was not always successful in figuring out my own and my students. My development of understanding emotions and the role they play in learning has been a slow process. The first time I started to learn about theories of emotion and the role in teaching and learning was in the Urban Education program with Professor Tobin. This was seven years after I had left the classroom. I was exposed to heuristics (Powietrzynska, Tobin, & Alexakos, 2015) as a tool to create an awareness of emotions, mindful listening and speaking (Tobin, 2009), which created an awareness of self (Davidson & Begley, 2012). Reflecting back on my classroom teaching, I see now how I might have navigated situations with students differently had I been more attuned to the role of emotions in learning. The complexity of students’ experiences in the classroom always challenges understanding; theory has helped me to use my awareness of my own emotions and the possible emotions of others to make sense of classroom events. I use these resources now in my work with new science teachers.

Working at the Museum of Natural History and Becoming a Teacher | Researcher

I began a full-time position at the American Museum of Natural History in New York City in 2008, providing professional development to science teachers from predominately New York City public schools. Initially I worked with veteran teachers in educator workshops at the Museum. Following the Museum’s launch of a Master’s program in Earth science education, I began to work with new graduates, supporting them in their first two years of work in public schools through a post graduate program called New Teacher Induction. At roughly the same
time that I began the work with new teachers, I became a doctoral student. Over the last five years, I have studied and worked as a teacher-researcher at a juncture among three powerful institutions of education and culture: the American Museum of Natural History, the New York City Department of Education, and The City University of New York.

In my work for the Museum, I’ve visited about eighty New York City public schools, offering support for new teachers through coaching and mentoring. It’s hard to categorize a school. The schools I visit are mostly high schools, with a few middle schools, and are located all over the five boroughs. Each school has its own feeling. Each school has its own degree of wellness. I sometimes have an immediate impression from the security guard. Some are wary. Some warm up after I make repeat visits. Some schools have metal detectors. Others do not. For me, the presence of metal detectors made a memorable impression of suspicion and mistrust looming over the entrance of a school. I sign in at each school I visit. Sometimes I get a sticker with the school’s name on it. I put these stickers in my notebooks and make a collage as a way to remember. I notice the school artwork – the way the school wants to present itself. I take pictures of the teacher’s classroom, their desk, and the view from their window, or the student work on the wall. I take pictures of teachers’ desks, rocks and minerals, the ways that they create a space for learning. In the five years that I have been taking pictures I’ve seen the hallways change; the school posters have new messages of building community, growth mindset safe schools, images of rainbow flags imprinted on safe school stickers and announcements for LGBTQ alliance meetings. For me, the pictures document moments in the continuous history of the stories and memories of teachers and students.

Doctoral study has strongly influenced my perspective on educational and cultural institutions; knowledge production; and research methodology. Doctoral study fostered my
development of a critical standpoint (Kinicheloe, 2008) from which I was able to view museums and schools as institutions, as structures that offer access to education and learning – and can also support hegemony and reinforce dominant cultural values I began to see the importance of history and the historical distribution of power in understanding institutions. I saw that phenomena such as the new science standards and charter school funding, and the enormous financial incentives in K-12 education unfolded in a social and historical context. In my visits to schools, I saw well-intentioned teachers trying their best to work in environments shaped by sociohistorical forces. I saw more clearly that knowledge is power, and that learning institutions play a key role in the distribution of power.

As a doctoral student, I joined a community of researchers. The process of being with and learning with others (Tobin, 2015) in a monthly research group called USER-S (Urban Science Education Research Seminar) changed my understanding of research. My previous exposure to research methods had been to positivistic concepts such as cause and effect, research “subjects,” data, and statistics. At USER-S I heard colleagues talk about research frameworks that value participants, and about awareness of the different levels of benefits from research, and about how to incorporate this awareness into the research process. I gained exposure to the authenticity criterion (Lincoln & Guba, 1984) as adapted by Ken Tobin (2015) into an authentic inquiry framework. This framework acknowledges that research is emergent and contingent; places an emphasis on respect for participants and their ontologies; and posits that when research is authentic, researcher and participants learn from each other (Tobin, 2015). The framework sets standards for the researcher to incorporate participants’ engagement in all aspects of the research; seek to learn from difference; advocate, based on findings, for change that benefits participants; and maintain accountability to the participants. I knew this was the type of
researcher I wanted to strive to be. I came to understand that, as a teacher/researcher working in cultural and educational institutions I was participating in knowledge production and in distribution of power, and I wanted to do so in a way that shared opportunities for knowledge production and power with teachers, students, and research participants.
Chapter 2

Dioramas and Teachers: Looking, Thinking, Drawing and Talking

In this chapter I examine how natural history dioramas are generative of visual stimuli, which afford various entry points for teachers and students not only to engage in science but also for teachers’ reflection. This chapter came about in 2015 after Sue Tunnicliffe’s invitation – during an encounter at NARST conference in Chicago – to contribute with a chapter about my work with dioramas and teachers to a book on natural history dioramas she was working on (see reference below). This was my first foray into writing and describing what I had been noticing with using AMNHs natural history dioramas with science teachers while at the same time trying to apply theory to understand what was going on. At the time of working on this chapter, deepening my understanding of the role of mindfulness and contemplation in education – guided my course work and in conversations with colleagues at the Graduate Center –, led to me starting to apply those practices in new teacher induction. I expanded and developed on these ideas in Chapter 5.


*Introduction: What is going on in this picture?*

A jaguar surveys a cattle ranch. A snowshoe hare hides from a Canadian lynx in a wintry landscape. Two mountain lions, one whose ears are alert and back legs in a position to pounce, look out from under an overhanging outcrop; another smaller one, lying down, seems to stare at the visitor. The backdrop is the dry, hot, and hazy environment of the Grand Canyon. Windows
on Nature, the book by naturalist and artist Steve Quinn (2006) describes what it is like to stand in front of a diorama at the American Museum of Natural History (AMNH). The “windows onto nature” vary depending on species and region, but in the hall, mammals take center stage in the scene. What is happening? The diorama recreates visual phenomena of the natural world. The viewer, looking and thinking, is in the position of a discoverer, rather than a passive recipient of knowledge.

I did not immediately start working with dioramas when I began my position in science-teacher professional development at the American Museum of Natural History – although I had many opportunities to do so. Looking back on this period, I would describe my encounters with the dioramas as somewhat superficial. I would stop with teachers and look for a few minutes or make a point about a diorama or share some fact about how they were made, but I did not look at them closely. I had a vision of engaging teachers with natural history dioramas as a vehicle for facilitating conversations, but I lacked a method.

*What do you see that makes you say that?*

As I walked around the Museum observing teachers and students looking at dioramas, I noticed that, like me, they looked but did not do much more. At times a teacher might comment to a student on what an animal is doing, or a student would say, “Is it real?” or, “What is it?” providing and seeking ”right” or ”wrong” answers. Teachers, like me, needed support for how to look, think, talk, and listen with their students.

The emphasis on the visual in teacher education has precedents at the Museum. Since its inception in 1869, the American Museum of Natural History has been entwined with public education. Public education was the impetus “which inspired a group of public spirited men who organized and founded the Museum” (Sherwood, 1914). AMNH broke away from the “old
museum” paradigm and made its priority service to the public rather than the maintenance of a vault of objects (Coleman, 1939).

As early as 1880, Albert Bickmore – a founding member and the Museum’s first curator of education – began providing lanternslide lectures for groups of teachers on different natural history topics (Sherwood, 1914). Lanternslides are photographic images, sandwiched between two glass plates, projected onto a wall. The lectures were popular, and in 1899 more than 13,525 teachers attended (AMNH Annual Report, 1899). Bickmore called his teaching method the “Visual Instruction Method,” and it was used to develop other education resources for the public schools (Ramsey, 1938). These early pedagogical methods were successful and began to shape the Museum’s focus on objects and visual images. In her 2002 book, Wondrous Difference: Cinema, Anthropology and Turn-of-the Century Visual Culture, Alison Griffiths refers to the lectures as the “visual antecedents”, to exhibit, photographs, film, video, and IMAX, which are resources for K-12 education today. The emphasis on learning from direct observation of objects and other visual stimuli, as well as learning from experts (e.g., museum staff) would become hallmarks of the Museum’s work with teachers and schools.

The potential of informal learning environments lies in the opportunity for visitors to engage (Hein & Alexander, 1998) in observation and conversation (Leinhardt & Knutson, 2004). Individuals’ interactions with the environment, the objects, and one another, all are critical in museum learning (Falk & Dierking, 1992; Hein & Alexander, 1998). Social interactions and conversations foster learning in museums (Leinhardt & Knutson, 2004).

I wanted to help teachers harness the potential for interactive learning inherent in the museum setting. The challenge I faced was – how to design a learning experience that includes intentional conversation that is inclusive, non-judgmental, and inviting. I began creating simple
worksheets for teachers to make observations and inferences about a specific diorama. This approach worked within limits. Brief conversations ignited, but proved difficult to sustain. Teachers easily moved away from the role of learner towards that of teacher. Teacher comments ranged from, “I like this but I know that my students would not be able to do it” to, “How did you get your job?” Other teachers responded with silence, which I interpreted as indicating shyness, fear, or dislike of the activity. Visitors typically believe that staff holds the knowledge about the artifacts or the exhibits, dismissing their own capacity to make sense of what they see.

In 2009, I met Amy Chase-Gulden who taught me Visual Thinking Strategy (VTS), which would change my way of interacting with the dioramas and in turn change how I worked with teachers and students. It was through VTS that I began to engage, look, and learn with teachers. In this article, I hope to illuminate the trajectory of how VTS influenced my work with natural history dioramas in teacher professional development. I will share what the VTS experience has meant for the new science teachers I worked with, as well as their students, and include teachers’ sketches of the dioramas as an illustration of the phenomenon known in VTS as the multi-perspective of looking.

Visual Thinking Strategy, an interpretive method, is utilized more in art museums than in natural history museums. In the 1980s and 1990s, researcher and cognitive psychologist Abigail Housen developed her theory on aesthetic development based on interviews with art museum visitors. Housen developed a five-stage developmental model to describe a person’s aesthetic experience while viewing art (1999). Housen and colleague, museum educator Phillip Yenawine, developed Visual Thinking Strategy to support visitors' capacity to look and engage with the artwork. VTS is used in a group setting while looking at art and is facilitated by three guiding questions: “What is going on in this picture?” “What do you see that makes you say that?,” and,
“What more can we find?.” Although these questions were formulated to facilitate examination of art, they have been applied to other disciplines including science (Yenawine, 2013).

In VTS, the facilitator listens and paraphrases comments while pointing to specific areas of the artwork or, in my own work with teachers, the diorama. The facilitator connects ideas to broaden viewers’ perspectives of what they are looking at (Yenawine, 2013).

The VTS structure is deceptively simple and, when it is facilitated well, it can appear effortless. However, it takes practice for a facilitator to become skilled at paraphrasing participant comments and maintaining a neutral position throughout the discussion. A participant may observe something the facilitator has not noticed before and describe it in detail, and the facilitator’s initial impulse may be to say, “Brilliant,” or, “Great observation!” But the skilled VTS facilitator does not place judgment on person’s observations. The educational power of Visual Thinking Strategy is its capacity to level the playing field in a group of participants: no one is the expert in looking and talking about what one sees. Visual Thinking Strategy creates a facilitating environment (Winnicott, 1965) that removes the risk of failure, welcomes plurality of perception, evokes curiosity and invites engagement.

**Incorporating Sketching as Part of the VTS Process**

I began my work with the dioramas using a modified version of VTS with experienced teachers in a three-year wildlife forensics teacher professional development program with twenty-two middle and high school teachers. The focus was on how scientists use molecular techniques to identify species that are illegally traded; understand the distribution of threatened animals; and plan for conservation. It included learning about how scientists collect scat to further the study of the populations of big cats. The main activities of the workshop were labs. In order to give teachers an opportunity to observe the actual big cats in their habitats and place the science and
the conservation efforts in a vivid visual context, my colleague Dr. Adriana Aquino and I decided to use the dioramas in the Museum’s halls of North American Mammals, Asian Mammals, and African Mammals.

We decided to modify VTS with a sketching component. We did this for several reasons. We knew from experience that teachers enjoyed the dioramas and wanted to know how to use them with students but needed support in engaging students in observation and inference. We also knew some teachers were shy to engage in dialog and did not want to talk about what they were looking at. We thought the sketching would promote looking before talking.

The sketching protocol is brief, but sets the tone and establishes expectations. Teachers engaged in a pre-activity of a four-minute sketch in silence. The prompt was: focus your attention on one aspect of the diorama. Maintain that focus of attention, and sketch what you see. I provided paper, pencil and clipboards and teachers begin putting pencil to paper. The first few times I did this I was amazed by the variation, detail and thoughtfulness in the drawings. I have worked with teachers for many years in science professional development and had not seen this level of pride in drawing. Who knew so many science teachers had such natural abilities and desire for drawing? Teachers asked if they could keep their drawings. Some took photos and gave the sketches to me. It was teachers’ evident pride in their work that prompted me to consider another modification to VTS. After the four-minute sketch, I asked teachers to share their drawings with two other people. I did not emphasize the sketch, but rather invited teachers to show others where in the diorama they had focused their attention and what they had learned by doing this. I initially gave three minutes for these conversations. But, these three minutes were filled with laughter and animation with teachers pointing and looking at what they had sketched in the diorama. There was a synchronicity of positive emotions and talking among the
teachers about their drawings, which set the tone for looking together and engaging in VTS. This happened consistently, every time the teachers shared their drawings. The four-minutes of looking and sketching in silence, followed by three minutes of discussion in small groups, helped teachers find a voice to enter VTS. The tendency to stray off topic and the reluctance I had seen in some teachers previously, were absent.

One experienced science teacher wrote, “VTS – absolutely great concept. Could use it in class [sic] using a picture on interactive board. I would have them draw – because I enjoyed that activity. I never draw. It opened up a different portion of my brain.”

Initial sketching supported the talking. Conversations were lively, and each person’s perspective helped all of us see things that we did not initially notice or might have never noticed. In *Mind in Society*, Vygotsky (1978) emphasized that interaction with others in the environment and cooperation with peers are essential features for learning. The teachers’ interaction and cooperation illustrated the core and the power of VTS. Everyone shares some aspect of what he or she is seeing; everyone learns.

I exhibited the teachers’ drawings during professional development, and we debriefed the process and commented on the variations where people had directed their attention. Some teachers had natural abilities and knew techniques for shading and using a line to show depth; they shared these techniques with their peers.

The addition of drawing to VTS is like a visual voice, a trace of an observation that can be seen by others. I became convinced that the modified strategy of VTS – i.e., incorporating sketching and small group discussion – was something that I wanted to continue to use in my work with teachers.
Facilitation of the VTS Three-Question Conversation

To illustrate, I am providing a snapshot taken from my notes of the VTS process in front of the Alaskan Brown Bear diorama in the Hall of North American Mammals with a group of beginning science teachers. The process begins as teachers assemble clipboards, pencils and paper and enter hall. We gather around the diorama. Some teachers sit on the floor. I say, “I am putting you on the clock for four minutes to make a sketch of something that has caught your attention. Please no talking.” Teachers begin to look and sketch. Some sketch the bear that is standing, noticing how big the head is; someone is focused on the dead salmon nearby; others are sketching the mountains. Someone is sketching the bear and notices the scars on his nose. I say, “We are going to engage in VTS, which is a strategy that has three questions to support us having a conversation about the diorama.” I say the questions, and then ask everyone to take a moment to look, and ask for someone to start us off, “What is going on this diorama?” I described the discussion in notes taken that day:

Two hands go up. Well, Roger who is a little behind me to the right wants to say something and Ann Marie who is sitting on the floor looking wants to talk. We defer to Ann Marie. She is reserved and it surprises us all that she begins. Ann Marie talks about the bear maybe eating the fish, and killed the fish. I point to the salmon and paraphrase her comments. Roger continues and says that maybe it was the animal in the back, and the reason is that the bite on the fish is small. Others start chiming in, and in between comments I paraphrase and ask the teachers what more can we find? David notices the small animal in the back and is trying to describe his expression. Melissa notices the watermarks from the fish being dragged from the stream/pond. I point to the fish and someone says that he hadn’t even noticed the fish. Belinda notices the clouds, and Jamiela defers to her about the different clouds. Kenny talks about the history of the diorama and is wondering if the bear is not looking out at us. I point to the bear and paraphrase some of the comments, and we focus on looking at the bears. Erica and Jamiela describe the stances of the bears, the position of being alert. Belinda talks about the time of year and others also chime in. Some mention the grass, the snow, and I am pointing and paraphrasing and trying to link ideas about the snow. Miguel gives a detailed description about the snow line being low and then Belinda says it’s spring because the salmon spawn in the spring. Melissa says she has just noticed the bear tracks. Erica mentions that the mountain in the back with the swirl of snow looks like an avalanche, and then Miguel says well maybe that is what that cloud is in the middle of
diorama an avalanche happening. I ask him to tell us more – what is evidence for this – and he says maybe that is why the bear is standing and listening, because of the position of the ears.

