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Sharing Our Teachers: The Required Graduate Class at the American Museum of Natural History for Lehman College (CUNY)

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This reflective study explores the history and outcomes of a teacher education collaboration between the American Museum of Natural History (AMNH) and Lehman College of The City University of New York (CUNY), in the Bronx, NY, USA. AMNH developed and teaches a Lehman course, Museum Resources for Teaching Science, for Master's degree candidates in science teaching in secondary schools. The course focuses on teaching and learning using a variety of informal science resources and contexts. In this study, the authors examined the observed practices of instructors, students' assignments and thesis work, and course evaluations. Qualitative and quantitative data collected over nine years highlight the kinds of experiences that teachers had and valued. The authors found evidence that the Museum was a powerful resource for inspiring students through hands-on and self-directed science learning; that through exposure to these practices while still in their teacher education program, teacher learners experienced and expanded their science pedagogical content knowledge by learning about students and how to use appropriate resources in the two distinct contexts of the classroom and museums.

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INTRODUCTION AND BACKGROUND

The role of museum education in relation to schools and teachers at AMNH has changed over years. Since its foundation, over 130 years ago, AMNH has provided services to school groups. More recently, the drive for mutual accountability among institutions that prepare teachers and educate students has led to the creation of partnerships with urban public schools (AMNH, 1994) and other cultural institutions, universities, and colleges. During the late nineties, AMNH initiated several partnerships with higher education institutions, including CUNY's Brooklyn and Lehman Colleges, Bank Street College of Education, Barnard College, and Teachers College, Columbia University. Through intimate knowledge of the needs of the schools, these partnerships have enabled the Museum to become an effective resource for the teaching and learning of science in New York City (Adams, 2007; Rivera Maulucci, 2010). The Lehman College graduate course offered in partnership with AMNH, now in its ninth year, was designed by a scientist and a curriculum specialist, both of whom have experience in teaching in informal settings at AMNH. Most of the students in the course have had only one year of teaching experience in middle or high school. We present different types of evidence documenting the professional development of the teachers attending the course, the impact of this experience on the teaching career of some of the participants, and the impact on the college-based instructors who coauthored this paper.

This reflective study begins with a review of supporting literature and the theoretical framework for analysis, as well as with descriptions of Lehman's position in educating New York City science teachers, the history of the partnership with the Museum, the research design, the course context, and the participants. The results and discussion will highlight two data sources. First, quantitative survey data collected over nine years; second, qualitative data from course portfolios and student thesis work. Finally, the implications and future directions of the collaboration will be discussed.

REVIEW OF RESEARCH: MUSEUM EDUCATION AND INFORMAL LEARNING ENVIRONMENTS

Experiences in informal environments for science learning typically have been characterized as learner motivated, voluntary, personal, ongoing, contextually relevant, collaborative, nonlinear, and open ended (Falk & Dierking, 2000; Griffin & Symington, 1998). Research evidence has shown that learning through field trips—under favorable circumstances—can be a valuable supplement to classroom instruction. Nevertheless, schools often have not been supportive of informal learning experiences, particularly in the face of the time constraints due to the pressure of standardized tests and student assessments in middle and high schools.

Research has shown that, despite their potential, field trips have often been underused as learning experiences (DeWitt & Storksdieck, 2008).

Informal learning environments such as museums have demonstrated their success in making science accessible to a broad range of learners (Bell et al., 2009). The design of these environments has allowed students to navigate freely through authentic scientific contexts, where they can choose experiences that fit their needs, interests, and educational agendas (Bell et al., 2009; Cox-Peterson et al., 2003). The students' learning has depended not only upon exhibit interactions within a safe, stable space, but also upon the social and mediating factors that have allowed them to process their emotions and sensory responses (Rennie et al., 2003). Interactions with facilitators, museum staff, teachers, and peers were essential aspects of the value of the social setting in supporting science learning (Fadigan & Hammrich, 2004).

CONSIDERATIONS FOR URBAN SCIENCE TEACHER INDUCTION

The Museum course has been developed with an eye towards recent research highlighting the shortcomings of science teacher induction and the ways in which it might be improved. Traditional content coursework has often been too specific, and pedagogical courses have had limited value (Adams & Krockover, 1997). The seamless integration of science methods and disciplinary knowledge, which refines pedagogical content knowledge, has been a key component of effective graduate coursework in science education (Blackwell, 2004). Teachers have also gained tremendous insights from field experience, particularly when they have had the opportunity to acquire contextual knowledge of procedure and of how students learn in specific environments (Kang, 2008). By designing lessons and curriculum, and presenting them to their peers, teachers have developed a knowledge base for addressing misconceptions and maximizing student engagement (Abd-El-Khalick & BouJaoude, 1997).

The ability of students to connect with curriculum has had a significant influence on the desire to learn (Smith & Smith, 2009). For teachers, graduate courses and professional development that encourage reflective practice and resilience have contributed to greater self-efficacy (Cook, 2009; Freedman & Appleman, 2009). The opportunity to engage in purposeful discussions—a sustained practice in the Museum course—has allowed teachers to embrace and maintain inquiry-based practices. This is of particular importance when considering the demands of diverse settings (Luft & Roehrig, 2005).

