

Teaching Science in the City: Exploring Linkages between Teacher Learning and Student Learning across Formal and Informal Contexts

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This paper describes the Science in the City seminar, an innovative approach to in-service and preservice science teacher development that bridges formal and informal science learning contexts. Drawing upon the tenets of design and evaluation research, the study focuses on the teachers' presentations of evidence of student learning from trips they made to the museum. The findings show linkages between teacher education, teacher practices, and student learning through (a) novel use of the museum as a place to learn science connected to mandated science curricula and (b) clear, reciprocal connections between students' learning in the museum and in the science classroom. We discuss instances of teacher learning falling short of equity goals and examine how structured and unstructured student engagement strategies were employed at meso and micro levels.

In crafting science teaching practices in urban public schools, in-service and preservice teachers face many challenges. These challenges include navigating the current policy context of No Child Left Behind (NCLB) that has led to a heightened focus on literacy and mathematics instruction, often at the expense of quality time and resources for science (Rivera Maulucci, 2010). In addition, teachers must meet

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the needs of culturally and linguistically diverse students while helping all students achieve in heterogeneous classrooms. Teachers particularly need to understand current reform efforts relating to science education, including the National Science Education Standards (National Research Council, 1996), how those efforts align with New York State science standards and assessments, and how to design curricula that address the standards and engage students representing diverse cultures and languages. At the same time, in many urban centers, informal resources for teaching science, such as museums, parks, and other cultural institutions, remain underutilized, particularly by schools serving high-poverty youth (Committee on Education of the Council of the City of New York, 2004). Research is needed to better understand how to prepare teachers to teach science effectively while drawing upon unique community-based opportunities for learning science.

The Science in the City seminar was developed as a partnership between a local natural history museum, local public schools, and an undergraduate teacher education program. The design of the seminar brings participants into three contexts for learning: the seminar, held at the college campus; the museum; and the elementary school science classroom. Four central tenets provide a foundation for the content and the process of the seminar: (a) collaborating in practical partnerships, (b) using the city as a resource for science teaching, (c) building on what students and teachers bring to science teaching and learning, and (d) using evidence to assess student learning. We elaborate on these below.

COLLABORATING IN PRACTICAL PARTNERSHIPS

The Science in the City seminar brings together in-service teachers from local public schools and undergraduates enrolled in a science content and pedagogical methods course in a teacher education program. The teachers attend all class sessions and partner with a preservice teacher to plan and implement science lessons in their classrooms. The seminar meets weekly for 14 weeks and includes readings, science activities, and museum visits. Museum trips are designed to expand the teaching capacity of the participants by immersing them in the direct experience of scientific discovery using the resources of New York City. The teacher education program partners with the museum to model how to use the city as a resource for science teaching and learning. Preservice teachers complete 40 practicum hours in their cooperating teachers' classrooms observing, coplanning, and coteaching science lessons. Teacher teams also develop hands-on science units that meet New York State standards in the physical and life sciences and that complement materials already in use at the schools. In-service teachers keep a journal in which they reflect on the readings, connections they are making to their practice, and course activities. Inservice teachers receive a stipend for their participation.

USING THE CITY AS A RESOURCE FOR SCIENCE LEARNING

New York City abounds with resources that could be used to augment science teaching and learning. Rather than taking a survey approach, we focus on using our partner museum as a model for how other science institutions might be integrated into the curriculum in meaningful ways. Three seminars led by a museum educator are held at the museum, and teacher teams are required to plan a field trip to the museum for their students during the semester. The first session at the museum focuses on how to engage in science inquiry in museum settings. The second session is held over an entire day. The morning consists of a model field trip; the afternoon is devoted to time for the teacher teams to plan their field trips for the seminar in consultation with the instructors and museum educators. During the final session, the teacher teams report on the evidence of student learning that has occurred during museum visits.

Allen (2004) describes some of the strengths of museum education: “[T]he exhibit space of a science museum seems an appealing educational alternative to a school science classroom: hands-on exhibits are novel, stimulating, evidence-rich, multisensory, and fun. The environment provides myriad personal choices, without any teachers forcing learners to do something unappealing, without curricular constraints, without testing or accountability” (Allen, 2004, pp. S17–S18). At the same time, she notes that museum exhibits “must be sufficiently motivating that [visitors] make the choice of continuing to invest time and attention there” (p. S18). Thus, exhibits must be designed to appeal to diverse visitors and attend to their agendas or individual expectations for the museum experience (Falk & Dierking, 2000). Depending on the age of the children in their class and the type of museum, teachers may need to provide a plan that effectively scaffolds students’ engagement with the exhibits and helps focus their attention on the learning goals. At the same time, care must be taken to ensure that worksheets and teacher agendas do not render what could be an engaging, student-driven experience into one that is teacher-directed.