Given the object of observation – a scene of the natural world – I found that the use of VTS with dioramas allows teachers and students to engage in the process of science, which begins with observations made by using the senses (and extensions of our senses). A museum diorama embodies a moment in nature, and the question what is going in this picture/diorama prompts students to make observations and inferences. Typically, the responses alternate between direct observations of what they see (e.g., “I see a salmon fish”) and inferences from those observations (e.g., Belinda thinks it is spring because the salmon spawns in spring). Since this is a critical aspect of the nature of science – the difference between observation and inference – the second question, “What do you see that makes you say that?” encourages students to support their observations and/or inferences (e.g., “maybe that is why the bear is standing and listening: because of the position of the ears”). These two questions are at the core of scientific thinking and are essential for understanding the process of science. The third facilitation question, “What more can we find?” aims at making participants notice that there is always more to find. This is true of science. Current knowledge is based on the available evidence; thus, science knowledge is intrinsically tentative and iterative, based on new observations and evidence.

However, the difference between the object of observation in art and in science makes the nature of the exchange between facilitator and participants slightly different. Observation of an artwork (i.e., the objective description of what we see) is based on the sense of vision; the inferences or interpretation of what we see is intrinsically framed by openness and subjectivity. It can vary depending on whether the observer is an art critic or a school student, but ultimately both are evaluating a product of the imagination.
Besides the exquisite artistic value of the dioramas, these are meant to represent, as realistically as possible, actual places, animals, plants, skies, etc. They were designed to be consistent with material reality. This creates a new challenge for the facilitator, who, following a VTS protocol, avoids providing evaluative feedback and definitively correcting participants. A student, for example, could misidentify an animal. Should we correct him? One alternative could be to invite the observations of other students, thus eliciting alternative hypotheses. The teacher could also encourage the student to find more about it back in the classroom. VTS can thus foster students’ reconsideration of their observations and inferences as well as learning from the group conversation.

**VTS: Supporting New Teachers’ Induction**

In 2012, my position at AMNH changed from delivery of professional development to self-selecting New York City teachers (primarily public school teachers) to working with graduates in teacher induction of AMNH's newly founded Masters of Arts in Teaching (MAT) residency program. The goals of the New Teacher Induction program at AMNH are to develop teachers’ abilities to: surface student thinking and plan instruction; to strengthen teachers’ use of museum resources and pedagogy; and to develop culturally responsive teachers to accelerate student achievement.

The MAT program includes museum and school residencies. During the first museum residency, pre-service teachers in training (residents), working alongside Museum educators, facilitate conversations with the public about exhibits in the Cullman Hall of the Universe, the Gottesman Hall of Planet Earth, the Guggenheim Hall of Minerals, the Morgan Memorial Hall of Gems, and the Ross Hall of Meteorites. In the school residency, residents placed in public middle and high schools in the New York metropolitan area develop class field trips to science exhibits.
and cultural halls at AMNH. In the second Museum residency, participants engage in scientific research in the field and lab. Over the 15-month period, residents become well versed in museum pedagogy and AMNH collections.

In my new role in new teacher induction I wanted to spend time with VTS and dioramas, but I was not sure how this approach would be received by a group of 18 beginning middle and high school earth science teachers who had just spent 15 months in the Museum’s MAT Residency program. This cohort of teachers knew each other and the Museum well. I framed the purpose of our visits to the diorama halls by stating that part of our work in induction would be strengthening MAT graduate teachers’ use of the exhibits and dioramas for school visits, as well as providing time for teachers to engage as learners. I intuitively felt the cohort could benefit from engagement with the dioramas by learning together and from each other and experiencing their own love of learning as a resource for teaching.

Once a month on Friday evenings, the cohort of teachers meets. One of the benefits of the Museum’s new teacher induction is access to the dioramas when the Museum is closed. We usually visit a diorama for about twenty minutes at the end of the evening. I will remember vividly the first meeting in which I suggested that we go to the Hall of North American Mammals to do VTS. I had collected drawing paper, pencils, and clipboards. I said little about VTS to the teachers in the classroom where we had gathered, preferring instead to engage in front of the diorama. The sketches of the Alaskan Moose Diorama (Figs. 1 and 2a-d) I selected illustrate the variation in teachers’ chosen foci of attention and perspective.
Figure 2. 1: Photograph of the Alaskan Moose Diorama (Hall of North American Mammals, American Museum of Natural History)
Figure 2. 2a-d: Teachers’ sketches of the Alaskan Moose Diorama.
Within a few months of my integration of modified VTS with dioramas in New Teacher Induction, the activity had demonstrated its power to provide new teachers with a valued opportunity to think and reflect on their teaching. Teachers were vocal about appreciating the time with the dioramas, “I appreciated having time to look closely at a diorama and just be.”

Two of the teachers said that VTS with dioramas was a motivator for attending induction meetings, and they looked forward to the time sitting on the floor in front of a diorama – looking and drawing and talking. Teachers need to engage in learning experiences that prompt curiosity and conversation in ways that parallel what they can do with their students to foster engagement and inquiry.

One first year teacher working with predominately second language learners in an Earth Science high school class commented that she appreciated having the time during new teacher induction to engage with the dioramas.

Like meditation, it required focus, but was enjoyable. It was meaningful to pay attention to small details that would normally go overlooked. It created an allotment of time that was reserved for silence and peace. It forced us to have a break from the busy schedule of teaching to relax and focus on detail. Specifically, since induction had a lot of discussion on the challenges of teaching, and was the ending of a stressful workweek. It was a great stress releaser that kept my mind active. I've thought about going to the museum on the weekend to draw some of the dioramas.

But this same teacher did not appreciate the facilitated discussion in VTS:

I know the purpose in a science sense was to think about the subject and ask questions (why do the clouds look like that? Why does the animal have that feature? Etc.) But I wouldn't focus on questions. Instead, I found the enjoyment in drawing and paying attention to detail with the goal of drawing it, not how it came to be in real life. I personally didn't enjoy the discussions that followed VTS, and would often keep drawing through the conversation not really engaged.

Some of the teachers did not like to draw and felt a little frustrated with this aspect of modified VTS. I started to provide writing prompts for teachers who did not wish to draw, inviting them to write for eight to ten minutes. The writing prompts were typed out on slips of paper and touched
on topics that are specific to new teachers’ lives and/or topics that I knew were relevant at school. Here I provide some writing prompts that we used in front of the dioramas:

- What is getting in the way for you to plan lessons?
- Write about a student that challenges you.
- Reflect on how you are making lessons culturally relevant to students.
- Write about what you are learning about yourself in your new role as a teacher.”

Teachers were asked to sit in front of different dioramas and write or draw. The goal here was to have teachers reflect on their teaching and find quietness by sitting in front of a representation of a natural setting. Afterwards teachers were asked to share in small groups and then the entire cohort would circle up to have a whole group discussion. One teacher, in her first year of middle school teaching, preferred to write in front of the dioramas. She often shared her writings, which explicitly described the struggles she was having with establishing her presence in the classroom. I felt that by her giving me the writing she wanted someone else to know her reality. Recently, I asked her to comment on this experience of sitting in front of the diorama and writing:

It was peaceful and relaxing. The museum was quiet and was a calming place to be and allowed me to think about the week/month/year. It allowed me to reflect in a peaceful setting and to think of ways to use the dioramas with students.

Looking at learning outside of schools to support learning in schools can provide insight on how to support novice teachers and strengthen students’ engagement and learning outcomes. Informal science learning environments (ISEs) are a potential resource that can support new science teachers. Early exposure to ISEs broadens teachers’ perceptions of the instructional support ISEs offer (Kisiel, 2014). The work may reveal alternative educational approaches, which increase engagement with groups of students with limited engagement in science education. Avraadimou (2014) and Kiesel (2014), both recommend additional research for middle and high school teachers. There is evidence that informal science environments provide a safe environment for teacher learning (Avraamidou, 2014).
What more can we find?

The responses of the new teachers to the use of VTS with natural history dioramas, and the impact it appears to have in their own teaching are consistent with the recognition of the potential that work with informal science institutions has for developing reform-minded science teacher identity during teacher preparation programs (Avraamidou, 2014). The first year of teaching can fill new teachers with doubt. Teachers succeed and fail in front of many people (students) all day long. It does not take much for new teachers to question their value and identity or career choice, or to experience themselves as incompetent. The development of a positive teacher identity is significant for teacher retention. How can natural history dioramas help? Here is a first-year teacher commenting on working with her students with VTS and dioramas.

To start, this activity was a very low maintenance activity. As a new teacher, it was great to run a successful activity that was not strenuous. When bringing large groups of students to a museum, it's important to be well planned and knowledgeable. VTS allows you to take some of the stress away from planning the trips, since the goal is to have students think and construct their own understanding, as opposed to looking for a correct answer. [...] having the students build on each other's images in order to construct a story [...] allows the students to see the dioramas in ways they have never seen them before. Yes, we connect the VTS to the Earth Systems. My students were just starting a unit on geoscience. As such, I had the students look for elements of atmosphere, lithosphere, hydrosphere and biosphere within the diorama. It was very effective for showing how all systems interact. It was beautiful to see students thinking and constructing for themselves! No matter the level of the student, each student can participate. Each student had ownership of their work!

A few teachers commented how they worked with art teachers for assistance on viewing the dioramas and modifications were made that maybe only benefited the students who like drawing.

Here is a second-year teacher commenting about her visit.

I took students to the museum this year and collaborated with the art teacher. Students had to find artefacts/objects in dioramas to draw, with a particular focus on texture. I
noticed that most students became restless with this activity after 5 minutes. The only students that were completely engaged were those who enjoyed drawing.

The diorama is a resource, and VTS invites the viewer to look and describe what she sees, which is open and allows for various entry points for people to engage in science. Research from the National Research Council on Learning Science in Informal Environments (NRC, 2009) suggests that when students from non-dominant groups in science are provided with resources, learning experiences in and out of the classroom can support skills and improve sense making in science.

Natural history dioramas serve as a facilitating environment to support new science teachers’ development. Teacher responses to the use of VTS and modified VTS, described in this article, suggest that these strategies have a positive impact on teacher learning and reflection. Two strategies I’d like to explore further in relation to modified VTS is its potential as a contemplative practice and its application in the classroom setting, I am interested in how new science teachers transfer the process of looking and thinking from dioramas to their classroom environment. I think there is still more to find about how the use of dioramas can strengthen teacher reflection and student learning. My goals are to continue to observe, talk and listen with teachers as we interact with the dioramas.
Chapter 3

Breaking Dichotomies: Learning to be a Teacher of Science in Formal and Informal Settings

In this chapter I examine the nexus of informal and formal learning and the role of affordances of both spaces in shaping the science teacher identity of residents in the Museum’s MAT program. This chapter was also published as an article written in collaboration with AMNH colleagues Preeti Gupta and Maritza Macdonald (reference below). This experience, which was my first writing in collaboration, helped me to develop a theoretical framework for my ideas on teacher identity. My major contribution to the paper was the examination of the role of museum affordances in shaping new teachers’ work in their New York City classroom.


This past decade has yielded a deeper understanding of how formal and informal learning contexts, are not at odds with one another but rather complement each other. The formal and the informal environments create ecology of learning spaces (NRC, 2009). When learning occurs at the nexus of formal and informal learning spaces, leveraging the affordances of both spaces, that is when students not only engage with the endeavor of learning science, but also are prepared to carry out the practices of science. Teachers need to be prepared to maintain an identity of not just a school teacher, but a teacher of science, one that crosses boundaries of teaching in both formal and informal spaces and one that espouses a reform-minded identity steeped in a worldview that privileges science inquiry, where the teacher believes that a learners’ prior knowledge and
everyday experiences are critical in the process of learning, the goal being to steer youth towards science literacy by deepening understanding of specific core foundational topics (Avraamidou, 2014). Informal science learning environments can be broadly defined as non-school settings that offer opportunities to experience and make meaning of scientific phenomenon. These environments range from a schoolyard to an amusement park. For the purpose of this chapter, informal science learning spaces are structured institutions such as museums, zoos, aquaria, and gardens. These institutions are where people can engage with science in ways that are authentic and participatory. The resources in informal science learning spaces include exhibits, collections (living and nonliving), educators, scientists, and science labs. These resources are important in supporting teachers, and in particular, those learning to become teachers because they afford the opportunity to enact culture in particular ways that contribute to reform-minded teaching (Avraamidou, 2014; Luehmann, 2007). The affordances of learning to teach in such settings include opportunities to work with multiple and diverse audiences thereby mastering one’s skill at student engagement, being comfortable to teach the same content to different audiences, time to refine the lesson, and the opportunity to develop an awareness of self as a teacher and a learner, which all contribute to identity development as a science teacher (Gupta & Adams, 2012). Based on the research of Avvaamidou (2014), we define teacher identity as “the ways in which a teacher represents her views, orientations, attitudes, emotions, understandings, and knowledge and beliefs about science teaching and learning” (p. 826). We use this definition to illuminate how a person’s identity as teacher of science becomes visible through enactment of culture, and is always transforming. The practices of that teacher are an embodiment of her ideas and beliefs and how she uses available resources.
In this chapter, we examine the affordances of museum resources in informal settings and how they shape science teacher identity. More specifically, we discuss how residents learning how to teach in school settings leverage experiences of learning to teach in museum settings. We describe a Master’s of Arts in Teaching (MAT) program that is situated at the American Museum of Natural History (AMNH). The MAT, an earth science teacher preparation program, is a 15-month residency program. People with undergraduate degrees in earth science/astronomy or a closely related topic can apply with the intention of becoming certified to teach earth science in New York State. These people, hereby referred to as residents, undergo a program that begins in June and consists of two museum residencies and two school residencies. Residents also complete 36 credits of science and education courses, which are co-taught by science and education faculty, many from AMNH. The two-museum residencies serve as bookends for the 15-month program. Upon graduation from the program, the cohort of teachers participates in a two-year new teacher induction program at AMNH.

In the first museum residency, teacher candidates rotate through three distinct museum activities that build on their instructional abilities to use informal science resources. This eight-week residency provides experiences with everyday museum visitors and middle and high school students enrolled in museum youth programs. In the first two-weeks of the rotation, residents work in small teams with interactive museum touch carts in the museum halls. Residents spend about 20 hours with the museum touch carts in the halls, which provide many opportunities to engage and access visitors’ prior knowledge, and introduce science concepts and assess for understanding. During the second rotation, residents get an in-depth experience of observing and coteaching with museum educators while working with middle and high school students who participate in week-long and month-long museum youth programs. In the third rotation, the
residents have the opportunity to design and teach their own lessons for high school students who are invited for a summer science institute. During the museum residency, residents take a course that provides the theoretical foundations for learning in informal settings.

In the second museum residency, residents spend time learning in the field and doing research with museum scientists. This experience allows residents to collect rock and mineral specimens to use in their instruction. This chapter focuses on what we are learning from the first museum residency and how teachers are enacting museum resources in their own teaching once they become teachers.

MAT graduates participate in the new teacher induction program, which takes a multi-level approach to supporting and developing new science teachers. The program consists of school visits with classroom coaching, monthly meetings at the museum, and 30 hours of professional development. During this time, teachers become part of a professional learning community, share their student work as well as participate in activities to improve their facilitation of student discussions and deepen science conceptual understanding using museum resources.

To date, 50 candidates from three different cohorts have graduated and are teaching in high-needs public schools (defined as schools with at least 70% of students living below poverty level). The cohorts are comprised of 50% men and 50% women, 18% Black or Hispanic, and 37% career changers.

*Emerging Identities as Teachers of Science*

Learning to teach is a cultural activity, one that is shaped by the contexts of the environment, but also shaped by one’s own sociocultural and political standpoints. We describe cultural activity as occurring in a field, where culture is produced, reproduced, and transformed (Sewell, 1999).
Fields are sites of activity with porous boundaries and have structures, both visible and invisible and those structures are comprised of resources (material, societal, cultural) and schema. Resources may include objects, people, tools, and rules, and schema are the ideals and beliefs one holds. One’s practices are a set of actions that draw from one’s schema and available resources. If we claim that the museum is a field, then we can say that as residents work in these fields, they are using the structures of the field to afford them the power to act, to have agency. As a resident becomes agentic in the field, she actually mediates changes to the structures of that field. One way to visualize relationships is by using the Sheffer Mark, $\mid$, which denotes dialectical relationships (Roth & Lee, 2007). Then, we can represent the concept as such, structure $\mid$ agency where structure is defined by the dialectical relationship of resources $\mid$ schema.