THEORETICAL FRAMEWORK

Details inherent in our view of culture are embedded within museum experiences. We view culture as a dynamic relationship between schemas (systems of symbols and their associated meanings) and practices (Sewell, 1999), which is enacted in many different places. Culture thus influences action by shaping a collection of symbols, stories, rituals, and worldviews. Sites for cultural enactment, whether they are homes, corners of a classroom, or halls at a museum, provide resources (material, human, and temporal) that promote structure. Agency, the power to act and change structures within a site of cultural enactment, involves being able to access and appropriate these resources. Because these sites are dynamic and have no boundaries, the culture that is enacted in one can also be enacted in others. This is extremely important in view of the diversity and complexity of urban schools, the demands of formal science education, the uneven distribution of resources and administrative support, and the careful planning needed to ensure a curriculum and assessments-driven museum field trip experience.

In this reflective study, the dynamic interactions of cultural, social, and symbolic capitals (Bourdieu, 1986) are examined through the lenses of sociocultural theory that view social life in terms of the dialectical relationship between agency and structure. The rationale for grounding this study in such a perspective is that it allows us to determine how salient features of learning can be illuminated in order to mediate understandings that naturally unfold in the lives of urban science teachers, their students, and others within the museum community. Sociocultural lenses afford insights into how science teaching and learning identities are transformed in the urban context, and to what degree science fluency (the enactment of the teaching and learning of science in a timely, anticipatory, and appropriate manner) factors into gathering and using resources (Bayne, 2009). We view the urban context as a rich source of potential understandings involving how cultural factors mediate the teaching and learning of science at the Museum.

DEVELOPING A REFLECTIVE PRACTICE AND TEACHER IDENTITY

Dewey (1997) presents an ideal foundation upon which the teaching and learning of ideas through museum experiences can be conceptualized and constructed. Gardner's (2000) perspectives on the learning of various disciplines and the interconnected possibilities for teaching also honor what is possible when museums, the city, and the school become contexts for learning science, appreciating beauty and seeking information. Many of these ideas include a need for critical examination of an educator's own teaching practices.

The idea that true education allows for the growth of the learner as well as the opportunity for "experiences to take place along a continuum" is essential for the

development of teacher and student. Dewey's work also emphasizes the importance of educators having a "sympathetic understanding of [an] individual as [an] individual" allowing for a sense of "what is going on in the minds of those who are learning" to be made known. An important idea in his work, directly related to mastering the intricacies of planning and successfully conducting field trips to the Museum (especially since it is visited by such a diverse student population), is that educators must "know how to utilize the surroundings…[in order to build] up experiences that are worthwhile" for their learners.

Dewey cautions that although purpose often begins with an impulse, that is, a desire to know and understand, one must consider the *meaning* of purpose and its multifaceted nature. He notes that although purpose involves observation, observation alone is not enough; this concept is essential to understand the great potential that museums have to shape visitors' construction of scientific knowledge. Hence, through their experiences at the Museum, teachers can strengthen their understanding of their observations and learn how to relate observations to prior experiences and knowledge in order to intelligently translate them into a "plan and method of action" for future experiences with their students (Dewey, 1997, p. 28).

THE MUSEUM GROUP AS A COMMUNITY OF PRACTICE

A group of individuals who work together to accomplish a specific goal by becoming proficient in a particular activity or practice will become "experiential" learners. Lave and Wenger (1991) described this type of learning as the collaboration between a wide range of people who have different roles in a specific discipline and different experiences, each adding to the work in a special and important way. Such a community has been created through the Lehman/AMNH partnership and the opportunities that teachers and their students can reap from it. As Lehman graduate students continue to learn about the many aspects of teaching and learning as urban teachers, they simultaneously develop ways of being and of knowing that are strongly aligned with those of AMNH's scientists and science educators.

Situated learning at the Museum, as described by Lave and Wenger (1991), is learning (to teach and learn science) in the same context in which it is applied. The Museum experience is meant to provide a variety of opportunities for science teachers to co-construct pedagogical knowledge while they share, teach, and learn science content knowledge with colleagues and students in a social and contextualized manner. Participation within this community is based on situated negotiation and renegotiation—the ability to make meaning of the past and the future in order to construct the meaning of present circumstances and experiences. The Museum has often been experienced as a science teaching and learning environment that is radically different from that of many of New York City's teachers and students. Situated learning is valuable because it provides an interactive,

participatory framework for learning that is created by varied encounters, rather than an abstract body of knowledge (Rennie et al., 2003). Experience is shaped and challenged by other coparticipants in such an environment, creating a community of learners who work in the same field (science education), each having increased access to participatory roles in "expert performances."

LEHMAN COLLEGE AND ITS POSITION IN EDUCATING BRONX CHILDREN

Lehman College is one of the senior colleges of CUNY, which educates over 480,000 students and is the largest provider of teachers for New York City's public schools. New York City has a culturally diverse population of 8,000,000 and is the largest school district in the United States, with 1,400 schools, 1.1 million students, and 77,000 teachers. Close to 70% of all New York City students are eligible for free or reduced lunch, and more than 10% speak languages other than English. Sixty-one percent of CUNY freshmen are graduates of New York City schools.