Research on school field trips to museums points to the importance of understanding teacher motivations in designing learning experiences for students in free-choice environments (Kisiel, 2005). Kisiel identified eight such motivations: “to connect with the classroom curriculum, to provide a general learning experience, to encourage lifelong learning, to enhance interest and motivation, to provide exposure to new experiences, to provide a change in setting or routine, for enjoyment, and to meet school expectations” (p. 1). Importantly, none of these teacher agendas is singled out as better or more likely to promote learning than any other. Instead, the emphasis is on the need for museums to be responsive to different teacher agendas and to support teachers in strengthening their motivations. Thus, a teacher seeking a break from routine might be encouraged by finding strong connections between museum offerings and the classroom curriculum. Kisiel (2006)

also identified five overarching strategies used by teachers on field trips, “including plan of action, structured engagement (such as tours or worksheets), unstructured engagement (such as teacher facilitation), event documentation, and supervision” (p. 434). Teachers reported using multiple strategies, including having and following a clear plan of action for the trip, arranging a docent talk (student engagement), grouping and chaperoning students (supervision), and taking photos (event documentation). Structured student engagement strategies tended to focus on information seeking (scavenger hunt) or receiving (docent talk) whereas unstructured student engagement strategies included teachers interpreting exhibits, connecting concepts to the classroom curriculum, facilitating student thinking, reading labels, preparing students for the next exhibit they will be seeing, and allowing free exploration. In summary, teacher support should include helping teachers: (a) identify and expand their motivations for field trips, (b) draw on strategies they are already likely to use, and (c) develop new strategies for fostering student engagement and learning in free-choice settings.

BUILDING ON WHAT STUDENTS AND TEACHERS BRING

The vision of equity science pedagogy put forth in the Science in the City seminar rests on three tenets. First, equity pedagogy must address “entrenched inequalities” (Lipman, 1998) in science education, including any differences in performance linked to gender, race, class, linguistic ability, and/or special learning needs. For example, the schools we partner with have large numbers of English Language Learners as well as special education students in inclusion classrooms. Thus, to contribute to more equitable science outcomes, science curriculum development must specifically address students’ diverse learning needs. Second, students’ “funds of knowledge” contribute to science learning (Moll et al., 1992). Equity science pedagogy positions teachers to recognize and help students draw upon personal, classroom, and outside resources in support of student achievement in science. The seminar engages in-service and preservice teachers in a series of observations and exploratory activities designed to build teachers’ awareness of the cultural, experiential, familial, and linguistic resources students bring to learning science. In the first assignment, teacher teams explore children’s ideas about science through writing and draw-a-scientist activities. In the second assignment, teacher teams interview a subset of students about an upcoming science topic. Teacher teams then draw on their findings as they develop a museum field trip unit. Third, methods of designing curricula that are responsive to students’ and teachers’ needs, interests, and cultures are discussed, explored, and built upon throughout the seminar. Teacher teams explore scaling (Barba, 1998) and play-debrief-replay (Wasserman & Ivany, 1996) models of science teaching. The former is designed to support language acquisition and the second is designed to foster inquiry and critical thinking.

Teachers are encouraged to build a practice around the strengths of each model, the needs of their students, the requirements of their curriculum, and their personal experiences, motivations, and preferences.

USING EVIDENCE TO ASSESS STUDENT LEARNING

We encourage teachers to use a variety of sources of data—including stories, photographs, analysis of student work, and analysis of classroom videotape—as evidence to support their claims about student learning. Particularly at a time when science education is being pushed to the margins by NCLB accountability pressures, teachers need to be able to provide strong evidence of science learning outcomes and to articulate how science learning can also support literacy and numeracy learning goals. Accordingly, during the seminar teachers reflect on alternative and performance-based forms of assessment and other ways to gather formal and informal evidence of student learning. Research on learning in museum settings highlights the need to observe students more closely as they engage in activities and to listen to their conversations for evidence of learning (2004). At the same time, the literature on learning in informal settings includes discussions of values—such as enhancing students’ sense of aesthetic appreciation, sparking their motivation and interest, and personal identity development—that are often not taken into consideration in traditional assessments of student learning (Schauble et al., 2002).