When residents operate museum touch carts, they are enacting culture in the museum. They are using the resources and schema available to them. At each interaction with a visitor at a cart that contains objects, the resident has to act in compliance with the resources available and the schema that exists in that moment in time. The person also has to experience passivity (Roth, 2007), that is, receptivity to learn and learning without agency by being-in-with others. After a resident asks a question or poses a challenge, the visitor’s actions and words are unpredictable. The resident has to accept this reality and experience this state of being and then be ready to act in response to the moment before, and use the structures available in that new moment. In this way, each interaction becomes a time to use and simultaneously transform structures. Each successful and unsuccessful interaction mediates the way resources are used and schemas are developed. After 20 hours of facilitating with the museum touch carts, their agency at teaching at the carts is greater than it was when they started. Because it is a dialectical relationship, as their agency increases, the structures also change at that cart. The way the objects are used, and the
nature of the conversations with the visitors are different. The resident develops the ability to act and maneuver in different ways, in response to visitors. She develops strategies for how to engage visitors. In the vignette below, we see how one particular resident discovers the value of creating a challenge at the museum touch cart.

During my first rotation with the Ocean Life museum cart [sic], 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, the boy said it was a squid’s tooth and the girl said that it was the whales. 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.

Natural history museums are built on the foundation that objects in their collections tell an important and compelling story. Learning how to teach with objects takes time, and one needs to develop strategies that are comfortable, effective, and make sense for the curricular goals. In the vignette, the resident has discovered the power of engaging learners by posing challenges and reveals how she connects an object to a set of exhibits. In the following vignette, we see how a different resident is developing an appreciation for object based learning, but also incorporating a learner-centered pedagogical approach.

When a large group gathers 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 contexts (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.
The two vignettes illustrate the trajectory of how the residents develop a comfort with using the objects by trying different strategies with different people. Short interactions with numerous visitors means that each time the resident uses the resources of the museum touch cart and engages the learner, it mediates changes in her schemas. Each interaction makes her think about learners and learning differently. As her ways of thinking about how to interact with people changes, her use of resources on the cart changes. As the resources | schema dialectic continues in each interaction, her practices change. As the residents are successful with visitor interactions, they are seen as a certain kind of a person by their peers and by visitors, a person who knows how to teach science (Gee, 2001). Over time, they begin to see themselves as successful teachers of science and this mediates changes in their identity. Identity development becomes intertwined with the act of doing. Since the construct of identity is dynamic and fragile, often, unsuccessful interactions can lead to threats to one’s ability to teach. However, because residents are required to spend 20 hours on the museum touch carts, there is an opportunity to learn from the unsuccessful interactions and to use resources and apply practices differently. Unsuccessful interactions can become a way to revise a teaching strategy, which then can lead to a successful interaction. The unsuccessful interactions, which may emotionally challenge one’s self-perception of being able to teach, are followed by a successful interaction, which balances emotions. Because the nature of working at museum touch carts means many short interactions in a chain, each interaction becomes a chance to start over and the rate of successful interactions is far greater than the rate of unsuccessful ones. A resident begins to identify with what teaching with objects means and this is not a shallow understanding, but one steeped in multiple lived experiences, with each time being given a chance to apply practices differently as governed by the resources | schema dialectic.
The Affordances of Exhibits

While objects can be brought into another learning space, exhibits often cannot be replicated in the same way. Field trips become the primary way for accessing and using the exhibits for schoolteachers. Field trips, especially for new teachers, can be a daunting task for reasons that include uncertainty of the teacher’s role, lack of comfort with the content, logistical challenges, and administrative obstacles (Kisiel, 2014). To combat some of these issues, the MAT program aims to develop comfort and confidence at facilitating field trips. The second rotation in the museum residency places residents in coteaching roles with various expert museum educators who lead a three-week summer program for middle and high school youth who are in a museum program that is designed to teach key concepts of anthropology, biology, and physical science in ways that fully integrate the exhibits of the museum with classroom activities. The summer program is designed so that students visit exhibits each day and over the three-week period with different museum educators. When residents are working with a number of the museum educators throughout these three weeks, they observe multiple teaching styles and multiple approaches to using the exhibits in a lesson. In the following vignette, we experience a resident who believes in the value of informal learning spaces and is pondering how to use non-classroom experiences to augment the formal learning space.

The instructor for the 6th grade biodiversity program jumped into the museum on the first day with visiting the halls of Biodiversity and Ocean Life. He then followed up with another assignment that required a visit to the Hall of Reptiles and Amphibians. The kids also did an activity that required them to virtually gather anthropological items to create their own museum collection.
Having multiple opportunities to see how children get engaged at exhibits, get excited and bring that excitement into the classroom is important for aspiring teachers because it allows them to imagine and understand what good museum learning experiences can look like. When residents experience and compare different pedagogical approaches taught by the museum educators and observe the way that children respond to those approaches, they are able to create schemas for themselves comprised of strategies and successful experiences. The museum educators have their unique style, but all use instructional strategies to engage children with objects on display in a natural history setting. During this rotation, residents observe and reflect on how particular approaches are used such as sketching dioramas, talking in front of large-scale specimens, and using worksheets to gather evidence in exhibits. The residents realize that using the exhibits as a resource and with particular schemas associated with it allows children to exhibit their interest and abilities in multiple ways.

Residents take courses throughout the academic year that follows the first museum residency. In one of the courses, there is an assignment to develop, implement, and assess a museum investigation that is embedded in a specific unit of instruction for students at their residency schools. The goal of the assignment is for residents to build on their summer museum residency experience by integrating museum resources into the school curriculum. It is the nexus of bridging the formal school with the informal learning experience. Residents are asked to reflect on student work and share insights for the evidence for student learning. When the residents conducted their museum investigation assignments in this course, it was not surprising to see that they chose numerous exhibition halls within the museum where they had spent time during the museum residency. Residents were asked to reflect on the field trip experience and in particular focus on the work produced by the students on the trip. In the vignette below we see
how students in a special education class thrive during the museum experience. The resident states,

I took 7 kids. I have one Marine Science class that I have been taking the lead on for most of the semester … attendance and excitement was just not there … They attended irregularly. They needed something. Excitement about the subject was there but museum trip would be perfect. It would get them excited about anything they wanted, but I would try and direct them to the Ocean Life stuff when we got there, because that is what we were doing. We had done an intro before, to get a sense of marine environment. I tried to do a lesson but it was so boring for them even though we had some visuals, but they weren't great. But then, dioramas on top of the Ocean Life Hall you can see the environment, they are everything short of interactive. They loved it … Then I said pick your favorite. They all went to the Polar seas one. They got excited about that part of it. After they were done with their worksheets … It was nice to see them put down the sheets and actually look, instead of looking with something in mind, and then they had all kinds of questions and their work was fine, it was accurate.

Since the visit was a field trip as part of a formal school structure, worksheets and assignments were used to check for student understanding. This resident above had a reform-minded approach, one that was learner-centered, and grounded in the learners’ interests. For the assignment, she asked the students to choose an ecosystem to learn about it in the Hall of Ocean Life. She leveraged the free-choice learning mantra of informal learning settings to give them power over their own learning. A number of the residents reported that because of the experience in the museum residency they knew the value of letting their students have options for their own learning on the field trip. For this to happen, residents needed to trust the students and trust the potential outcomes of having them lead a portion of their own learning experience.

The museum investigation provided an opportunity for this resident to get to know students in a different way. The museum and the school are both fields of activity, but these fields have porous boundaries. Residents who have learned to use the structures of the museum carry that agency and associated structures into their formal classroom space and then back. As they enter back into the museum learning space, they now have the structures learned from a
formal environment mediating their agency. The dichotomy of formal and informal learning spaces breaks down. The structures and associated agency developed in both fields now mediate activity in both fields.

The Journey Continues

The first three cohorts of the MAT residents are now first and second year middle and or high school teachers. The teacher shifts from being a student in the MAT program to teachers in new teacher induction. We observe the shift in their identity from MAT resident to new science teacher. One of the goals of induction is to use the affordances of the museum to nurture the teacher’s own informal learning and strengthen their ability to use museum resources, especially while their new teacher identity is in flux. The shift of forming identities as reform-minded teachers takes time and is influenced by context and experiences early on in teaching. One activity in the induction program to support teacher learning in the museum is to engage in various strategies to observe, draw, and talk about a specific diorama or museum exhibit. Afterwards, teachers reflect on how to translate these types of experiences into their classroom instruction.

By the time, the teachers begin new teacher induction, they are comfortable planning museum learning experiences and using objects, but whether they actually plan and carry out depends both, on their school context and their identity as a teacher and learner. The MAT teachers exhibit practices that convey their interest in using objects, and the physical resources at the museum. In the first 4 months of teaching, 56 percent of the teachers (n=42) made a visit to AMNH and by the end of the first year, 85 percent had visited AMNH or another informal learning site. The teachers who visited late in the year regret not taking their students earlier because of how much the students learned and how the teacher was comfortable facilitating in
the museum. In documenting the experiences of particular MAT graduates who brought students for a field trip, we saw evidence of their transforming identities, as people who feel the museum is an extension of their classroom, and is a place where they can engage their students. We also saw the power of being seen as a certain kind of person by both students and administration (Gee, 2001), a person with access to the museum, and a person with passion and expertise in science. In one case, one teacher, Dan, was struggling with making his lessons active and was met with some resistance by his students. He was challenged to connect with his students and was afraid to take a field trip. He did so after hearing about another MAT graduate that taught in a similar school setting and how the field trip was successful for the students. In the third month of school, Dan brought his class to the museum and as he began to use the museum resources like the geology exhibits that he knew well, and drew upon his associated schema for teaching with those resources. He exhibited confidence, a comfort and an agency in teaching his students. He later reported that this visit became a turning point for his relationship with his students. Dan had a museum badge, access to particular exhibits that normally cost additional money and was being treated by the museum as if he belonged there. He stated that students talked about the trip once they returned to school and he received some “cred” in the student’s eyes for providing a trip that did not cost money and had extra access. They also respected his ability to use the exhibits with ease and passion. Dan’s practices were comfortable in the museum because he had the agency to use the exhibits proficiently. His students saw this fluent practice and now identified him as someone who knows science, is passionate about science and is linked to an institution of science. Although he had the ability to practice reform-minded teaching in the school environment, his students were not affording him the structures necessary for success. When they experienced his practice in a field that was outside of their comfort space, their
schema about what’s possible changed. When he returned to a formal school structure, the students now carried back this schema and afforded him the space to teach science, and to use the agentic practices he exhibited at the museum.

*Mina’s Approach*

For some teachers, while field trips were not options immediately available because of school structures, their identities as reform-minded teachers exhibited themselves in different ways. Mina’s story provides an instructive example of bringing the museum resources into the classroom. Mina placed pictures of herself in the field collecting rock samples with her MAT colleagues on her classroom walls. She had rock samples that she had collected showcased in her classroom. One of her first student assignments was to have students take their own photos in a place where geology is found in the city. In her classroom, she had many of these photos of her students standing in a park, near a river or on a rock. Throughout the year, Mina kept using museum resources in her classroom. She invited two scientists to her class that she had worked with in the MAT program. Although it appeared that she is an ideal candidate who would conduct a field trip, she was challenged by school administration. In February of her first year of teaching, she asked her principal if she would be able to bring students and parents on a weekend day to visit AMNH. She came to realize that if she visited on the weekend, her principal really could not refuse. She worked with the parent coordinator and planned a trip for a Sunday in May for about 70 students and 50 parents. The trip was pivotal at stabilizing her teacher identity. One of the parents that went on the trip was so impressed with the how much the students and parents learned, the parent called to inform the principal. It was this call from a parent that shifted the principal’s idea toward trips. But, it did something for Mina. Mina believes her principal saw her as someone who had “cache”, a resource by having an affiliation with the museum. The
principal’s ambivalence toward trips dissipated and Mina stepped into taking a leadership role at the school leading to a number of school partnerships with AMNH. Mina had the agency to keep bringing resources into her classroom and ultimately planned a weekend trip. Being seen as a certain kind of person by the parent, mediated the actions of that parent to talk with the principal, which led to the principal seeing Mina as teacher with access to AMNH resources, and more critically, an ability to engage students and parents using the affordances of the museum.

Implications

Informal science education institutions are critical partners for teacher preparation. The opportunity for aspiring teachers to use the affordances of such settings allows for a shaping of identity that blurs the lines of formal and informal learning and allows teachers to use the resources of such settings in varied ways to engage learners, garner respect for themselves by both adults and students, and develop a sense of self as teacher of science that is strong. We describe a number of affordances that museums offer that position aspiring teachers to practice teaching in low-stakes settings, with objects, to diverse learners and work alongside many different experts each time building a framework for what good teaching looks like. Throughout the program, opportunities to exercise those strategies are present leading to relative comfort and familiarity with conducting field trips. As these aspiring teachers become teachers of record, we see threads of evidence for how particular schema trigger practices that lead to using the affordances either in the form of science activities, object based teaching, or science museum investigations.

There is much to be learned as the AMNH MAT continues to graduate more science teachers. In particular, we are curious about the extent to which MAT graduates are using informal resources in instruction to strengthen student understanding and engagement in science.
However, we hope that the ideas presented will support others to document their experiences working with teachers in informal settings and to build on how these experiences shape teacher identity and strengthen instruction for all students. There are more than a thousand different science museums in North America and many of them are situated near institutions of higher learning. Many already have partnerships with each other. What are the opportunities to develop ways for aspiring teachers to work in such places where they can practice teaching in low-stakes settings using different exhibits and objects with intergenerational visitors? How can museum faculty work with higher education faculty to create structures and processes to weave theory into practice? How can museums be used for supporting new teachers through induction experiences? These questions and many more are critical for consideration as we experiment with teacher preparation at the nexus of formal and informal learning settings.
Chapter 4

Mining Science Capital: Experience in New Teacher Induction

In chapter I describe a program (Advances in Geosciences) designed to bring together MAT graduates participating in the induction component of MAT, some of their students, and a working scientist. The program consisted of various out-of-the-classroom experiences that aimed at providing students a more direct perspective of the work of an Earth Science scientist. This chapter represents a shift in the way I started to theorize about the role of students and teachers engaging outside school to support reciprocal development of new teachers and their students. A version of this chapter was submitted (September 2017) to Connected Science Learning, an online journal dedicated to linking in-school and out-of-school STEM learning.

“It was a perfect day. I was impressed with the students’ curiosity, questions, and seriousness about volcanic rocks and how engaged and focused they were for the entire day,” said American Museum of Natural History (AMNH) scientist and curator Dr. Jim Webster after working with a group of 44 middle and high school students and 11 science teachers from 10 different New York City public schools who participated in an event called Advances in Geosciences.

Advances in Geosciences brings together graduates of the AMNH Master of Arts in Teaching (MAT) program, some of their students, and working scientists to visit AMNH science exhibit halls, tour a scientist’s lab, and collect rocks at an underground zinc mine. These days are full of experiences that could not occur inside a classroom. Students gather closely in the scientist’s lab for a first-hand view of mechanical equipment used to melt rocks to replicate the natural processes of igneous rocks. In the field, teachers eagerly introduce their students to teachers from other schools as they examine and collect rocks. In the museum, teachers and
students sketch and describe large volcanic rock samples. Deep in the zinc mine an audible gasp rises from the group when mine staff switch on the lights that cause walls of underground minerals to fluoresce in a rainbow of colors.

Figure 4.1: Display of fluorescent rocks at Sterling Hill Mine

Figure 4.2: Dr. Webster engaging with students in his lab

These Advances in Geosciences days are shared by new Earth science teachers who are recent graduates of the MAT science teacher education program at AMNH, their students from New York City public schools, and a scientist from AMNH who is on the faculty of the MAT.
Advances in Geosciences days are one facet of a teacher education program housed in a renowned natural history museum, which supports its graduates for two years with a museum-based post-graduation new teacher induction program.