In keeping with CUNY's historic mission to provide access to higher education for all city students, Lehman College is uniquely positioned to prepare competent, reflective teachers for the Bronx's middle and high schools youth. Lehman College is the only CUNY senior college located in the Bronx and currently serves 13,000 students. The college student population is 48% Hispanic and 33% Black, as well as 72% female.

The Bronx, a high-poverty, densely populated county, is one of the five boroughs of New York City. According to the 2000 U.S. Census, the Bronx 1.3 million residents are 48.4% Latino (primarily Puerto Rican, followed by Dominican), 14.6% White, 31.2% Black, and 2.8% Asian. The median household income is approximately $35,000 (United States Census Bureau, 2004). The population of underrepresented minority students in Bronx schools is greater than 90%. The Bronx has the lowest graduation rate in the city (47.8%), and 91% of its students qualify for free or reduced lunch. Only 20% of Black students and 16% of Hispanic students from the Bronx graduate with college-ready transcripts, compared with 46% of White students (Greene & Forster, 2003). Only 12% of Bronx high school graduates have completed a physics course (Kelly & Sheppard, 2009).

Improving the quality of science education and of student performance requires meaningful, sustained collaborations between Lehman and established community organizations. When resources are mobilized at the local level, students' interests in authentic scientific experiences science can be leveraged to promote academic engagement and future careers in STEM (science, technology, engineering, and mathematics) disciplines. The institutional strength of AMNH makes it a natural educational partner; it is a vast resource for enhancing science learning experiences that engage partners in the processes of its different programs.

The following letter, for example, engages principals in the course expectations to promote success for the teachers and direct service to the students.

AMERICAN MUSEUM ⁂ NATURAL HISTORY

Re: Letter to principals, assistant principals, and/or science supervisors
From: Dr. Adriana Aquino, AMNH Scientist
Re: Science-Based field trip requirement for Master students from Lehman College
Date: March 9, 2010 "**ESC 767 Museum Resources for Teaching Science"**

Dear principal, science supervisor, or assistant principal,

We are writing to let you know that one of your teachers who is finishing her/his Masters at Lehman College is enrolled in a required science and pedagogy course at the American Museum of Natural History. The course meets at the Museum on Saturdays for six hours. The course content is based on access to science resources and how to use them to supplement content areas connected to standardized assessments such as the 8th grade exit projects and Middle School exam, or the Regents Exams for the Living Environment, Earth Science, and Physics or Chemistry. The course is taught by teacher educator (Dr. Macdonald) and museum scientists (Dr. Aquino). Participants experience, replicate, field test, and develop lessons based on research practices for teaching science in informal settings and on specific printed, digital, and online resources. The expectations include weekly teaching and learning assignments, and the culminating "evidence" is a field trip to the museum with a group of students. To complete this "**EVIDENCE-BASED AND CURRICULUM ALIGNED**" requirement is where these teachers will need your collaboration and guidance. Forty percent, 40%, of their grade is based on the implementation of pretrip lessons, field trip plan, and after field trip assignment and assessment of student work. The group of students could be from 10–60 depending on your school and it is free. All field trip planning can be found at www.amnh.org/education. From past experience, we have found that for new teachers the most successful trips for their students learning were the ones where supervisors or mentors taught then the schools protocols such as timelines, parental permissions, emergency cards, and other school policies for field trips.

We thank you in advance for your collaboration this semester. Should you wish to review our resources, please check www.amnh.org (Education and Field trips) where you will see the types of resources. If you are in a middle school, the urban advantage website is also very informative on the matter of exit projects and resources that meet scope and sequence www.urbanadvantagenyc.org. We thank you for your support and encourage you to contact us if we can answer any questions or provide additional support to your groups. Best, mmacdonald@amnh.org and Aquino@amnh.org

HISTORY OF THE LEHMAN/AMNH PARTNERSHIP

Using the Museum as a Learning Resource originated as an experimental Lehman College course in 2001. Students who had enrolled in the CUNY Teacher Opportunity Program (TOP), an alternative certification route, were offered the course in the summer before their first year of teaching. It began as a workshop-style seminar, where students engaged in discussions about pedagogical philosophy and explored museum exhibits. For two years, it was offered as an experimental special topics course. In 2003, when Lehman was going through recertification for all of its teacher education programs, college faculty recognized that the experience at the Museum had become an essential component of the teacher training for Lehman's urban science educators. Consequently, it was approved by the Faculty

Senate as a permanent course and made a requirement for all Master's degree candidates in science education.

RESEARCH DESIGN

This reflective study employs a mixed-methods approach to analyze the outcomes of the partnership. Quantitative questionnaire data provided a descriptive framework of what teachers learned and how they evaluated their own field trips. Qualitative insights were gained from teacher portfolios and thesis work. Through a process of grounded theory (Strauss & Corbin, 1990), open coding was employed to identify shared perspectives among the course participants. The combined quantitative and qualitative data provided a rich perspective for analyzing course outcomes and the impacts on urban science teachers.