RESEARCH DESIGN

Design-based research in educational contexts places the researcher in the classroom and allows them to investigate more than one variable at a time, describe how learning unfolds in context, and answer how and why (as well as what) questions (Tabak, 2004). We use a design-based lens to focus attention on the ways our decisions regarding readings, course assignments, and seminar and museum activities impact teacher learning; how teacher learning impacts the ways teacher teams plan and implement science lessons; how teaching practices impact student learning; and on the role of teacher reflection throughout the learning process. Design-based research “views outcomes as the culmination of the interaction between designed interventions, human psychology, personal histories or experiences, and local contexts” (Hoadley, 2004, p. 204). In contrast to experimental studies, design-based research may be more theory-generative than theory-driven, as it pursues twin goals of developing effective learning environments and using such environments to study teaching and learning. Thus, a guiding premise of this study is that unique opportunities and challenges to learning are presented by bringing together individuals from different points and trajectories on the teacher professional continuum—in-service teachers, preservice teachers, science majors

thinking about teaching as a career, teacher educators, and informal science educators—with different sets of expertise, questions, and concerns directly related to teaching science in urban schools.

In addition to a design-based methodology, we draw on critical narrative inquiry as a way to make sense of the data. Critical narrative inquiry rests on the epistemological assumption that people come to know the world and its power relations through story (Clandinin et al., 2007). Thus, from an ontological perspective, the researcher attends to narrative elements, including character, setting, events, dialogue, action, emotions, and time. Furthermore, critical narrative inquiry views storytelling as a meaning-making experience, both for the participants as they tell their stories and for the researcher as she interprets and retells stories to advance theoretical and analytical points. Telling, interpreting, and retelling stories transforms both participants and the researcher in ways that implicate the need for personal and contextual change on the ground. Finally, critical narrative inquiry foregrounds a need for tactical authenticity; the research process empowers participants and the researcher to act on the need for change.

The data sources for this study include course assignments; copies of plans for lessons before, during, and after the field trip; videotape and photographs of students during the field trip; and copies of student work from the field trip unit. In addition, the teacher teams examined evidence of student learning and developed PowerPoint presentations summarizing their goals and findings. We also audiotaped the teachers' presentations. Data were transcribed and used to formulate team case-records, which were then analyzed using a grounded theory approach, involving coding for emergent themes and conducting within-case and cross-case analysis. This study explores the following research questions: (a) How did teachers use the museum as a resource for science teaching and learning? (b) How do students show evidence of learning? and (c) In what ways do teachers show evidence of learning? Design-based research often casts a broad net to capture data documenting the enacted program and how it changes over time in response to local needs, actors, and contexts, as well as any unanticipated outcomes of the intervention (Hoadley 2004).

For this study, we focus on the lessons one teacher team designed for the field trip to the museum. The members of the teacher team were a science cluster teacher, Linda¹, and an undergraduate science major, Alana. During the week, Linda taught students from kindergarten through fifth grade; for the two teaching periods a week that Alana attended, Linda taught third-grade classes. The science curriculum in Linda's school follows the NYC Science Scope and Sequence. During the period of this study, the third-grade class was working on the Full Option Science System (FOSS) Measurement kit.

¹ Throughout the paper, pseudonyms are used for team teachers and other seminar participants.

FINDINGS

Analysis I: Using the Museum as a Resource for Science Teaching

At first, Linda and Alana had a difficult time figuring out how they could connect the unit on measurement—which focuses on standard and nonstandard measurement of length, mass, and volume—to exhibits at the museum. However, they had recently completed a lesson in which students used hand measurements to estimate length, and when Alana noticed the large rocks in the Earth Halls during the planning visit, she decided that students could further practice hand measurement in that area of the museum. Earlier in the semester, Alana had written the following in her reading journal:

Adam's article explains the value of museums as learning centers and ways that they can positively enhance the learning of science. One of the key points she addresses is the importance of interaction between teachers and students in the museum setting. Under limited time constraints, what are some ways the teacher can balance self-paced museum learning with on-task, organized learning...? How can we deal with students who may not be as interactive, playful, or engaged as others in the museum?

Alana kept these questions in mind as she and Linda planned the field trip.

Once they had decided what the focus of the field trip would be, the teachers prepared a booklet titled, "Kids Rock! Rock Adventure Book." Inside the booklet there was a schematic that showed the students each of the stations they would be visiting. The directions opened with, "Okay scientists, you are beginning your rock and measurement adventure at the museum..." In order to make the best use of the space in the exhibit the students were divided into groups and the hall was divided into stations: (a) Earth Resources, (b) Earth Formation, (c) Deep Earth, (d) Dating Rocks, (e) Earth Globe, and (f) Dynamic Earth. Students had to find, describe, measure, and draw two igneous, two sedimentary, and two metamorphic rocks. They also had to find two objects in the exhibit of each of the following lengths: 100 cm, 10 cm, and 1 cm. The booklet closed with three open-ended questions, asking students what their favorite and least favorite parts of the exhibit were and what they wanted to learn more about.