Launched in 2012 by the American Museum of Natural History (AMNH), the Master of Arts in Teaching (MAT), is a 15-month program, which began as a pilot initiative to help address a critical shortage of qualified Earth science teachers in New York State. The program catered particularly for high-needs schools. In 2015, the MAT program officially joined the Museum’s Richard Gilder Graduate School, which is accredited in New York State by the NYS Board of Regents. The MAT is the first urban teaching residency to be offered by a museum. Courses are taught by museum scientists and education faculty, and residents complete: classroom residencies at high-need schools, and two museum residences – one in youth programs and the other in a science practicum. Graduates receive a Masters of Arts in Teaching, with a specialization in Earth Science for 7-12 grades. After graduation, teachers participate in the Museum’s new teacher induction program, which extends relationships between the MAT program and its graduates beyond course work and into the first two years of professional employment. The Museum’s induction program provides monthly cohort meetings, teaching and learning activities, and classroom mentoring and coaching.
This article describes an initiative of the Museum’s new teacher induction program that facilitates learning experiences among new science teachers, their students, and practicing scientists. Situated in new teacher induction, *Advances in Geosciences* are non-school day events that support new science teachers’ work with their students outside of school to deepen understanding of the work of scientists, build on Earth science content, and engage with students from other New York City schools. An equally important goal is to build on first and second year MAT teachers’ expertise and knowledge of the AMNH, the scientist, and camaraderie with the cohort, which allows the new teachers to facilitate learning from a place of strength with their students. This article represents varied perspectives by students, teachers, and a scientist who participated in *Advances in Geosciences*; and suggests the value of integrating informal and formal learning (Avraamidou & Roth, 2016) environments to enhance reciprocal development for new teachers and their students. While the program is specific to the AMNH and the MAT graduates in New York City, there are implications for informal science educators to forge relationships with new teacher induction initiatives affiliated with school districts and
universities to support new science teachers and their students in a critical period -- the first years.

Looking outside of schools to support schools, teacher education departments have shown growing interest in the potential role of museums and other informal science education institutions (ISEIs) in pre-service teacher development. Many teacher education programs use ISEI’s resources in their course work and development of pre-service teachers and these experiences are strengthening student engagement (Aquino, Kelly, & Bayne, 2010). Teachers’ early exposure to informal science education institutions broadens their perception of instruction and the instructional support available for the classroom (Kisiel, 2014). In addition to student engagement, museum affordances such as exhibits, people, and objects play a role in this critical phase of early teacher identity development (Adams & Gupta, 2017; Avraamidou, 2014). Informal science education environments and staff are well positioned to provide support by building on pre-service teacher education programs to continue as new science teachers’ transition into the classroom.

New Teacher Induction

New teacher induction programs typically focus on instructional coaching and analysis of student work to guide teacher development with the ultimate goal of accelerating student outcomes in the first years of teaching (Goldrick, Osta, Barlin, & Burn, 2012). New teacher induction is one approach to supporting teachers and promoting teacher retention. Over the past 25 years, there has been an increase of induction programs (Ingersoll & Strong, 2011) and 29 states require at least one type of professional development for new teachers (Goldrick, 2016). Drawing on various beginning teacher survey data, researchers Matthew Ronfelt and Kiel McQueen (2017) suggest that participation in induction initiatives in the first few years of teaching predict a
decrease likelihood of attrition. The first few years of teaching are a critical window for informal science institutions to forge relationships with new teacher induction initiatives affiliated with school districts and universities.

For new teachers, building classroom rapport and student engagement are still some of the hardest aspects to figure out in the first year (Feiman-Nemser, 2012). To address this challenge, one approach within the Museum’s new teacher induction program is to build on MAT graduates’ capacities to use the Museum with their students. Out-of-school environments can be a vehicle to shift students’ thinking about themselves and science learning, as well teachers’ sense of themselves and their students (Avraamidou, 2016; Kisiel 2014). The research is well documented that out-of-school learning experiences support students from diverse backgrounds to engage and strengthen their ability to construct science understanding (NRC, 2009). In the context of new teacher induction, out-of-school learning experiences enhance new teachers’ understanding of students.

*How did we start Advances in Geosciences days?*

In the third year of the Museum’s new teacher induction program, scientist and MAT faculty member and Earth and Planetary Sciences Curator Dr. Jim Webster received funding for broader impacts and educational outreach as part of a National Science Foundation award to support MAT teachers and their students with a program offering an in-depth examination of how scientists study the Earth. Funding from Dr. Webster’s National Science Foundation educational outreach award allowed transportation to the Sterling Hill Mine and Museum, purchase notebooks for students and rock samples for teachers’ classrooms, and provide breakfast and lunch at AMNH. The Museum’s new teacher induction budget provided stipends for teachers.
The planning of *Advances in Geosciences* has been a collaborative effort with MAT induction faculty (science educators who are MAT faculty) working with Dr. Webster and with the MAT teachers. Teachers were adamant that students see behind the scenes of the scientist’s lab, engage in an informal conversation with the scientist, and also get to spend time in the Gottesman Hall of Planet Earth while at the Museum. In addition, the teachers had visited the Sterling Hill Zinc Mine and Museum (Ogdensburg, NJ) with Dr. Webster as part of the Summer Practicum during the pre-service program, and felt that it was very important to provide a similar educational experience for their students.

While preparing for the first Advances in Geoscience day, Dr. Webster, teachers, and MAT induction faculty were excited and apprehensive about the day for different reasons. MAT induction faculty were concerned about attracting a sufficient number of MAT graduates and their students. From experience working with new teachers, they knew that they frequently felt tired and might be hesitant to make any teaching commitments beyond their school days especially the extra burden to come in on the weekend with some of their students. Dr. Webster presented his own concerns, as a research scientist, he had limited experience teaching large groups of teenagers who did not know each other and he was not sure how it would all work. Since teachers were asked to bring 3 to 5 students, teachers were worried about how they would recruit. Teachers shared strategies and in the end, some teachers brought students who were struggling in class and were disengaged while other teachers asked students to write short statements on why they wanted to participate while others choose students who were particularly interested in Earth science.

To coordinate the day, induction staff worked with MAT teachers and with Dr. Webster. During monthly new teacher induction meetings, teachers gave input and shared ideas of how to
organize the day so that it would include a variety of immersive activities to review and extend learning about rocks and minerals; as well as to provide time for teachers to share some of their favorite Earth science exhibits.

The event was called *Advances in Geosciences* to symbolize that this was a day of high expectations that would build on Earth science classroom instruction and give an inside view of the work of scientists. From these discussions, the agenda and student learning goals were outlined (see link). The primary goal of the day was to inspire students to develop their academic path in science by providing an immersive experience that expanded on the Earth science curriculum. Content learning goals aligned with the New York State Earth science curriculum were identified: how rocks and minerals support the understanding of Earth’s history; and how minerals and rocks are formed as a result of specific environment conditions. Different pedagogical strategies were used to foster students’ use of the Museum to deepen their understanding of rocks and to expose them to scientists’ uses of rocks to study the Earth. For example, an initial activity used silent sketching of rock specimens to elicit student ideas about igneous rocks. Teachers designed prompts for small group discussion and co-led exchanges among students from different schools. In addition, teachers were asked to have students share what they learned back in the classroom. Some teachers had students document the day with photos and make short power point presentations, while other students wrote about the experience.
In order to understand what resonated for the students, MAT induction staff, with support from the teachers, developed a feedback form (SEE LINK) that asked students to reflect on what they learned as well as to answer a few multiple choice and short questions from the Earth Science Regents exam, which is a New York State standardized science exam that most of the students would be expected to take at the end of the school year. Among Regents questions, the most relevant ones are about: characteristics of intrusive igneous rocks (mafic and felsic); processes that form these types of rocks: sequencing of events that caused particular rock formations from the oldest to youngest; and interpretation of bedrock maps. The addition of the Regents questions is to reinforce for new teachers how out-of-school learning can support student school learning and connect with a high stakes test.

What did the Day Look Like at the Museum?

The day started in the Hall of Planet Earth before the Museum opened with an investigation on volcanic rocks with teachers and the scientist both facilitating discussion in different areas of the exhibit. This was followed by a sketching activity of large volcanic rocks specimens. These
activities helped students from different schools engage with the topic, the Museum, and get familiar with each other. The silent sketching activity generated students’ observations, inferences, and elicited their ideas about igneous rocks.

Figure 4.5ab: Students sketching volcanic rocks.
Dr. Webster answered students’ questions about the rock specimens and gave a conversation style talk about his research on igneous rocks. After lunch, students and teachers were placed in three groups and rotated to Dr. Webster’s science lab and visits to different halls where teachers shared some of their favorite exhibits and students sketched rock specimens. In his lab, Jim (Dr. Webster) utilizes the controlled conditions to simulate the process of igneous rock formation. We say “Jim” because it was his informal approach and ability to encourage questions and discussion from students throughout the day that provided a point of connection to the scientist for students in what was otherwise a potentially intimidating environment. The point of connection for first year teacher Kin Tsoi’s high school students was being in the environment:

The most important part about showing students the lab is that it took them out of the mindset that education only happens in the classroom. It helped them think that education is more lifelong. A lot of them did not have any idea about why we did anything in class. They couldn't understand why we looked at things like geography, geology, astronomy, weather.

The context of the Museum, experiencing a scientist’s lab and getting time to discuss with a working scientist made the content relevant for these students and others. For a majority of students, it was their first time meeting a scientist and visiting a science lab. Danny (we use first name for student confidentiality), a tenth grader, commented “I actually went to a real scientist’s lab for the first time of my life.” The time in the lab resonated with students, as exemplified by one eighth grader’s reflection: “My favorite part was going to the lab and seeing how geologists perform experiments on rocks and learning about Jim’s lab and looking at the instruments he uses and how he uses them.” Dr. Webster thought the lab experience resonated with the students because “…I think

Figure 4.6ab: Students’ sketches of volcanic rocks and corresponding observations.
my enthusiasm for the lab work. I love being in my lab. I think sharing the melting rock samples and weaving a story, and to be in a room full of equipment. It is not a whole bunch of computer screens and lights and electronics. It is valves and gauges. It is a little more mechanical and I wonder if that is a little easier to appreciate”. One student, Jolene, an eighth grader, commented how the lab visit shifted her thinking about the work of scientists:

What left an impression on me was the lab, where scientists use different tools to help analyze different rocks, minerals, etc. I remember when we went into the lab … we saw all of the equipment that they used and they described what each one were used for. The day shifted my thinking because there were so many experts that knew so many things and personally I’m not into geology and I’m more into astronomy but despite my interests, the whole trip really grabbed my undivided attention.

The experiences in the lab and talking with Jim were of high interest to students and this was evident by the responses from the feedback forms. The collective enthusiasm for the day at the Museum led to planning a trip to a Mining museum.

Figure 4.7: Students engaging with Dr. Jim Webster in his lab at the American Museum of Natural History.

What did the Day Look Like at the Mine?

The Sterling Hill Zinc Mine and Museum in New Jersey is less than 50 miles from New York City. Mining in this location began in the late 1730s for zinc, iron, and manganese. The mine closed in 1986, and several years later opened as an educational museum. According to Dr. Webster, the sulfur-poor zinc ore minerals of the Sterling Hill Mine and the nearby Franklin
Mine form a mineralogical enigma; nothing quite like it exists on Earth. These two mines combined have 350 different types of minerals – representing 10 percent of minerals known to science (Bostwick, 2008) – 91 of which fluoresce.

In the MAT program, Sterling Hill Mining Museum holds a special place because it is part of the MAT summer science practicum and a favorite for many residents because they see rocks fluoresce in the mine and get to use rock hammers to collect rocks for their future classrooms. Each year, on the bus back to the Museum, the MAT residents strategize how they may bring their future students to Sterling Hill. The residents know these types of learning experiences can make a difference in building an interest in science. In other words, the day resonates with residents – both as learners and pre-service teachers – sparking their desire to incorporate this experience into their teaching. For students learning in the context of the mine and the adjacent Museum solidifies many classroom rock and mineral concepts.

*Advances in Geosciences at Sterling Hill Mine included: a tour of an underground zinc mine and museum and the opportunity to collect rock specimens in the field while working side-by-side with teachers and Dr. Webster.*

Figure 4.8: Teacher Kevin Gostomski working side by side with students.
Thirty-one students and 14 teachers from 13 different schools joined and learned about careers in mineralogy; strengthened their understanding of the history and science of mines; collected and identified rock samples; and engaged with other students and teachers from NYC schools. The day at the Sterling Hill Mine also aligns with the Earth science core curriculum and in particular the physical properties of minerals, and economic and environmental impacts of mineral resources. First year teacher Dejan Božović commented, “I appreciate that the students spent their day off on education. It’s great that the trip was about rocks and minerals, which is our current unit in Earth science class.” Aligning the trip to the Sterling Hill Mine at a time when most teachers teach the rocks and minerals unit allowed teachers to complement the experience back in the classroom. Students took photos during the trip and led class presentations that included using ultraviolet lights that the MAT Induction Program bought for the teachers to show the bright green and red colors of fluorescent zinc exposed in the minerals. Principal Yvette Rivera commented that for her students, “The day was a wonderful mesh of both science and education and that also captured the real-life experience of how geology has a real-life impact.”

Teachers and students communicated their reactions to Advances in Geosciences through student feedback form data, post trip emails, and follow up conversations. A few themes emerged that highlight the reciprocal learning that occurs during these days for new teachers and their students: enhanced classroom rapport; connections between science knowledge and professions; and changes in students’ perception of rocks.

Enhanced Classroom Rapport

For teachers and students, the shared experience helped both learn from each other, and build and solidify classroom rapport. After participating in Advances in Geosciences, first year teacher Kin Tsoi commented,
I chose the trip to reengage students in the content that we were working on and to build up a relationship with these students. This worked pretty well. They were more willing to come to after school for help, although the results varied at times.

For new teachers, getting to know students and building rapport is a critical first step in the first years of teaching. This is one reason why getting out of the classroom can support new teacher development. Second year teacher Erin Richley, who has participated in all three Advances in Geoscience days, highlights the reciprocal development for building relationships at school. She said:

I think the biggest thing I got out of that first Geoscience day was how it made such an impact on Manu [student] and my relationship. I think it meant a lot to her that I wanted to show her part of my world, and following that experience and into the next year teaching her again, we had a more trusting relationship.

Similarly, Dejan Božović, a first year teacher, describes what many Earth science teachers want for their students. He commented:

They had the opportunity to collect some samples, to talk to scientists, to see numerous pieces of equipment used while the mine was in operation, and to interact with other kids from NYC public schools. In addition, it was my pleasure to get to know these students better, in a different context.

These comments highlight the value in getting to know students in an expanded capacity, and its potential role in supporting teachers in building their classroom community.

Students’ comments reflect that, like their teachers, they valued the opportunity to see their teachers outside the classroom and to learn along with them. For example, Fateah, an 8th grader, summarized her impression about her teacher, “My teacher, Mr. G., is obsessed with rocks. It was a nice new thing to learn about my teacher.” Michael, an 11th grade student, shares what he learned about his teacher, Caity Tully, and what he thinks she learned about him:

… I mentioned to Caity prior to the trip that I have already taken Earth science in middle school and in a sense boasting that I had a 93 on the Regents. Acknowledging this information, she thought that I would be more knowledgeable about geology and I failed her by not really knowing the answer to her questions. She was fine with all of that. I had questions along the trip and she would always try to give me an answer or she would ask
Maya, another teacher if she didn’t know the answer. I admire her for that; her attempt to give me the solution, knowing that she doesn’t know it, yet still strives to figure it out is a rare quality to have.”

Michael describes how his teacher is accepting him even if he is not able to apply what he has learned in previous Earth Science classes to the rocks and minerals in the mine. At the same time, he sees a side of his teacher not knowing the answer and how she asks a fellow teacher. This is a parallel process of both of them showing their vulnerability of not knowing and it is OK. At both the Museum and the Mine, teachers collaborated and worked with students across different schools.

Figure 4.9: Teacher Jessica Sharoff and students sketching and making observations.
Connections between Science Knowledge and Professions

Advances in Geosciences days offered students the opportunity to see professional science in action. For example, one 9th grade student noted, “I liked seeing Jim’s lab, it was interesting to see how a scientist works pretty much on a daily basis.” At Sterling Hill Mine, Miranda, a 10th grader, made a connection between the science, the rocks, the mining profession, and her new awareness of rocks. These students expanded their ideas about science careers, the awareness of
science to obtaining a career, and in turn their science capital (Archer, 2015). Opportunities such as *Advances in Geosciences* allow the MAT graduates to share their expertise with their students. As a result, students indicated that they saw their teachers as scientists in the field. For example, when asked how he liked interacting with a scientist, Michael said, “Technically the teachers are scientists so yes, I did interact with scientists.” Both teachers’ sense of identity and students’ interpretations of their teachers’ identity shifted towards “scientist” on these days. Second year teacher Erin Richley said:

> It made me feel like I can still be a part of the larger scientific community. It helped me solidify the idea that I can help expose my students to what made me love geology, and still teach them something at the same time. It also helped to remind me I still had a place at the museum, and that I should bring my students back to see it from a more insider perspective.

*Advances in Geosciences* days highlight the value the teachers place on being affiliated with a science community and the Museum.