DATA SOURCES

Four types of data were used to document the outcomes of the course: (1) responses to course evaluation surveys, and in particular, responses to questions that could lead to metacognitive insights. Such questions included the following: What did you learn from the scientists and from the teacher educators? How do you contrast your own learning in a museum and in a college classroom? What supports or barriers did you encounter in bringing students to learn outside the classroom? What suggestions do you have for the future? (2) participants' accounts of planning a curriculum-driven field trip and of its outcome; (3) student work done in preparation for the field trip and afterward. This work was evaluated, in particular, with regard to the extent to which students implemented the teaching strategies related to linguistic or cultural diversity that had been modeled or addressed by course instructors during the semester; (4) thesis work presented as the culmination of students' graduate study at Lehman.

CONTEXT

Profile of Science Teachers Participating in Partnership

The novice science teachers who participate in the partnership have come from either traditional or alternative teacher certification programs. All have earned a bachelor's degree in one of four scientific disciplines: Biology, geology, physics, or chemistry. Lehman's traditional teacher education program typically enrolls graduate students from the Bronx area; they closely mirror the population they serve, in terms of both ethnicity and socioeconomic status. The majority of teachers in the special alternative certification programs are White.

The Course Structure

The instructors designed a science curriculum course that would address science content and pedagogical content knowledge as it applies to the use of informal environments for teaching science and to informal resources for teaching in the classroom. Attention to students' knowledge and their school contexts is central to the course. The course design included the following components.

(1) **Class meetings**: The class meets for seven Saturdays over a four-month period. Each session is five hours long. In addition, there is a free-choice museum research day and a day for training for the implementation of a field trip. During the day-long field trip class, students attend a lecture/demonstration, study in the exhibition halls, apply research methods used in museum learning (observations, conversations, tracking, interviews, etc.), use specific resources (objects, educators' guides, science bulletins, media, and assessments of student investigations), and participate in closing discussions on classroom applications.

(2) **Science content**: Specific science content is determined each semester by the nature of class participants' jobs or teaching contexts, with regard to subject area, grade level, cultural context, and degree of involvement with high-stakes assessment. This flexibility is possible because of the range of scientific expertise at the museum and the diversity of science topics covered by its temporary and permanent exhibits.

(3) **Museum resources**: Participants have access to an array of resources, including scientists and museum educators, halls and temporary exhibits, IMAX films, space shows, teachers' guides, and online and digital materials such as AMNH Science Bulletins. (The Science Bulletins can be viewed at http://www.amnh.org/sciencebulletins/).

(4) **Written assignments and readings**: Weekly selections of reading/writing assignments always address the same three questions: Why did you select this reading? How does it relate to your prior experiences with science? How does it connect with your current work? One of the required texts is based on the work of the Center for the Advancement of Informal Science Education (CAISE). (For information about CAISE, visit their website, http://caise.insci.org/).

(5) **Evidence-based assessment**: The assignment that accounts for the greatest percentage of the grade (40%) is the planning, implementation, and evaluation of a month-long curriculum-focused unit of study that must include both a field trip to the museum for more than 20 students and a portfolio. Portfolios include entries such as observations of students, both at the museum and in the classroom (comparing students' behavior and attitudes in the two environments); pre- and post-lesson responses to the curriculum, and evaluations of the resources used

throughout the unit. A final peer-reviewed portfolio presentation is also required. The final exam consists of a research essay or thesis chapter presenting the students' rationale for using informal resources.

(6) **Faculty, other instructors, and new exhibitions**: The course is cotaught by a scientist and a teacher educator with a background in urban research and curriculum design, both from AMNH. In addition, each semester guest scientists share their expertise in areas in which teachers need more content knowledge. The museum has a staff of over 150 research scientists, and most curators contribute to the improvement of science education and to the broader impact of their research. Each semester, a temporary exhibit opens at the museum. Participants attend curators' introductions, educators' opening nights, and evaluations of the exhibit. Many of them also decide to include the new exhibit in their field trip plans. In past years, for example, many trips included visits to the *Water*, *Darwin*, *Einstein*, *Climate Change*, and *Silk Road* exhibits.

RESULTS AND DISCUSSION

The data collected over nine years consisted of questionnaires, portfolios, final essays, and thesis work. Each of the sources revealed different aspects of how teachers' participation in the course impacted their views and practices.

SURVEY RESPONSES

Course surveys were distributed to teacher-participants on the last day of the class. Responses were compiled cumulatively over a five-year period (2000–2005). The questions asked in the survey were as follows.

(1) What did you learn from your interactions with museum scientists?
(2) What did you learn from your interactions with curriculum specialists?
(3) What did you learn from your interactions with museum educators?
(4) Did you use temporary or permanent halls?
(5) How did you use the packet of printed resources and books you received for the course?
(6) How did you use the digital and online resources included in the course?
(7) How was learning at the museum different from learning on campus or at schools?

The first set of questions ((1), (2), and (3)) addressed what teachers learned from Museum staff (see Table 1). Teachers' responses indicated that the Museum was a rich context for preparing them to teach science in meaningful ways. The curriculum specialists and Museum educators were instrumental in modeling the use of

Table 1. What teachers learned from interacting with Museum staff

WHAT TEACHERS LEARNED	FREQUENCY
From Museum scientists (n = 128)	
▪ How to use the Museum for teaching, connecting the Museum to the classroom, making learning more exciting for students	57.0%
▪ Content	32.8%
▪ How the halls were designed; behind-the-scenes considerations	26.6%
▪ What scientists do at the Museum; how deeply knowledgeable they are, their passion for their disciplines, their humility, professionalism, friendliness, approachability?	16.4%
▪ Interacting with scientists is inspirational	7.0%
From curriculum specialists (n = 119)	
▪ How to use the Museum and other resources outside the classroom as teaching tools integrated with classroom teaching?	49.2%
▪ Teaching process in general; engaging students with different learning styles, inquiry, use of essential questions, relation between theory and practice	36.7%
▪ Inspiration, experience, and feedback for novice teachers	
From Museum educators (n = 124)	
▪ How to use the Museum for effective teaching, managing logistics, making connections to curriculum and assessment	52.3%
▪ How to be a more effective teacher in general; how to engage and develop lessons and activities	27.3%
▪ Learning from the experiences of colleagues provides inspiration, motivation, confidence, and a sense that it is possible to be successful in engaging students	21.9%
▪ Content	1.6%

informal resources in effective teaching. The teachers also acknowledged that their content knowledge improved through interactions with Museum scientists.

The second group of questions (4, 5, and 6) asked teachers to reflect on their use of specific Museum resources (see Table 2). Teachers expressed a much stronger preference for permanent exhibits (91.7%) than for temporary, special exhibits (8.3%). They valued the printed and digital resources, particularly for planning their field trips and classroom teaching. Interestingly, they also valued the printed and electronic resources for their own personal enjoyment.

Teachers recognized the advantages of using the Museum as a learning resource, and their survey responses on question 7 indicated that they could readily contrast the Museum with the formal classroom environment (see Figure 1). Overall, they valued the exciting and inspiring Museum atmosphere, the way in which Museum exhibits helped students learn abstract concepts, the hands-on

Table 2. Teachers use of Museum resources

RESOURCE USE	FREQUENCY
Permanent halls vs. temporary exhibits (n = 157)	
Permanent halls	91.7%
Temporary exhibits	8.3%
Printed resources (n = 62)	
Preparation for Museum field trip	59.7%
Classroom teaching	32.3%
Personal learning and enjoyment	27.4%
Digital and online resources (n = 61)	
Preparation for Museum field trip	42.6%
Classroom teaching	34.4%
Reference, personal learning, and enjoyment	18.0%
Have not used	11.5%

opportunities that promoted self-directed inquiry, the interactive nature of the exhibits, and the availability of science resources (both scientists and objects).

COURSE PORTFOLIOS

Teachers' portfolios consisted of reflective responses regarding their social, personal, and pedagogical experiences in the course, as well as documentation of their own students' experiences while participating in Museum field trips. The teachers' reflections demonstrated how the intended outcomes and thematic elements of the course (see Figure 2) paralleled their personal observations and emerging teaching practices.

AMNH COMPLEMENTS CLASSROOM LEARNING

While participating in varied explorations at AMNH with scientists and Museum educators, teachers were able to connect their standards-based curricula with the authentically designed exhibits. One teacher expressed her amazement that her students' visit to the Museum inspired them to pursue their own learning when they returned to the classroom.

> Students had been prepared to work within the exhibit and had spent much class time focusing on the ways in which rocks, the earth, and its minerals are important to man, but had not been told about the seismograph or learned much at all about the tectonic plates. The section of the Hall of Planet Earth that contains the real-time updated

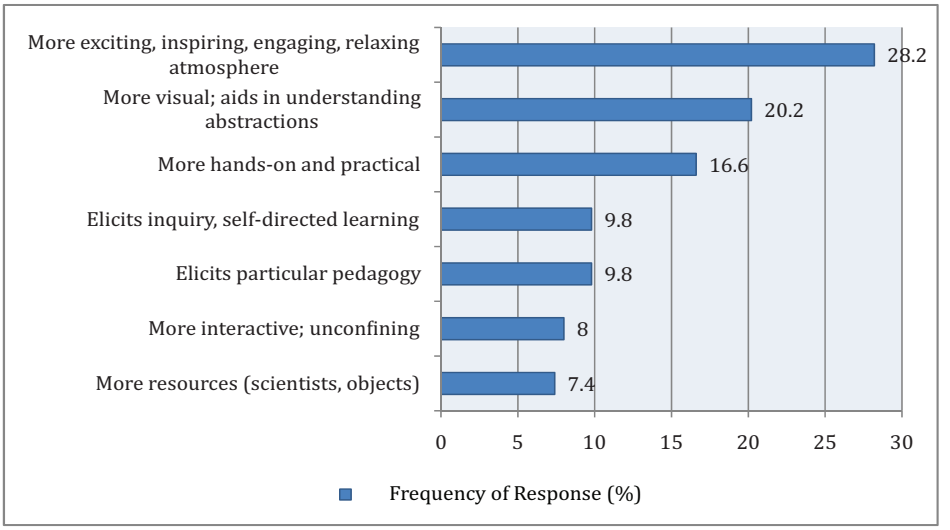

Figure 1. Teachers responses to how learning at the Museum differs from learning in formal school environments (n = 157)