**Changes in Students’ Perception of Rocks**

The trips afforded new teachers contextualized opportunities to teach about the dynamic property of rocks. Before the trip to the mine, some students were dismissive of the rocks as boring; however, after students’ comments revealed a new relationship to these rocks. Genesis, a 10th grade student, reflected on how the trip inspired a new awareness of rocks in her neighborhood,

> I really enjoyed the experience of going into an actual mine that was once functional…. I learned that there are minerals that glow in the dark. There are minerals that come in different shapes, sizes and colors. I learned as a person I would really enjoy doing this as a profession. I was like to look for actual rocks… That very weekend I went to the park [...]


We tend to assume change happens only with living beings, but non-living things can also change us and this is a more holistic approach to being in the world (Bai, 2015). Another student captured this, saying,

I enjoyed being able to pick our own samples of the minerals. First as a group but then individually with the rock hammer. I enjoyed this because I had never picked rocks before and it was really cool to see the minerals that made up the rocks.

The students were surprised by how engaged they got with the rocks at the mine and the Museum. Through this experience, students had an interactive authentic experience, not only with their teachers and other students, but also with the rocks as scientific specimens.

Figure 4.12: Poster advertising a three-day event, Advances in Geosciences.

**Improvement and Implications**

To date, MAT induction faculty have hosted three Advances in Geosciences days and plan on two events this year. Areas of potential improvement for Advances in Geosciences include developing standardized preparation activities for the day and extended learning opportunities back in the classroom and alignment with middle and high school curricula. MAT induction
faculty would like to develop a plan to expand the evaluation efforts to understand the influence of the program as the new teachers continue in their teaching careers and students move through their academic/career pathways. In addition, teachers and MAT induction faculty will develop a teacher survey as well as expand the student survey to measure outcomes to inform how to build on these days both in and out of the classroom. Dr. Webster recently submitted a proposal for additional funding from the National Science Foundation for broader impacts in education to continue this component of work in MAT new teacher induction. The program has the potential to be replicated by other scientists and informal science institutions collaborating with induction programs in their own communities to design educational events that bring new teachers and students with working scientists.
Chapter 5

Drawing Attention: Notes from the Field

Chapter 5 explores the use of natural history museum dioramas for contemplative practices with new science teachers and the role of silent sketching to promote mindfulness. For teachers, contemplation and silence are in short supply in school environments. Natural history museum dioramas lend themselves for looking and contemplating. My goal in this chapter was to extend and provide a theoretical framework to ideas previously introduced in Chapter 2. The chapter was published in 2017 in a book – edited by M. Powietrzyńska and K. Tobin – that explores the place of mindfulness in education and well-being (reference below).


I am drenched in sweat as I take the subway to the last stop in the Bronx – 242nd street – to participate in a drawing and nature hike in Van Cortland Park. It is one of the hottest nights of the summer of 2016. The weather conditions are far from ideal, but I feel compelled to go, to be a participant and an observer in a nature and meditation drawing event.

At the park, the group is small (nine people) but diverse: a mix of parents with children ages 7 to 9 years old, a mom and her teenage daughter, and a few women together. After walking into the woods, we end up at a section of Tibbets Brook that opens to a pond. We gather on a bridge over a marshy area and are told to draw what we want for 15 minutes or so. It is liberating to have the freedom to draw what I want and at the same time scary to try and figure out where to focus my attention. I notice the tall green weeds (phragmites) gently moving in the distance against the soup green pond; the light is quickly changing; the sounds of nature come into focus;
and in the far distance a Snowy Egret stands still on a branch and a Blue Heron stands close by on the shoreline. I take the pencil and tell my hand to relax and I let the pencil make a long stretched out S shape to capture the curve in the head and the neck of the shore birds. I am starting to enjoy being in the moment.

For the past several years, as a manager for science teacher professional development, I have engaged science teachers in sketching, thinking, and talking in front of dioramas at the American Museum of Natural History. Initially, I facilitated professional development activities using Visual Thinking Strategy (Housen, 1999), a structured discussion protocol originally developed for use in art museums. I noticed teachers were reserved about sharing their observations. I modified the protocol, adding an interval of silent sketching before asking participants to share what they had observed. This addition of silent sketching contributed to a shift in my thinking about the dioramas and their generative potential for contemplation. I started to see the dioramas as places for meditation, and for supporting mindfulness practices.

In education, there has seen burgeoning interest in applications of mindfulness since the turn of the 21st century (Schonert-Reichl & Roeser, 2016). It is increasingly common for educators in school settings to engage both students and teachers in mindfulness exercises (Impedovo & Malik, 2015). One example of this, the New York City Department of Education's Move to Improve program, has trained 8,000 elementary teachers in mindfulness and stretching activities (Harris, 2015). This represents approximately 1 out of 11 teachers in the Department of Education. In addition, many middle and high schools are using breathing meditation as a mindfulness exercise throughout the school day.

A common refrain from my work with new teachers is the need to maximize learning and minimize stress in the classroom. Research suggests that teachers’ engagement in mindfulness
practices and contemplative interventions support effective classroom environments (Bernay, 2014). The research on the emotional environment of classrooms (Ritchie et al., 2011) makes a strong case for preparing teachers to use mindfulness interventions. The benefits of mindfulness strategies, such as an increased attention, self-regulation of emotions and creativity (Azarin, 2016) are well suited to supporting school communities. It is not surprising that contemplative practices and mindfulness programs are being considered for teacher education curriculum programs (Impedovo & Malik, 2015).

My work using the museum as a site for contemplation with first year science teachers took shape in the context of my exposure to ideas about mindfulness. My doctoral courses at the Graduate Center of the City University of New York, (in particular, courses with Professors Kenneth Tobin, Gillian Bayne, and David Forbes) influenced me to incorporate mindfulness in my professional development work with science teachers. On the first day of the course with Professor Tobin, I was pleasantly surprised to engage in five minutes of breathing meditation. It was liberating and inspiring to do this in a doctoral course. In addition, Graduate Center colleagues introduced breathing meditation and heuristics as interventions for raising one’s awareness of degrees of mindfulness when speaking and listening (Powietrzynska et al., 2015). I started to see the diorama as an intervention or a heuristic to focus attention for contemplation, reflection, and meditation. I began to notice teachers’ experience in the museum with dioramas at a macro and meso level and applied different sociocultural theories and my own framework – illuminating some aspects of what I am seeing while obscuring others (Tobin, 2008).

My research stance is guided by the authenticity criterion developed by Egon Guba and Yvonna Lincoln (1989) and elaborated by Kenneth Tobin (2015). This work with the dioramas has been guided to understand what is happening for new teachers engaging with the
phenomenon of sketching as a mindfulness exercise. For me, the value of engaging in this work is to support first year teachers’ reflections on teaching and learning. Along the way, my ontology is changing in relation to how I value contemplation in my work and seek to increase opportunities for teachers to engage, and finally, to strengthen my ability to do this in other environments outside of the museum.

The activity of sketching and looking at dioramas is a way to examine reality and say what is happening in a complex scene. It is a close proximate of reality and when this activity is done with other people (sketching, looking and talking) participants' plural realities and experiences can be shared and the group can create together knowledge of sensory perception and its interpreted meanings. These notes from the field are an attempt to describe what I am seeing and how teacher contemplative experiences in the museum can alleviate some of the tensions and contractions new teachers face in the classroom.

Mindfulness has its origins in Eastern religious Buddhist traditions and, starting in the 1970s, began to appear in psychology literature (Renshaw et al., 2015). There are varying ways mindfulness is conceptualized (Bishop et al., 2004). For the purposes of my work, I draw primarily on definitions of mindfulness proposed by Jon Kabat-Zin (2009) and Marsha Linehan (1993). Kabat-Zin provides a succinct description, “Mindfulness is awareness that arises through paying attention, on purpose, in the present moment, non-judgmentally” (p. 107). Linehan’s definition emphasizes paying attention in the moment; observing thoughts, facts, and feelings non-judgmentally; and participating with awareness. Contemplation, is closely related to mindfulness, but is not the same. In his work on contemplation in schools, Tobin Hart (2004) refers to contemplation as, “the act to shift the habitual chatter of the mind to cultivate a capacity for deepened awareness, concentration and insight” (p. 29). For teachers, contemplation and
silence are in short supply in school environments. Natural history museum environments lend themselves for looking and contemplating.

*Drawing with Dioramas in the American Museum of Natural History*

Dioramas recreate visual phenomena of the natural world and provide vistas for looking. Natural history dioramas, termed "windows on nature," by Steve Quinn at the American Museum of Natural History (2006) are scientifically accurate three-dimensional displays of animals in their habitats that include fabricated real or artificial elements (Kamcke & Hutterer, 2015). The dioramas hold in them rich science content and concepts, which could support learning for teachers and students. In his book *Ways of Seeing*, John Berger (1972) comments that seeing comes before words. The dioramas are a rich backdrop for seeing and sketching before talking.

As mentioned, my work with sketching and mindfulness with science teachers began with a modification of Visual Thinking Strategy (Housen, 1999) – a well-known facilitated protocol for observation and discussion, originally developed for use in art museums. The protocol poses three questions, “What is going on in this picture?” “What do you see that makes you say that?” and "What more can we find?”. My initial intent in modifying the protocol to include sketching was to give participants time to look before verbalizing observations and inferences. Over time these activities with first year science teachers have evolved to become a mindfulness exercise and provide a space for contemplation.

*Teachers’ Responses to Drawing Drew my Attention*

One of my first experiences facilitating group discussion occurred after silent sketching took place with science teachers in front of the Mountain Lion Diorama in the iconic Hall of North American Mammals (Fig. 5.1).
What impressed me was that the hall roared with teachers' voices. Teachers shared what they had noticed and where they had focused their attention. To illuminate this experience, Randall Collins' (2004) theory of interaction ritual chains describes the characteristics of how a group functions. First, there was proximity of individuals to one another, which was evident in the intimacy of participants gathering in front of the diorama. Second, the shared focus of looking at the diorama and the full engagement of looking attentively with the group. Synchrony was visible in the group's shared focus looking intently and sketching the diorama; the teachers displayed positive emotions; laughter, engaging and listening to each other and a feeling of generosity to share their sketches. Over the years, I have done this activity with hundreds of science teachers and the response is generally similar. Teachers appreciate the silence followed by the engagement of having a shared experience of discussing where they put their focus in the diorama. The drawing is about focusing attention to detail and not about the actual sketch. I wondered if the diorama is a catalyst for group cohesion.
What was clear from the beginning was that it did not matter if the activity occurred during a one-day or weeklong workshop; this relatively brief activity of looking, sketching and talking for 15 minutes was consistently noticed and commented on in evaluations. When asked about their impressions of the day, teachers commented how much they appreciated it. “Using visual learning, drawing allowed me to focus attention,” commented a high school science teacher. This was a common refrain in evaluations. Shannon Murphy (2016), in her work with children and art and meditation in a NYC art museum, also saw a similar pattern – the meditation or focused attention of looking resonated strongly with participants.

Below are examples of science teachers’ four-minute sketches of the Mountain Lion Diorama at the American Museum of Natural History, which highlight the multiple perspectives and plurality of attention to detail evoked by silent sketching in a group (Figs. 1a-d).
I chose these sketches because they demonstrate commonalities and differences of how teachers view the diorama and where they put their attention. The two mountain lions are prominent in the foreground with a detailed landscape of the Grand Canyon in the background. In Figure 1a,
the teacher kept his attention on sketching the outline of the two mountain lions with detail on a boulder behind them. In Figure 1b, the teacher focused on one mountain lion with detail of the fur texture and the head region – whiskers, eyes, and nose. In Figure 1c, the sketch captures the focus and stance of the mountain lion as well as noticing an often-missed detail – vertebrae bones on the ground. In Figure 1d, the teacher focused her attention on the rock overhang, the plants, and the horizon. These sketches are examples of polyphonia. A core principle of authentic inquiry is that there are many truths, perspectives, and multiple interpretations and learning from difference is valued (Tobin, 2015). This also parallels a characteristic of mindfulness, which is the ability to identify several perspectives of a situation. The images are four different views and together they create another perspective, which highlights the aspects of the diorama.

*Drawing Attention: Sketching as a Mindfulness Exercise with Science Teachers*

In looking at the diorama, with its focus on phenomena of the natural world, the viewer is looking and thinking, and is in the position of a discoverer, rather than a passive recipient of knowledge transmitted by others. This was evident with the level of engagement, the questions, the ideas generated and the curiosity for wanting to learn more among the teachers with whom I worked. The natural history dioramas are complex environments that generated observation, multiple perspectives, and reflection.

The museum presents affordance for contemplative practices. The idea of affordances described by James Gibson (1977) is that objects in the environment present possibilities for taking action. The natural history diorama is an object that is complex, layered with science concepts and history, ideas about representation, and values about nature (Haraway, 1984). The diorama offers visitors possibilities to take actions of learning and contemplation. In addition, the diorama is generative. The idea that objects and words can be generative is prominently situated
in the work of Paulo Freire (1993). For Freire, generative themes or words elicit – or generate – new thoughts, ideas, and observations.

The natural history diorama is a facsimile for nature. Research suggests that people’s cortisol levels lower with exposure to nature. For many teachers, the museum setting is a refuge from the realities of public schools. The museum is also a vehicle for developing teacher identity and agency (Adams & Gupta, 2015). The context, the atmosphere, and exhibits make it an ideal environment for reflective learning. A contemplative space, the museum can engage new science teachers in reflection and dialogue about classroom practices and culture. Contemplative practice provides an immersion in reflection with a focus and an awareness of the present moment (Impedovo & Malik, 2015).

Maryann, a first-year teacher, reflects on using a sketching and visual thinking strategy and how her students construct their understanding by first quiet sketching and looking and talking with others,

As a new teacher, it was great to run a successful activity that was not strenuous… VTS allows you to take some of the stress away from planning the trips, since the goal is to have students think and construct their own understanding, as opposed to looking for a correct answer. It is beautiful to see students thinking and constructing for themselves!

The teacher’s comment of various student perspectives in the quote above highlights what Ellen Langer (2016) refers to as mindful learning. In an earlier work done in the seventies, Langer defines mindful learning as, “the continuous creation of new categories, openness to new information, and an implicit awareness of more than one perspective” (p. 4). This teacher also acknowledges that the activity lowered her stress levels, which in turn contributed to her students’ engagement in a mindful learning experience, “Like meditation, it required focus, but was enjoyable. It was meaningful to pay attention to small details that would normally go overlooked.” (Maryann, a first-year middle school teacher).
My work with first-year science teachers in new teacher induction is part of the Master of Arts in Teaching program at the American Museum of Natural History. During monthly induction meetings and other professional development activities, I use the Museum’s dioramas to engage new science teachers. The teachers value this time of silence and reflection in front of dioramas. These unforeseen observations, drawn from lived experience, shaped my practice. I can’t overstate teachers’ appreciation for silence and reflection. The quotes from first and second year teachers encapsulate many teachers’ responses to sketching and observing in the Museum. In this context, the sketching activity is a mindfulness exercise that can be used with teachers to reflect on the realities of their classroom. It also has the potential to foster teachers’ effectiveness in the classroom.

It created an allotment of time that was reserved for silence and peace. It forced us to have a break from the busy schedule of teaching to relax and focus on detail [...] specifically since induction had a lot of discussion on the challenges of teaching, and was the ending of a stressful workweek. (Lani, a second-year high school science teacher)

While most of the science teachers with whom I worked seemed to appreciate silence, not everyone appreciated sketching. For teachers who did not wish to sketch, I provided writing prompts on topics that are specific to new teachers’ lives:

- What gets in the way with lesson planning?
- Write about a student that challenges you.
- Reflect on how you are making lessons culturally relevant to students.
- Write about what you are learning about yourself in your new role as a teacher.

Teachers were asked to find silence (i.e., quieted their minds) and reflect on their teaching while sitting in front of a representation of a natural setting. A few teachers who shared their writing noted that it was cathartic to put their emotions on paper and describe their struggles in the classroom. The group was sitting in front of the American Bison and Pronghorn diorama and teachers were given a choice of sketching or writing. The teachers who wrote were given a
prompt to "Write about where you would put yourself on a graph of the Attitudinal Phases of New Teachers Toward Teaching" (Moir 1990).

Here a first-year teacher’s comments in her third month of teaching:

I feel like I live in survival mode and I am very disillusioned about teaching. I am just trying to make it through the week [...] I constantly think that there is no hope for humanity. I feel like I’ve been asked to do more than I should and that my students have been asked to learn more than they realistically can in one year, especially from a first-year teacher, who doesn’t really know what she is doing [...] (Diane, a first-year middle school science teacher.)

The comment highlights many teachers' experiences with their daily environment as disquieting and stressful. Mindfulness exercises such as sketching in front of a diorama can be used as an intervention to support reflection and have the potential for supporting teacher wellness.