> list of the nation's earthquakes was an immediate magnet to some of my most hard to reach kids. They began recording the information of the location and intensity of each earthquake into their notebooks and had to be physically pulled from the screens so that we could make it to the IMAX on time. Later that week, one of the aforementioned students found an old earthquake-based *National Geographic* magazine on my desk and asked to take it home, struggling through the language, to learn more about earthquakes. I think this exemplifies the type of learning that the place-centered lens perspective purports; it uses a pre-existing framework and independent exploration to encourage learning and it was amazing to see it in action with my students.

The exhibit had expanded upon the Earth's structure and history in ways in which the students had not yet learned. The scaffold for more complex understandings that it provided empowered at least one student to seek other ways of fulfilling his desire to know more about the world around him. In this way, the Museum experience developed his skills and desire for independent science learning.

BRIDGING CLINICAL THEORY AND PRACTICE IN EDUCATION

Several teachers commented on how their pedagogical practice was improved once they realized that certain strategies were conducive to teaching science in both informal and classroom environments. For one teacher, the emphasis on structuring

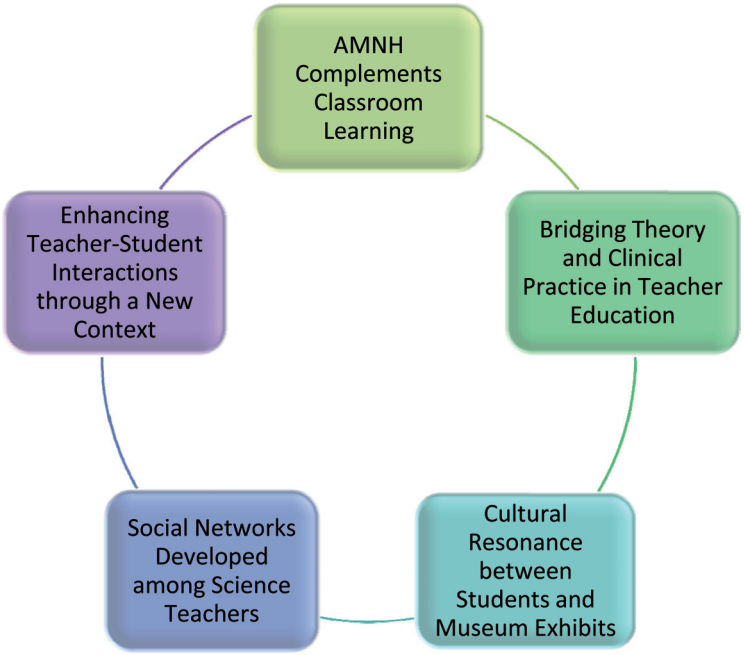

Figure 2. Select thematic elements of the Lehman-AMNH partnership

lessons to maximize student engagement, particularly with well-designed questioning, helped him to improve his teaching in ways he did not expect.

> The most important gain that I have made from this course [is] reiterating the philosophy of supporting student questioning. I have also learned methods for enabling it in my classroom. I feel like my teaching has drastically improved by focusing on student engagement and enabling students to make their own observations and interpretations ... This helps invest them into the lesson because they have their own questions that they want to see answered… When students are asked for their own thoughts, they gain confidence in their own thoughts and begin to think for themselves. The classroom is a much more pleasant environment when everyone's opinions and ideas are valued.

The Museum course allowed him to trust his students to construct their own understandings by developing scientific inferences. He experienced the positive results of empowering youth to share their thoughts in a safe classroom environment.

In addition to focusing on student-directed learning, the course also helped teachers situate practices in the context of urban learners. Another teacher discussed

Figure 3. Lehman college teacher-participants at AMNH, Fall 2009

the value of Museum exhibits in providing interactive learning opportunities that are often missing for urban students.

> I need to work to make the topics of Astronomy meaningful to students who do not necessarily experience the wonder of seeing a full field of stars in the night sky, another challenge particular to urban education.

The Museum collections and exhibits opened a world for many students that they had never experienced. The vast resources allowed teachers to make their content relevant and tangible in ways that the classroom could not, which is particularly important for traditionally underserved students.

CULTURAL RESONANCE BETWEEN STUDENTS AND EXHIBITS

In addition to providing opportunities for urban students to share in experiences that they might not have in their neighborhood environments, the Museum exhibits have often fostered cultural connections between students and the scientific enterprise. By participating in the situated learning provided by AMNH, students could recognize the connection between exhibit content and their own experiences in ways that were not otherwise possible. As one teacher noted, students developed a new appreciation for evolution by exploring the historical development of music.