Out of the diorama and into the classroom: explicit application of mindfulness to teaching

Like the diorama, the classroom is a complex environment that invites observation and multiple perspectives, but – unlike the diorama – the classroom includes people’s emotions, and teachers need to have the capacity to make many choices and take action in an environment that can be over stimulating emotionally. In the first year of teaching, emotions effuse. Many first-year teachers with whom I've worked have shared experiences of the smell of their own sweat from being nervous or the salty tears because words could not describe their frustration or not recognize the sound of their own voice because of anxiety.

Teachers need to navigate through their own and students' emotions all day. At the end of the day, a new teacher might be able to say, "I did one thing that worked but I was unhappy with 99 percent.” The beginning teachers face an expectation of competence, and as such a high level of public exposure to failure. It is hard for many individuals to take hold of their attention under optimal circumstances, but the classroom, which evokes powerful emotions (Tobin, Ritchie, & Oakley, 2013), presents exceptional challenges, particularly for new teachers. The provision of
the museum's affordances to potentiate teachers' practice of mindfulness can strengthen their capacity to take hold of their attention in the demanding environment of classroom.

*Drawing with the Non-Dominant Hand: Facilitating Nonjudgmental Observation and Teaching*

My work with teachers continues to be emergent and contingent (i.e., to emerge from my lived experience with teachers, and to be contingent on their benefit). In my mentoring visits to new teachers in their schools, as part of new teacher induction, I have become convinced of the need to support teachers' capacities to focus their attention on what is happening in the classroom, what is happening with their own emotions, what teaching objectives reflect their students' needs, and what behaviors teachers can choose to achieve their objectives.

I am working to use a protocol for helping teachers take hold of attention in order to increase the effectiveness of teaching and learning. Based on work with mindfulness (Linehan, 1993) being conducted with medical residents (Wilkinson & Lobl, personal communication, 2016), I encourage teachers to: maintain nonjudgmental awareness of what is happening with them and their students (distinguishing among thoughts, facts, and feelings); identify their objective(s) in the moment and for the lesson; and choose behaviors to stay on course with achieving those objectives. The protocol’s acronym, HOB (Happening, Objective, and Behaviors), prompts teachers to engage in a reflective cycle repeatedly during the course of the lesson (and especially when things in the lesson are going off course). The prompts have the potential of supporting teacher efficacy and student learning:

- What is happening with my students and me right now? (Identify facts, thoughts and feelings, without judging)
- What is my objective? (Consider that one may have multiple objectives, competing objectives, short and long-term objectives)
- What could I say and do (behaviors) to achieve my objective? (And how could I say or do it?)
I decided to introduce this protocol to new science teachers with a sketching exercise to illustrate the non-judgmental qualities of mindfulness. Drawing with the non-dominant hand liberates the sketcher from judgment and attachment to a product. The activity of drawing with the non-dominant hand refocuses attention on the experience of seeing. Kiat Hui Khng (2017) comments that there is a tendency to being on autopilot or doing something without awareness, which prevents a full engagement. The use of the non-dominant hand reduces expectation to get it right or be “perfect.” The possibility of failure is eliminated. The protocol for the activity supports noticing without judging. Teachers were given 4 minutes to focus attention on noticing and sketching an object using their non-dominant hand.

The fear of failure reduces participation and receptivity to an experience. It is prevalent in classrooms, in both teachers and students. Fear of failure can cause avoidance and withdrawal, which interfere with the focus and attention on experience. Eliminating the possibility of failure can free attention for learning. It promotes a core component of mindfulness, which is awareness without judgment:

Drawing with my non-dominant hand, I knew I didn't stand a chance of creating a satisfactory drawing […] I did not judge myself because I had low expectations that I probably would not be good and this felt good […]. (Kristen, a first-year high school science teacher).

By drawing with my non-dominant hand, I was forced to draw more slowly if I wanted to keep the proportions. So, it forced me to practice being patient, which helps in keeping focus […] (Simon, a first-year high school science teacher.)

How is it that just asking someone to do something for which she has no evaluative standard or expectations – sketching with a non-dominant hand for 4 minutes could elicit strong responses? The experience left me wondering how to incorporate non-dominant ways of doing things to focus attention and remove judgment. This could be a potential intervention to support a deeper understanding of what it means to do something without judgment. In an early study on peoples’
perceptions of drawing and mindfulness, by Adam Grant and colleagues (2004), the authors concluded that drawing is a way to increase mindfulness. In a letter to his brother in 1883, van Gogh wrote, “Drawing is at the root of everything” (Kulkarni, 2015). And maybe this is what we need to support others to do – to create spaces in parks, museums and schools to support environments that minimize judgment and help individuals draw attention.

Next Steps: Out of the Classroom and Into the City

I have highlighted how the environment of a museum provides affordances for teachers to practice contemplation and sketching. There is no single way to take hold of attention with awareness, and notice without judgment. The museum’s dioramas provide a contemplative site for teachers to engage in sketching. The act of putting pencil to paper in this setting can be a meditative experience, inviting the participant to be present in the moment, notice different views, and recognize that there is always more to see and understand.

Over the past three years, I have grown in my conviction of how important it is to support teacher wellness by developing ways to hold attention. Although the sketching activity has been my primary method, I am beginning to take opportunities to use breathing meditation and mindfulness heuristics (Tobin, Alexakos, & Powietrzynska, 2015). For the teachers, there is a genuine desire to engage and build an appreciation for creating these experiences within new teacher induction. In monthly meetings with the teachers it is becoming a norm to include breathing meditation. Teachers are interested in maintaining their wellness and appreciate that it is woven into their development as a teacher – new teacher induction. I will continue to do this work and hope one day to exhibit the drawings and teachers’ comments and reflections to inspire others to create spaces for silent sketching for drawing attention as well as a way to honor teacher wellness. I am interested in continuing this work with teachers, as well as to work in
public informal learning environments beyond the museum. I am interested to engage the public in drawing their attention and working with others to continue to support wellness using urban environments.
Chapter 6
Out of the Museum into the Classroom (and Back Again)

How does a novice science teacher integrate the informal into formal learning and what are students learning?

In this chapter I expand on my reflective writing from Chapter 3 of my observations of new teachers using the museum’s affordances. A version of this chapter has been submitted in collaboration to AERA 2018 conference.


Because I saw it. It's something real. Something makes you realize what's happening. And it goes to your imagination, because the teachers just give you numbers. Like, the size of Earth is numbers, numbers, numbers, you won't get it. Because we're not at that level. But when you see it, we realize how small or big it is. (Samia, a 10th grade student, recent immigrant from Yemen, and emerging bilingual, describing her experience of an exercise representing the scale of the solar system in a football field.)

In this chapter, I examine experiences of a recent graduate of the American Museum of Natural History (AMNH) Master of Arts in Teaching (MAT) program as he integrates the Museum and its resources in his Earth Science teaching in a New York City public school, and illuminates students’ impressions and learning with these resources. The teacher articulates – and arrives at resolutions for – perceived tensions between his pedagogical experiences in inquiry based learning using Museum resources; and the complex demands of his school setting, including the use of a high stakes science exam. I discuss these issues with an emphasis on the teacher’s efforts to synthesize informal and formal learning experiences in a science classroom. The research
highlights themes that emerged regarding the effect of the Museum and its resources on students: e.g., the fostering of positive emotions, embodied learning, enhanced social interactions, deepened understanding of concepts, and a shift in the power dynamics between student and teacher. Over a period of two years, I conducted research using an authentic inquiry approach that included extensive classroom visits, collaborative reflection on student work, and interviews of the case study teacher and his students. This teacher demonstrated a dialectical integration of formal and informal learning, which suggests future directions for teacher science education and induction programs: to support teachers in the development of pedagogy and curriculum that integrate learning in various styles (formal and informal) and locations (in and out of school) to ensure that all students maximize their learning (Avraamidou & Roth, 2016).

*Informal and Formal Learning: An Ongoing Dialogue*

Museums and other informal science education institutions (ISEIs) are engaged in a longstanding dialogue with academic settings about the nature of formal and informal learning – and the evolving relationship between the two. In the last ten years, scholars have investigated intersections of formal and informal learning across multiple settings such as schools, afterschool programs, the home, ISEIs, learning expeditions, etc. (Avraamidou & Roth, 2016). Researchers have examined the value of museum-based resources in science instruction; the transformation of teacher identities among teachers using museum resources (Adams, 2006); and the role of informal and formal collaborations in improving science literacy.

Looking outside of schools to support schools, educators have shown growing interest in the potential role of museums and other ISEIs in pre-service teacher development and in strengthening student engagement (Aquino, Kelly, & Bayne, 2010). Many teacher education programs now use ISEI’s resources in their course work and development of pre-service
Teachers’ early exposure to informal science education institutions broadens their perception of instruction and the instructional support available for the classroom (Kisiel, 2014). There is evidence that informal science environments provide a safe environment for development of a reform minded science teacher identity (Avraamidou, 2014). Museum affordances such as exhibits, people, and objects play a role in this critical phase of teacher identity development (Adams & Gupta, 2017). Despite this increased interest in the incorporation of informal science education institutions in teacher development, relatively little is known about how science teachers taught in a teacher education residency program located in a museum make use of the museum and its resources in the classroom once they are employed as novice teachers.

The American Museum of Natural History Master of Arts in Teaching program, inaugurated in 2012 as a museum based program preparing teachers to provide Earth science instruction in New York City public schools, is situated at an intersection of formal and informal learning.

**Two Institutions: One Informal and One Formal, With a Long History of Collaboration**

The American Museum of Natural History has been entwined with public education since the Museum’s inception in 1869. In the United States, AMNH was the first museum to work with teachers in a formal program (Ramsey, 1938). Starting as early as the 1880s, the Museum provided short talks to teachers and programs of projected images for school groups. In 1899, 13,525 teachers attended Museum lectures for educators (AMNH, 1899). The Museum’s long history of working with public school teachers shaped the institution’s pedagogical commitment to provision of classroom resources, teacher professional development and fieldtrips. In 2006, the Museum launched a Ph. D. program in Comparative Biology and in 2012 inaugurated its
Master of Arts in Teaching Urban Residency Program. Each of these museum-based degrees granting programs was the first of its kind in the United States, innovating at the intersection of formal and informal learning. The MAT degree seeks to address a shortage of qualified Earth science teachers in public schools New York State, particularly in high-needs schools.

The New York City public school system is the largest in the United States, with 1.1 million students and more than 1,800 schools (NYC DOE, 2016). New York City public schools vary widely in school specialization and philosophy; number of students enrolled; quality of resources; and admission requirements. NYC public school districts are the most racially and economically segregated in the United States (Saxena, 2016). Disparities associated with this divide adversely affect the system’s Black and Latino students, who make up 70 percent of the student population (Harris & Fessenden, 2017). In science education, this disparity is seen in access to Advanced Placement (AP) classes and the ratio of graduates who subsequently major in science in college (NYC, DOE, 2017). Despite multiple initiatives to increase participation of under-represented students in AP courses, the pathway to a career in science is limited for a high percentage of NYC students. Science in City public schools is typically taught with a focus on content, and connection of content to students’ lived experiences, is not a widespread curricular priority (Emdin, 2016).

The MAT urban teacher residency program is one of many educational initiatives that aim to address needs and disparities in science education.

*The MAT: An Innovative Collaboration Between Informal and Formal Education*

Alternative certification teaching programs offer a route outside the traditional university setting for the recruitment of individuals with content specific backgrounds in high-need subject areas who lack preparation in education. (NCTQ, 2014). The Master of Arts and Teaching program at
AMNH shares similar goals with alternative certification programs. The MAT program aims to address a critical shortage of qualified science teachers in New York State, particularly in high-needs schools with diverse populations. In 2015, the New York State Board of Regents authorized the Museum’s Richard Gilder Graduate School to grant the MAT degree.

At its inception, the MAT program relied on the NY State Department of Education’s definition of a high-needs school – i.e., eligibility of 60 percent of the school’s students to receive free or reduced cost lunch. This definition, while concise, did not capture the complexity of high-needs schools. Other criteria for high-needs schools – irrespective of socioeconomic status – are high teacher turnover rate; and the number of teachers teaching without certification (No Child Left Behind Act of 2001). Complicating the identification of high-needs schools, was the New York City Department of Education’s decision, in September 2017, to provide free lunch to all students regardless of income level (Piccoli & Harris, 2017). Poverty and high teacher turnover rates adversely affect school environments and student learning.

The Museum and its vast resources are woven into MAT course work, residencies, and new teacher induction. The MAT program is based on a residency model, in which pre-service teachers (residents) act as apprentice instructors with guiding mentorship from the beginning of the 36-credit program. Initially, residents work with Museum visitors and adolescents in summer science enrichment programs. They are then placed in residency schools meeting high-need criteria, where they coteach with veteran science teachers (mentors). Residents are required to bring their students to the Museum for at least one learning field trip investigation. Science and education course work in the program engages residents to use permanent exhibitions to illustrate science content, concepts, and practices. The summer before graduation, residents support ongoing science research with AMNH scientists, and participate in extensive fieldwork
to strengthen their understanding of New York State geology. As teachers transition to professional employment in the classroom and to the MAT’s new teacher induction program, exhibits and dioramas are used to foster teachers’ reflection and contemplation, and serve as resources for classroom lessons. The intent is that MAT graduates take advantage of life-wide learning (NRC, 2009) across the context of their school, the community and informal education institutions to engage in learning science with their students.

The Study – Selection of participant teachers, students and timeline

I engaged in participatory action research with a graduate of the American Museum of Natural History Master of Arts in Teaching (MAT) teacher residency program, during his third and fourth years of employment as a science teacher in a New York City public school. The research continued for almost two years and spanned two academic calendars. In this study, I addressed the following questions:

1. How do recent MAT graduates integrate Museum resources in science instruction, and what are students learning?
2. How do MAT teachers use Museum resources in a unit of study?
3. Which particular resources or strategies for learning in informal environments are effective, and which are less so?

For the purpose of this study, a Museum resource is defined as a Museum based asset for learning used in the AMNH MAT program: the physical setting of the museum, objects, pedagogy, and people. Such resources include rocks and minerals; multimedia resources; exhibitions and dioramas; field research collections; work with scientists; and museum pedagogical strategies.
I used multiple methodologies and methods in the case study. The research was emergent and contingent, and different theories and frameworks were applied to illuminate aspects of the phenomena of using the Museum and its resources. I used a sociocultural framework (Vygotsky, 1978) with emphasis on the learning theories of Lave and Wenger, and the ecological framework that is rooted in developmental theory (Bronfennbrenner, 1978.). Collins’ theory of emotion was salient as a lens for understanding student learning while using museum resources.

The research was guided by the authentic inquiry framework that was adapted by Ken Tobin (2015) from the authenticity criteria (Lincoln & Guba, 1984). The authenticity criteria consist of four pillars that guide ethical authenticity in research with participants. The first criterion, ontological authenticity, refers to the researcher’s awareness and acknowledgement that participants and researcher will change in the process of the research. The second, the educative criterion, calls for a commitment to reciprocal learning between participants and researcher, which includes the researcher’s accountability for planning opportunities for such learning to occur. The third criterion – catalytic – identifies the researcher’s commitment to support and facilitate beneficent change in participants and institutions involved. The fourth criterion, denoted as tactical, regards the researcher’s planning for supporting change and for advocating on behalf of those who are disadvantaged or in positions of less power than the researcher (Alexakos, 2015).

Collectively, these four criteria mandated awareness of myself as a researcher; the power of the role of researcher; the value of learning from difference; the recognition that participants and myself would change; and the responsibility to implement and support changes within the MAT program.
The method is a case study approach (Yin, 2015), utilized to understand the phenomena of a teacher integrating the Museum and Museum resources in the classroom; and student engagement. The research embraces different perspectives (polysemy) and many voices (polyphonia) learning from difference and contradictions in an effort to understand what is happening and why it is happening (Tobin, 2015). I committed to learn from all participants and to seek their perspectives throughout the project.

In the process of selecting a participant teacher for this study, an email request was sent to seventeen MAT graduates who had completed new teacher induction (the MAT’s two-year program of postgraduate support for newly employed graduates), to solicit participation in a study about use of Museum resources in an Earth science unit. Five teachers responded and three teachers were selected to participate, based on their ability to use Museum resources in their teaching; and on differences between schools in their schools’ pedagogy, student populations, and teaching philosophies. Learning from difference is a core practice of the authentic inquiry framework (Tobin, 2014) and this was incorporated in the selection process.

In my role as an educator in the MAT degree new teacher induction program, I have substantive contact with every teacher who completes the two-year postgraduate program. Prior to participation in the research, the three teachers selected had attended monthly meetings and professional development which I had facilitated, and I had coached and mentored these teachers in their classrooms approximately 4-5 times each over the two-year period prior to the research. When the research began, the three participant teachers were all in their second semester of their 3rd year of teaching and had already completed the new teacher induction.
Phase I

The first phase of research began in early March 2016 and ended in late June 2016. The teachers were compensated with $500 honorariums through Donors Choose school accounts. In this phase, I made seven visits to Carlton’s (pseudonym) classroom and visited Riley’s (pseudonym) classroom on two occasions. I interviewed all three teachers before, during and after the research. At the end of phase I, in June 2016, I met with all three teachers for a joint conversation to reflect on the research process, and for them to share information and insights about their use of museum resources in a unit of study.

After phase I, I continued research with one of the three participant teachers because of his ongoing availability and ability to use multiple Museum resources in his teaching. This chapter will focus primarily on this teacher, referred to as Ed (pseudonym) and his efforts to integrate informal and formal learning in and out of the classroom.

During Phase I, I made five school visits to Ed’s 10th grade Earth Science classroom and spent time in three different classes per visit. I joined Ed on a visit he made to the Museum with his students during his astronomy unit. Before the astronomy unit began in May, I met with Ed for an extended discussion about different strategies and resources to consider in preparing to enact the unit. I interviewed Ed during the visits and after the astronomy unit. In addition to interviewing Ed throughout the four-month period, I also interviewed four students in a group conversation at the end of the semester and re-interviewed two of those students six months later.

Phase II

During Phase II, I made seven visits to Ed’s fourth period class during a rock and mineral unit in November and December of 2016. I scripted student and teacher dialog using a laptop, IPAD, and a notebook. During classroom visits, I interacted with students, helped with instruction as
needed, and engaged in conversations with students about their learning. I assisted students with answering questions and defining words, discussing the work, and handing out materials. After each classroom visit, I followed up with a 20-30 minute interview (recorded) with Ed to discuss the class. At the end of the unit I invited all students to participate in a student discussion with five students – held during the students’ lunch period, one week after the unit was completed.

My aims in the group conversations with students were to elicit their reflection on their learning through examination of their own student work; to foster their understanding of their own shifts in learning; and to invite their discussion of their preferences for learning using Museum resources and any advice they might have for teachers.

In both phases of the research, I recorded detailed field notes about each school visit, wrote weekly field memos, and photographed classroom artifacts. I collected teacher artifacts such as unit plans and worksheets, as well as student work. All interviews were transcribed and loaded into a qualitative data analysis program, Dedoose (SocioCultural Research Consultants, LLC, 2016). This program allowed for the organization of documentation, interviews, field memos, and classroom notes – as well as coding of initial themes in Phase I. Throughout the entire research process, I met with Museum colleagues weekly to discuss the research, manage notes, and identify next steps. These meetings provided time to reflect on the research, gain additional perspectives, and problem solve. These meetings, in conjunction with talking with the teachers and students, provided opportunities for reciprocal learning.

The School Setting

Global High School (pseudonym), where Ed has taught since his graduation from MAT, values teamwork; student responsibility for their own learning; student support of each other’s learning using a new language; and preparation of students for college and careers after high school.
These values are visible in the school’s strong emphasis on group work; the teachers’ grade team meetings; and the many group presentations made by students.

The school is located in the Bronx and serves a population of almost 400 students with a demographic composition of 70 percent Black and Hispanic and approximately 16 percent Asian students. The average daily attendance is 88 percent and 96 percent of the students received free or reduced lunch through 2016 (Inside schools, 2016). There are more than 12 languages spoken at the school and 77 percent of the students are English language learners.

The linguistic and cultural diversity of the school is visible, valued and integrated into the school’s pedagogy across classrooms. Outside each classroom is a laminated poster with a picture of the teacher and bulleted information about where the teacher attended high school and college; students' place of birth; parents’ mother language and birthplace; the number of languages the teacher speaks and things the teacher loves to do. These descriptions reveal that the majority of the school’s teachers speak more than one language and were born outside the United States. Ed’s students are predominantly recent immigrants; e.g., from Yemen, Bangladesh, Albania, Pakistan, Ghana, Ivory Coast, the Dominican Republic, and Vietnam. Their levels of English proficiency vary widely. It is common for students in Ed’s classroom to switch to their mother tongue with other students, translate for someone, or look up a word in a dictionary or on a Chrome book.

As a visitor, I sensed that many Global High students wanted to practice their English with teachers, and did so. It was not uncommon for students to approach me to say hello, or to ask for help with their work. Many of the students showed agency in practicing English; others were shy in speaking. Overall, there was a culture of collective encouragement in the school and
in Ed’s classroom for students to try to express themselves, even if it felt awkward or ideas were articulated incompletely in English.

Ed immigrated to the United States from the Republic of Georgia as a child. He has an affinity for understanding his students’ immigrant experiences, and uses effective language learning strategies fluidly. Ed is fluent in English and Russian and likes to converse in French. Ed teaches four sections of 10th grade Earth Science Regents classes and an environmental science course. He is also the science department chair and mentors two new science teachers. In addition to his school responsibilities, Ed got married at the end of his second year of teaching and had a baby girl in the middle of his 4th year of teaching.

The story of Ed’s decision to become a science teacher illustrates the influence a teacher can have on a student. After earning a bachelor’s degree in Geography and Geology, Ed tutored, but didn't plan a career in teaching in the near future. While completing his Master’s degree in Climate and Society at Columbia University, Ed took an elective class at Teacher’s College, which changed his mind, “I met a professor named Chris Emdin, and I really just became so fascinated with his work that my project at the end of the year for that grad school program was making a climate curriculum with his help.” Ed pinpointed this experience as a turning point at which he realized he did not want to do science research as a profession. A vision of himself as a science teacher began to develop.

Ed recalls that when a friend mentioned the Museum’s MAT program, “I thought it would be a cool place to learn how to become a teacher – in a museum.” Ed matriculated in the inaugural class of the MAT program.

So I don't think, originally, going into the museum program, I thought about, 'This will allow me to bring kids to the museum.' I thought that I can do that no matter what grad school program I go to. I can bring kids to the museum, but certainly being familiar with
the museum was a big plus, and there are all sorts of things that you can show at the museum that I don't have in the classroom available.

Contradictions and Constraints in Integrating Informal and Formal Learning

In the first phase of the study, all three participant teachers discussed their use of the Museum and Museum resources in the classroom. The teachers described their own learning in the Museum; their exposure to Museum resources such as educator guides and science bulletins (short animated videos on recent science research); rocks and minerals they had collected in the program; and visits to the Museum on fieldtrips. Each of the three teachers had different views and definitions of Museums resources. All three teachers encountered significant barriers to using Museum resources, and each made his own efforts to resolve contradictions.

Carlton, a 9th grade Earth Science teacher in a small Manhattan school with a pedagogical philosophy, was hindered by the school’s approach to instruction. He commented,

I haven't really gotten the opportunity, I've had kind of roadblocks to that, using hands-on material, and it's been very frustrating. It's been a big struggle, actually. I can't believe it, to tell you the truth, how hard it is to convince people of [the value of] even doing labs. I really can't believe it. In different schools, [it’s] a completely different situation.

Carlton stated that the school’s pedagogy prevented him from teaching with Museum resources or making fieldtrips to the Museum. The school did, however, grant him agency for displaying resources. He created a small classroom display of rocks and minerals, which were available for his students to touch and pick up. He placed beautiful minerals and fossils near the entry of the classroom. Carlton commented how proud he was of his cabinet and his solution in the situation. William Sewell (2005) observed that cultural activity is produced, reproduced and transformed in a field with porous boundaries. Carlton, despite his school’s strictures on educational (cultural) activity, had mediated a porous field to transform the instructional and aesthetic culture
of his classroom. The display cabinet has different rock specimens surrounded on the outside with reference materials from the Earth Science Regents table.

Ed and Riley both commented on the powerful influence of the New York State Earth science Regents exam content on their decisions about when and how to use Museum resources in teaching. Riley a 10th grade teacher at a small Manhattan high school stated, “The Regents is king here.” Ed echoed this observation:

We certainly feel pressure from admins to get kids to pass. So, when we're thinking about what to teach or how to teach [...] that's constantly in our minds. The first thing that comes to mind when I come up with a lesson, just to be honest, is not, ‘What Museum resource can I use?’ It's like, “How will this help the kids pass the Regents’?”

When Ed or Riley perceived a Museum resource as lacking a direct link to Regents outcomes, they were less likely to use the resource. Riley provided feedback to the MAT program that he wanted support in drawing connections between the Earth science Regents exam and the use of Museum resources in instruction.

The influence of high stakes testing on teachers’ pedagogical decision making confronts new teachers with difficult contradictions among their pedagogical values, their teacher education, and systems level priorities (Fulton, Yoon & Lee, 2005). New teachers in the New York City Department of Education are particularly vulnerable because job tenure is now attached to student test scores.

Riley expressed his frustration candidly:

That's probably the biggest challenge of bringing the Museum resources. I really do want to teach it like I think you guys had in mind, like the Museum, like the cross-cutting principles, all the NGSS [New Generation of Science Standards] stuff. It seemed really good and it seemed pretty true to science, but then they just need to have a bunch of trivial knowledge about all these different topics to pass the Regents. They need to know about how many tides are there in a day or…random stuff…which will completely leave their mind right after they take that test. They need to be able to look up stuff in the reference table. That's basically what I am being assessed on. You know what I mean. Like at the end of the year, it's just like this class […]math had this pass rate. English had
this pass rate. Science had this pass rate. They don't really give a crap about how much you care about teaching real science in school.

The three participant teachers in the study identified additional barriers to the use of Museum and Museum resources in their teaching: omission of consideration of Museum resources; planning challenges; perceived deficits in competence at using Museum resources; and physical classroom limitations. The ecological framework for learning rooted in Bronfenbrenner’s model of development (1977) provides a structure for examining the various levels of a school environment that might influence a teacher’s integration of Museum resources. The ecological framework locates teachers’ pedagogical decisions in social and institutional contexts (Fig. 6.1).

Figure 6.1: Barriers for using museum resources across the school context.

*Ed: Dialectical Resolutions*

Phase II of the research examined in detail the use of Museum resources by one participant teacher – Ed – as well as the effects of use of Museum resources on student learning in his classes. Ed recalled making connections to museum resources and teaching early on in the MAT program:
So when I think about Museum resources, I think what the Museum really has to offer, they're, in many ways, educational tools. It's not always easy to figure out how to use them. But I think that the summer residency program [working with Museum visitors and adolescents in summer science enrichment programs] that I mentioned, it was like through experience that I realized, "This is something I can teach." Or I've had experiences even walking around [the Museum] with friends or family, where I sort of had that like, "Wow, I can talk about this, you know, this topic in front of this rock.

Ed synthesizes informal and formal learning. He views these terms dialectically rather than dichotomously, and practices an integrated pedagogy that engages his students at the same time as they prepare for the Earth science Regents exam. In both his astronomy unit and his rocks and minerals unit, Ed teaches content through students' labs and engagement with objects and three-dimensional models. He provides direct instruction in short mini-lessons with power point slides that make extensive use of visuals and real-world examples. He uses various formative assessments such as exit slips, Regent questions and quizzes to check for student understanding. Ed is pragmatic in his pedagogical decisions and prioritizes student preparedness for the Regent’s exam. In addition, he modifies lessons, labs and activities to meet the particular learning needs of his students – almost all of whom are emerging bilinguals.

Ed’s astronomy unit plans are in-depth documents that include the following: New York State physical science standards, essential and conceptual questions, skills and anticipated misconceptions, sentence frames, assessment evidence checkpoints, vocabulary, weekly learning plans and learning guides. He incorporated a variety of Museum resources in the unit: a Museum-produced space show (*Journey to the Stars*); a visit to the Museum’s Hall of the Universe and the then current space show called *Dark Universe*; and a scale walk activity he’d learned of at the MAT. Ed and I met to discuss his ideas and preferences about infusing the Museum and Museum resources into the Astronomy unit.
Ed thought critically about the strengths and limitations of specific exhibits for connecting to the Earth science content. Sharing his insights about the exhibit on the scales of the universe in the Museum’s Rose Center in relation to the challenges of visualizing relative distance of planetary objects. Ed expressed his reservations.

The one thing about the scales exhibit that I think about when I'm there is while it gives students or people the idea of general mass or the relation of the size of the planets to each other and to the sun, it doesn't give the justice of the distances between them. So it almost makes me a little worried about, “Oh, will kids think that they're really right next to each other like this [i.e., as they appear in the exhibit]?”

When asked about his goals for the Museum trip, Ed commented,

I'm trying to think right now how to use the Museum experience in the most efficient way possible, because I think bringing them to the Museum just to explore, look, read is in itself valuable. But I want to try to take a next step and see how I can connect things from the Museum resources that are available to, let's say, the reference table [The Earth Science Reference Table – a table of measurements and maps used during the Regents exam], like I see something like this. I like it. It has, "Low-mass star, intermediate star, high-mass star, very high-mass star. Its mass in relation to the sun.

Ed’s comment demonstrates his need to be efficient in his use of the Museum and its resources.

His mention of the reference table used in the Earth science Regents exam is evidence of the perspective from which Ed views teaching and Museum resources. Ed gauges the usefulness of a Museum resource in relation to his goal of student preparedness for the Regents exam. He has visited the Museum for the past two years during his astronomy unit, and would like to refine his curricular application of the Museum's potential to excite and engage students with its potential to connect to the content and concepts that are part of the NY State curriculum and Regents exam.

Because I teach at a Regents-tracked school, whenever I use a resource, I try to think about, how can I use it by connecting it back to the New York State curriculum, by connecting it to the reference table?
Ed described an activity that he had learned in the MAT program: he wanted to make use of the activity in his classroom, but had not yet done so.

We had a solar system online course where we had to do this activity. We had to pick an object in New York City, and then figure out the distances to the sun. That was a really cool activity. I always wanted to do something like that with the students but I never explored enough of how I can do that in a realistic scale, because using Google Maps, which is how we did it, there's a lot of teaching of how to use online resources, how to use Google Maps. Like that activity would take probably a week for high school students.

Ed’s enthusiasm for this activity was evident. As he retold this story, he realized that his school’s football field would be a good place to try and have students make a model of both scale and size of planets in the solar system. He decided to modify the lesson that he had learned at the Museum and build this into his astronomy unit.

Ed’s integration of the Museum and its resources in the classroom to foster both formal and informal learning forged a dialectical pedagogy that reconciled contradictions that many science teachers confront.

The Impact of Museum Resources and Informal Learning on Students

In Ed’s class, informal learning engaged teacher and students in experiences that shape and change the environment (Vygotsky, 1978). My research during Ed’s astronomy and rock units suggested that integration of the Museum and its resources instruction had significant positive effects on students, apparently fostering positive emotions; embodied learning; variations in the power dynamics between students and teacher; enhanced social interaction; mastery of science concepts; and language acquisition.

During the astronomy unit, Ed adapted a digital activity that he had completed in the MAT program to an outdoor activity, completed on a school football field, in which small teams of students calculated the relative distances and sizes of the planets to make scale models of the solar system. The sun’s size was represented by a basketball and planets were scaled
accordingly. Impromptu rivalry broke out, as teams competed for speed and accuracy in their completion of their models. I attended the activity, and recorded the following field notes as I rode home on the subway:

[A few girls] giggled as they ran around the track in their hijabs. They were teenagers being kids. Ed’s students had just finished working together making a solar system that included scale and proportion of the planets on the school’s […] field. In class, the students had made the calculations for the scale — and kept asking their teacher “when do we get to go outside?”

Working in teams outside, the students worked eagerly in their teams to try and be the first ones to make the scale model of the solar system. They counted out to Uranus, measuring the distance with repeated applications of a meter stick. The first planet is 108 feet from the sun. Students argued about whether their line was straight. “Keep counting,” a girl said, “we need more meter sticks here. A girl reminded the group that the basketball is the sun. There was immediacy to the activity that felt competitive and collaborative at the same time. Ed was taking pictures of his students, and students were observing other teams, trying to figure it out. A few students were counting in Spanish. A student asked the teacher why their line was different; the group then realized they had forgotten a planet. It was the month of May, and the students were in the middle of the astronomy unit.”

Ed used the Museum resource of the scale activity and the informal setting of the football field to teach an astronomy concept that he wanted the students to understand. He commented about the experience, “We went outside to the football field and actually calculated the distance… I think they better understood really how far these things are from each other, especially Neptune.” Ed, too, had noticed his students’ reactions and energy as they completed the activity. “They started to compete, like who could do it faster.”
When I interviewed students three weeks later, they had retained vivid memories of the experience. Jaclyn recalled,

Tons of fresh air. It was nice weather. And like we worked like a team. In our class, we were racing. Who's going to finish first? Who’s going to finish last? We were like, ‘We didn't win, but it's okay.’ Yes, because you don’t have to read to remember. You just remember that moment. Yes. And it's fun.