> They really loved the hands-on element, where they were able to practice developing sounds using instruments from early cultures around the world. I think it was the integration of evolution with something they could touch that really made a remarkable difference… Most students wrote that the music portion was so interesting because it highlighted a similarity between us and our early ancestors. This similarity was definitely key in driving home the fact that our homologies are evidence of the common ancestor that we share, something that my students had difficulty in understanding in the classroom but became very clear while researching culture and music at the Museum.

Another teacher shared this perspective in a broader sense, by sharing her belief that she had to seek ways in which science could be culturally resonant.

> After observing my students at the Museum and seeing how they gravitated towards any facet of the Museum that included their own experiences or images, I know that I need to incorporate this to increase student investment and achievement in my own class.

ENHANCING STUDENT-TEACHER INTERACTIONS IN A NEW CONTEXT

Many teachers seemed genuinely surprised by how much they learned about their students after leading them on field trips. The comments of two participants suggested that they had developed a new understanding of how informal learning had fostered mutual respect.

> Our trip to the museum was a bonding experience and we have had even more fun in the classroom since our trip. I think the students trust me more [when I tell them] that the content that they are learning is relevant and useful.
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> ********
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> I learned during my visit about the value of social interaction and teamwork. Developing a relationship with students outside of the classroom, be it in the cafeteria, on the train, or at a museum, is an important step in creating a positive learning environment where students feel safe to take intellectual and social risks.

Often science teachers enter urban classrooms with a focus on maintaining order and struggling through the pressures of creating lessons and assessments. In attending to these everyday concerns, they can lose sight of the importance of creating a respectful learning environment. The Museum context presented the opportunity for teachers to share informal conversations and nurture trust.

SOCIAL NETWORKS DEVELOPED AMONG SCIENCE TEACHERS

One very important outcome of the Museum course was the relationships that formed among the teacher-participants. As they placed themselves in the roles of their students, they created a community of practice with shared experiences. This community was modeled upon the community of the scientists and educators who worked in the Museum and mentored them. The course, which was offered during the crucial induction years of novice science teachers, helped bring together teachers with common goals and varied backgrounds. One teacher commented on the impact of this community on his engagement with the collections, something he valued immensely.

> I will never forget the amount of fun I gained in learning as much as I did while experiencing the Hall of Minerals with fellow Earth Science teachers. At almost every exhibit, each of us would bounce off explanations about what we observed, such as why the mineral exhibited cleavage and why a particular gem contained a certain amount of luminescence. I remember thinking to myself at the time how unique this experience was and how unimaginable this would have been for me without this course.

The community of practice was beneficial for two reasons. First, it allowed teachers to share strategies to help students make sense of the exhibits. Teachers could engage in scientific discourse through which they reached common understandings, and they developed friendships and professional collaborations with colleagues. Second, teachers were able to view the exhibits through the lens of new learners. In the process, they gained a new appreciation for how their students might view the new Museum experiences. Their newly formed network of fellow educators contributed to their development as expert science teachers.

TEACHER THESIS WORK

Several teachers chose the Museum as the focus of their required Master's thesis, which provided an additional source of data for assessing the impact that the course had on participants. Two types of thesis work, curriculum development and scholarly research, were chosen to illustrate how the Museum experience helped teachers connect theory, research, and practice.

CURRICULUM DEVELOPMENT IN USING THE MUSEUM AS THE LEARNING CONTEXT

Cook (2002) and Scott (2002) developed an earth sciences curriculum for eighth-grade students, incorporating field trips to AMNH. The halls visited—Gottesman

Hall of Planet Earth, the Guggenheim Hall of Gems and Minerals, and the Fossils Halls—contain materials related to major Earth Science Regents Exam topics. The activities designed for the curriculum included the use of interactive displays in the halls that elicit hands-on experiences, thus supplementing the often-limited resources in urban schools. Scott (2002) stressed the motivating effect the experience had on students. The informal setting helps teachers develop student-centered activities, enhancing the connections that students can make with their daily lives.

Cabrera (2002) developed a living environment unit on genetics for tenth graders. Her thesis incorporated the visit to a temporary exhibit, *The Genomic Revolution*. In addition to numerous interactive elements and a comprehensive introduction to the field of genetics, the exhibit offered a thorough examination of ethical issues. Cabrera designed 20 lessons. The first nine focused primarily on science content. The visit to the exhibit was part of the tenth lesson, allowing students to learn about culturally influenced ethical issues. Subsequent lessons included a post-visit follow up to the trip. In her final reflections, Cabrera stressed the importance of the selection of an informal setting that can provide clear connections with the classroom lessons.