Another student, Zoya who is from Bangladesh said,

We [did the activity] – like to get an idea of how distant and how the sizes of those planets are compared to Earth and to our Sun. We went to the field and placed them around, and we saw how far the Jovian planets are from the terrestrial and the Sun, and we were like ‘Wow, okay.’ So, that was fun to do.

Interaction ritual chain theory (Collins, 2005) helps make sense of the level of engagement, resonance and emotional energy recalled by students and teacher. The activity generated a collective effervescence (Collins, 2005). The interaction ritual chain began in the classroom, within five minutes of class, as different students repeatedly asked Ed, “when are we going outside?” The activity of making a scale of the solar system generated interest and excitement. Once outside on the football field, the ingredients for an interaction ritual chain were visible in the students’ mutual focus on the activity; a barrier to outsiders not involved; and a shared mood of excitement. The students in their teams decided who would measure the distances, who would hold the materials. They worked together, laughing and having fun, and this “collective effervescence” and emotional energy continued after the activity was completed. Many of the young women ran around the track for enjoyment.

Six months later, I re-interviewed two of the girls and asked them to reflect on the astronomy unit and the activity in the football field. Without missing a beat, the girls say:

**Samia:** How far the planets are from each other.
**Zoya:** And how tiny. Or, how small they are.
**Samia:** Size of us.
Zoya: It was very surprising to me. So if these planets that we think are so big, are this tiny – and Earth is so tiny – and we're living here – how tiny am I compared to the whole universe? I am not even a microbe. I'm not even the neutron or something. It's like, I am so minute.

These students’ comments highlight the impact of collaboration, sensory experience, hands-on activity, and a setting outside the classroom on their learning about the scale and distance of the planets. A year after the research, I checked in with Ed and asked if he had repeated the scale activity again with his students and he said, “Yes! I certainly did take them out again last year and it was another success!”

I attended Ed’s class early in his rocks and minerals unit. Ed’s students, many of whom are recently arrived immigrants with very limited English, worked in groups; each group was assigned a student with relative proficiency in English. In the group I joined, where students worked to identify rock samples, Marianna spoke English with more ease than her peers. She examined a piece of Phyllite rock (foliated metamorphic rock), and pointed to the line drawing of the mineral in the Earth Science Reference Table (ERST) for metamorphic rocks. She seemed to have a visual/spatial ability to recognize the similarities of the three-dimensional object in the two-dimensional drawing in the reference table. She declared that the rock was foliated. I took a rock out of my pocket and she could tell that it was a mineral and she said, “rocks are made of minerals.” Marianna is from the Dominican Republic and described herself, “I am a serious student. I put effort in all my classes and especially in science. I am very interested in science. I try to learn as much as possible.”

In an interview at the end of the unit, Marianna commented, “I learned the rocks [are] classified by other characteristics apart from their components because I used to think that it was just by their components.”
Marianna also reflected on how she learned and what supported her learning. She commented,

I liked the best when we were with the classifications of the rocks. We would have physical rocks and we had to classify it by its characteristics. The visual ones. I like it because that way […] I felt that I know better how to find what type of rock [is] in my hands. I could see it and I realize what type of breakage […] [or] hardness by scratching it, I experience it and I think it was a very efficient way to learn[ …].

The lab experiences helped Marianna to develop a greater awareness of rock characteristics, which were linked to her evolution of a more sophisticated ability use of science language to describe what she had learned. Concepts key to embodied cognition – that learning is inseparable from the body; that sensory experience builds memory and language cognition; that individuals learn through interaction with the environment (Thelen, 2005) – are reflected in Marianna’s observations about her learning. Marianna’s lab experiences and group work allowed for legitimate peripheral participation – learning that is integrated in social activity (Lave & Wenger, 1991). The students’ collaborative activity and reciprocal guidance in knowledge and language acquisition illustrate characteristics of a community of practice (Lave & Wenger, 1991).

Rocks and minerals are commonly used resources in Earth Science classrooms. Marianna’s experiences highlight the manner in which a graduate of a museum based teacher education program has integrated formal and informal learning as well as Museum resources in a curriculum which maintains a concurrent focus on preparing students for a high stakes Earth science test.

In autumn 2017, I checked in with Ed about his students and teaching. He commented by email, “[my principal] said yesterday that due to my student's growth I moved from an Effective to a Highly Effective on my rating. To be honest, I don’t put too much emphasis or pride in these
things, but I guess that's a good thing!” The rating is based on multiple factors, including Regent’s test scores.

Learning in Museums: A Shared Experience, the Reality of Objects, and Organization of Information

Ed’s learning in the Museum during the MAT program was an experience he wanted to share with his students. “The space show is probably one of my favorite things in all of New York. But it's also a resource that I always look forward to showing my students, too.” Each year, Ed visits the Museum with his students during the astronomy unit. The Museum’s school visit records show that Ed has made this trip on almost the same date each year for the past four years. When Ed mentions the trip to his students on the first day of the astronomy unit, he shows a slide with a picture of the Museum and a meteorite and says, “We are going to learn here.” Many of Ed’s students are recent immigrants to the United States whose visit to the Museum with Ed is their first. The trip, at the end of the astronomy unit, is both a review for the Regents and a reward to the class at the end of the academic year.

Reshma, a recent immigrant from Yemen, commented on the value of learning with real objects,

The experience of being able to touch and see a large specimen helps to understand a type, a feature and concept. I noticed for me real things are what I want to see. I don’t like fake things…like, ‘What is this? Is this real?’ I want real things to see…That's what I noticed about myself.

Jacyln observed, “[…] We had the unit on dynamic Earth, I was like I can tell which rock is this, and it was fun for me.”

Gaea Leinhardt and Kevin Crowley’s (2002) theory on learning in museums identifies the authenticity of objects with a real-world connection to history and culture as a key factor in
learning. Authenticity is clearly valued by Ed, and motivates him to share his experience of Museum learning with students:

Because when you show students a piece of obsidian that fits in their hand, it's different than seeing it like a ton, seeing it in such a big size […] and being able to show things like tilting and folding at the Museum is, again, something you can show pictures of… but when you actually see it in front of you, I think that is [something] really important for kids to be able to experience.

Engagement through tactile and visual experience of authentic objects in the Museum supports science learning (NRC, 2010).

Accessibility of information was a characteristic of the Museum’s exhibits being highly prized by emerging bilinguals in Ed’s classes. These students immediately noticed that the exhibits were meticulously organized to facilitate learning. Jaclyn’s comments were agreed by others, “It was like very clear information. You didn't have to go, “Where's that?’” The clarity of the exhibit labels, a hallmark of exhibition design, supported both scientific learning and language acquisition in these emerging bilinguals.

Students discussed how experiences in the Museum had helped them to learn and make connections to content. Zoya commented on the space show and what she learned,

The dark matter, I remember the dark matter and the dark force […] And that most of the universe […] was made of the dark force, and then a part of it is dark matter and the normal matter, common matter that we see right now, is less than 5 percent. And I was like oh, but we still don't know.

She reflected on how much we still do not know in science – and wants to extend the conversation.

Future Directions

The research supporting this paper examined successful efforts by a graduate of a museum based science teacher education program to integrate formal and informal learning (including use of museum resources) in a high-needs urban school. The research, conducted through a case study
of a graduate of the MAT program at AMNH, suggests that use of Museum resources had multiple facilitative effects on student learning: positive emotions; embodied learning; enhanced social interactions; shifts in power dynamics between students and teacher; increased mastery of science concepts; and language acquisition. However, research conducted in this study also suggests that graduates of a museum based teacher education program face significant contradictions and constraints in their employment in public schools following completion of their degrees – notably, the influence of high stakes testing, pedagogical stances of schools, and individual and environmental limitations. A future direction suggested by this research is for the MAT program to continue to gain institutional awareness of the working conditions encountered by graduates, and to continue to strengthen its efforts to prepare graduates to achieve sustained integration of informal and formal learning and Museum resources to benefit science learners in high-needs urban schools. Lessons learned may be transferrable to other informal science learning institutions, which offer a valuable resource to teachers and students in urban settings.

This research has approval from the Internal Review Board of the American Museum of Natural History, the NYC Department of Education (file #1181), and The City University of New York Graduate Center (#2016-0187).
Chapter 7

Epilogue: Reflecting on the Process

My past five years of study at the Graduate Center of the City University of New York have taught me that as a teacher | researcher my conclusions are always tentative; there is always more to discover and to say; that research unfolds in dialogue; and that development happens on a continuum.

This manuscript style dissertation comprises seven chapters about topics related to the preparation of new science teachers in a museum based teacher education program. My research has been emergent and contingent (Tobin, 2013). At the conclusion of this dissertation, I am able to name a constellation of interests, ideas, and values that I could not have identified clearly at the outset: learning outside of school; building community; identity; emotions in learning; embodied learning; use of resources; reflection; and sensory experience in learning are woven throughout the dissertation’s distinct chapters. Many of these themes concern ways of knowing that extend beyond the text-based learning that is predominant in much of classroom instruction. In addition, my studies and the preparation of this dissertation have resulted in the development of my own “habitus” as a researcher – i.e., a practitioner who consistently poses a pair of questions: “What is happening, and why is it happening?” In addition, I gradually developed a deeper understanding of what it means to do research that is responsible, participatory, and authentic. Many of these shifts in my ontology happened within the community of researchers at the CUNY Graduate Center Learning Sciences program: USER-S, various research squads, and coursework. This final chapter underscores formative ontological shifts that challenged my previous ideas about teaching, learning, and research, as they occurred in the preparation of my
dissertation. I’ve been a learner learning about learning, and my conclusions have emerged from my experiences.

The very first course I took at the Graduate Center, a class in research methodology, included material on Sewell’s event-oriented research, which prepared me to pay attention in a different way than previously when I worked with teachers and sketching around the natural history dioramas at the Museum of Natural History (AMNH). I wrote about these experiences in Chapter 2, *Dioramas and Teachers: Looking, Thinking, Drawing, and Talking*, for a publication on natural history dioramas and education. Chapter 2 represents my emerging ideas about the authenticity inquiry framework (Tobin, 2015) and writing. As I reflect on this chapter it was through the process of paying attention to the teachers’ verbal and non-verbal movements and viewing their sketches that I internalized the concept of polysema. I also began to understand the concept of the emergent and contingent qualities of research. I saw how the dioramas emerged as a resource for the teachers: they started to use them as a visual environment for reflecting on teaching, which led me to incorporate the dioramas for contemplation. As I continued to pay attention, my ideas developed over time, and I wrote Chapter 5, *Drawing Attention: Notes from the Field*, which broadened my understanding of mindfulness and how mindfulness practices benefit wellness in teaching and learning.

I collaborated with two colleagues at AMNH to write Chapter 3, *Breaking Dichotomies: Learning to be a Teacher of Science in Formal and Informal Setting*, about the impact of museum affordances on teachers’ work in the classroom. Around the same time, I joined a research squad with other museum professionals, and we shared our research and writing. These regular meetings extended my understanding of the theory of identity frameworks (Avraamidou, 2014; Gee, 2001), which I used as a lens for examining teacher identity in Chapter 3. The
identity frameworks helped me to understand my own experience, as well: my identity was shifting from that of a museum educator to encompass that of a doctoral student and emerging researcher. I became more aware of the many privileges and affordances of being a student in a doctoral program. I started to see myself as a collaborator with other museum researchers.

I began to make a concerted effort to write every day, initially writing for 15 minutes daily, about what I saw in my work with new science teachers, and what I noticed about learning in settings outside the classroom, around the city. Over time, I wrote for longer periods, and writing became a mindful action. It was liberating because I wrote without judging my writing, which in turn allowed me to trust my ideas. This habit of writing clarified my ideas, and helped me to draw connections between theory and my own observations. My writing practice was formative for my identity as a researcher: it was through writing that I internalized a research stance of noticing and describing what is happening and why it is happening (Erickson, 1985).

I developed a critical lens (Kincheloe, 2008) for viewing the ethical responsibility of doing research; power dynamics in research; and generalizability (Eisenhart, 2009) while completing the two-year qualitative study described in Chapter 6, *Out of the Museum into the Classroom (and Back Again)*. I received a vivid experiential education in the gravitas of conducting research with vulnerable populations as I secured multiple consent forms and completed protocol documents for three Internal Review Board applications to do this research: American Museum of Natural History, the Graduate Center of the City University of New York, and New York City Department of Education. Ken Tobin’s authentic inquiry framework provided ethical criteria for examining my actions as a researcher. I recall an early visit to a teacher’s classrooms: the teacher thought he could not talk to me, because to do so would somehow taint the research. I saw that he viewed research – and the roles of researcher and
participant – differently than I did, even though we had met and discussed the process of the planned action research. These experiences magnified power dynamics that are inherent in the research process and my responsibility to be explicit with teacher and student participants. I came to understand that the researcher is granted significant power. I became aware of the potential for that power to be utilized in a collaborative or opportunistic manner – and of the critical importance of ethical integrity and vigilance on the part of the researcher. Throughout my research, I checked in weekly with a museum research colleague at AMNH. I also met for de-briefing with teacher participants after I visited their classrooms. I conducted interviews with student participants, as well as follow-up sessions to review their interview transcripts and student work and extend their reflections. I member checked the chapter with the teacher participant. I sought to meet the tactical and catalytic criteria (Lincoln & Guba, 1984), of the authentic inquiry framework through examination of issues facing teacher and student participants and through advocacy for changes in teacher education at the Master of Arts in Teaching program at AMNH. I want to further my development as a researcher who supports individuals in position of limited power to empower them to take action – and to weave this support into every aspect of the research process.

My efforts to clarify the issues facing graduates that we could address and support at the MAT program raised questions of generalizability. Margaret Eisenhart’s (2009) viewpoint was helpful: i.e., that theoretical generalizations in educational research are under realized and that educational research would benefit from increased generalization. Eisenhart’s conviction that “an ideal case…can reveal what is possible” (p. 55) shifted my own ideas of generalizability, which had been shaped by my background in educational and science institutions, that place a high value on probabilistic generalization. Following one teacher in the second phase of my research,
I learned that I could make tentative claims about what I was learning through in-depth research with an individual participant, and that these claims could be a starting point for taking action to ameliorate issues for individuals and an institution. I see the shift in my values and my awareness of whose voice is being privileged in the research and the importance of having different voices present and being equitably involved.

In the course of my research, I began to see how definitions can hinder and obscure (K. Alexakos, personal communication). It was a critical lesson for me to gain awareness that phrases such as “high-need schools,” “urban education,” and “English language learners” are laden with judgments. Bakhtin argues that a word is a signifier layered with meanings that have accumulated over time and vary according to context. As a researcher, I received feedback that helped me become more aware of the language that is used to describe students, teachers and communities, and how phrases like “high-needs school” can impede clarity and obscure issues of power and equity.

One of the last chapters of my dissertation that I wrote was Chapter 1, my autobiographical chapter. I am proud of this chapter because I feel that through writing it I found my voice and was able to articulate aspects of my lived experience that have shaped me to be the teacher | researcher that I have become. I do not think that I understood, when I started the process of doctoral work, that it would be a process of self-discovery and reflection. Writing the autobiographical chapter gave me an opportunity to reflect on my own ways of knowing (epistemology) and values (axiology). I saw that the qualities of learning experiences that had been meaningful in my own life were reflected in the recurrent themes that had emerged in my research and in the other chapters of my dissertation – broadly, themes related to learning outside the classroom, through embodied experience and in community. My autobiographical chapter
helped me better understand the sources of my interests in and beliefs about education. My doctoral work gave me multiple theoretical lenses to extend my understanding of my own lived experiences of learning and teaching.

My intention in writing this dissertation is to join the conversation with others working to prepare and support science teachers. Much of this dissertation concerns my work with The American Museum of Natural History MAT program – a model of teacher education at the nexus of informal and formal learning. Museum environments are uniquely equipped to facilitate both directed and spontaneous attention and learning. But museums are not the only places that can provide such experiences. I believe there are many unexplored opportunities and places to expand learning for teacher development, in turn supporting their students’ growth. The chapters in this dissertation ask, how we might continue to move outward to make innovative use of environments for new teacher development? – and to support their students’ access to diverse learning environments and experiences?

*When You See It*, the first part of the title of this dissertation, comes from a student’s comment about making a scale model of the solar system in the football field outside of school (p. 82). This student’s words bring to focus my passion for supporting teachers and students learning in out-of-school environments, and also allow me to honor all the students who I learned from during the last five years.
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