Trowbridge's (2005) curriculum thesis project, *Teaching Outside the Classroom: Is the Hudson River Clean?*, incorporated an outdoor experience as the informal setting. Her main goal was to develop a curricular unit on environmental sciences aligned with the New York State Living Environment Core Curriculum. The unit included fieldwork in New York City aquatic environments, which fostered the development of observation and inference skills, as well as providing content knowledge of the New York Harbor estuary. Ultimately, the curriculum offered urban school students a valuable learning experience about a local natural resource while using informal science resources in New York City. Trowbridge piloted the unit with her students while finalizing her thesis work. In her conclusions, she commented that fieldwork and field trips can provide a good foundation for understanding ecological concepts, and that as a result, students may become genuinely interested in advocating for the Hudson River. In particular, she highlighted cooperative learning, with students having clear individual tasks and roles, as a useful teaching approach. She emphasized how the experience elicited students' own questions and encouraged them to pursue similar fieldwork in other environments by themselves. Trowbridge's checklist of what to keep in mind when preparing a field trip has been incorporated into the materials given to students in *Museum Resources for Teaching Science*.

LEARNING TO RESEARCH LEARNING AND IDENTITY DEVELOPMENT AT THE MUSEUM

Wortel (2009) focused on a different aspect of the informal setting learning. For her thesis paper, *Developing Methodologies and Resources for Assessing Interest in*

Science Careers in Informal Environments, she researched methodologies for assessing student science learning at the Museum. Mentored by one of the AMNH educators, Wortel then focused her work on constructing an actual assessment to be piloted for special exhibits.

In working towards her goal, Wortel (2009) participated in a four-month apprenticeship to learn how Museum staff and their research team evaluated students' skills and attitudes. She was trained to collect qualitative data on a special exhibit, *Climate Change*, and on a two-day event, *International Polar Weekend.* The data was collected through one-on-one interviews with visitors after they visited the events, as well as through noninvasive observations. She described the complexities involved in evaluating the learning experiences of Museum visitors:

> The qualitative process of evaluating the learning of museum visitors requires a careful and multimodal approach. Learning in museums and other informal environments is intrinsically tied to personal identity, time and place, and group setting. Individuals themselves may be able to describe their emotional reactions and express some facts and details that they learned during a museum experience. However, the full breadth of the effect of an informal learning experience is nearly impossible to capture. An experience in a museum may result in the deepening of a family bond, inspiration to create art, or the ignition of a lifelong passion for science. (p. 31)

The structured interview protocol provided a mechanism for her to engage visitors in referencing objects to contextualize their new learning. By articulating their understandings, the visitors established their identities as lay scientists interpreting observed data. She recognized that this interview experience could be a powerful incentive for visitors to participate in other informal investigations, since the interpersonal exchange allowed them to feel further invested in the subject matter. This valuable experience encouraged her to think critically about the need to emphasize personal connections when introducing students to Museum exhibits.

DISCUSSION

The success of the Museum course has been well articulated by Lehman's novice science educators (a recent group of whom is shown in Figure 3). A course that began as a pilot workshop for preservice teachers has evolved into an essential requirement for graduate study in science education at Lehman College and has become a key experience for developing pedagogical skills and content knowledge. The evidence analyzed in this study supports three important aspects of training urban teachers in informal science learning: The Museum as a community of practice, the Museum as a promoter of science accessibility, and the Museum as an authentic context for science teacher induction.

First, the participants were able to experience how the Museum can foster communities of practice among both educators and learners. Teachers explored science and constructed teaching strategies through situated learning; their communal participation fostered social interactions and professional development in a contextualized setting. Data indicated that these valuable social networks extended to Museum educators, scientists, and curriculum specialists. Teachers increased their understanding of the sociocultural impact of informal learning by discovering new connections with their students as a result of sharing experiences outside the traditional classroom, which mirrored the group dynamics fostered in the course.

Second, museum education is an underutilized resource that promotes self-directed learning through student engagement, a goal that is difficult to achieve solely through in-school learning. By studying pedagogical theories, and by planning, creating, and leading field trips, teachers discovered that the Museum resources have the capacity to make science accessible to a wider audience. Indeed, they often took advantage of these resources for their own learning and personal enjoyment. Furthermore, they recognized that the exhibits often complemented standards-based instruction in ways that captured the imagination of students. Curriculum-based theses expanded upon standards through authentic, interactive Museum experiences.

Finally, science teacher induction is most effective when field experiences and professional development incorporate knowledge about how students learn in specific settings. These skills were fostered through a variety of techniques. The Museum course emphasized teacher reflection, allowing participants to integrate their professional work with prior science experiences and new theoretical and practical understandings. By providing a safe space for sharing ideas and offering critiques, the course instructors empowered the teachers to design engaging, logistically sound fieldwork for their own students.

In the future, the course will use different resources and approaches according to the needs of each group of teachers and their students. In addition, a preliminary study of induction resources and museum access began in Summer 2010 for teachers who took the course in 2009–2010 and who continue to teach in New York City. They have received AMNH identification cards so they can use the museum freely for continued study, professional development, educators events, personal enjoyment, and their teaching. We will observe how such access is used and continue to learn what is needed to keep science teachers in urban schools. So far, the new study has gotten off to a good start; upon receiving the AMNH identification card, one middle school teacher exclaimed.

> *Thank you for this great opportunity! I loved the class at the museum and I learned so much as did my students. This year was one of the best and it was all due to me taking chances and learning so much in this course. Thanks again for allowing me to continue my work with using informal environments to make my teachings better!*

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