In her essay reflecting on the museum trip, Alana wrote the following:

There were a few main goals of this field trip that we hoped our students would accomplish. First, we wanted the students to practice their estimation and hand-measurement skills, two things that we had been working on in class for multiple weeks. Second, we wanted the students to discover and learn about different kinds of measurement beyond the linear kind that we've covered in class. Third, we hoped

the classes would come away with a basic understanding of geological features, such as the three different kinds of rocks. Fourth, we hoped everyone would have fun, enjoy getting out of the classroom and learn a little about what interested them most in the exhibit through free exploration.

As discussed above, Kisiel (2005) indicates that teachers often have multiple motivations for taking students on field trips. Alana and Linda articulated motivations that included connections to the classroom curriculum, exposure to new experiences and contexts to put their measurement skills to use, and having fun. The field trip plan also built upon two important ideas about science that Linda and Alana had developed as a result of two earlier practicum assignments. In practicum assignment 1, students were asked to draw a scientist and write about what science is. From that assignment, Alana concluded, “It was evident from the drawings that none of the students consider themselves scientists, though they are perhaps the truest scientists of all learners, who make and test hypotheses constantly throughout their days.” In practicum assignment 2, Linda and Alana interviewed students about measurement. Through the interviews, they were able to determine that a number of students had difficulty with the concept of mass and conservation of volume. Alana concluded:

The most important thing I am taking away from these interviews is the importance of contextualizing measurements in the lives of the students. They all were aware of rulers and yardsticks as measurement tools, presumably because we’ve used them repeatedly in class. However, we should also emphasize how measurement factors into our lives every day without us even noticing.

The practicum assignments were designed to assist teachers in gaining a sense of the ideas students bring to learning science and in formulating ways to address the learning needs they identified. The museum activities that Linda and Alana created for the students clearly align with the goals of positioning students as scientists and helping them contextualize measurements in their lives.

The structure of these activities was loosely based on the play-debrief-replay model that had been discussed in seminar. Here is Alana’s description of the museum visit:

Each chaperone and teacher took a group of 6-8 students from their specified color group to the appropriately assigned area of the exhibit to begin their treasure hunt. Most groups started with 5–7 minutes of free exploration to find rocks or other parts of the exhibit that particularly interested them. Following the exploration, students could begin to fill out their rock books by observing the rocks, filling out their property information, drawing them, and measuring them

using their hand measurements. After about 50 minutes, the groups gathered in the center of the room seating area to have their questions answered by docents.

An actual play-debrief-replay experience would have been less structured; students would have been free to explore, ask questions, and draw conclusions without having to use a booklet. In addition, during the debriefing, the teacher and docents would not have simply answered students' questions; instead, they would have facilitated a discussion among the students that would lead to further exploration during a replay phase. However, Linda and Alana had gradually been building more play or exploration into classroom lessons. Their decisions to provide students with 5-7 minutes of free exploration at each station and let them choose the rocks for their formal observations were consistent with their efforts to expand exploration and choice in the classroom.

At a meso level (teacher-whole class interactions), the strategies that Linda and Alana employed at the museum included structured student engagement, both when students were completing the worksheets (information receiving) and when they were having their questions answered by the docents at the end of the 50-minute exploration period (information receiving) (Kisiel, 2006). Linda and Alana described their supervision grouping strategies and documented the event with videotape and photographs.

In the following section, we explore evidence of unstructured student engagement at the micro level (teacher-student interactions), with teachers following students' interests, making connections to what they have been learning, or discussing new ideas within the overall structured activity.

Analysis II: Evaluating Evidence of Student Learning

To evaluate evidence of student learning, the teachers relied on the students' drawings and descriptions of the physical properties of the rocks, the accuracy of their measurements, and their ability to record those measurements. In addition, the teachers drew upon their observations at the museum and their reflections from watching the videotape of the trip. Linda and Alana concluded that they had strong evidence of students' learning. Both of them believed that there was a high level of student engagement. Linda said:

I questioned the students and they loved the trip. Not one child said that they did not enjoy the field trip, so that was a great reinforcement for them and their learning. They all picked a favorite part because at the end I put a survey of what was your favorite part, what was your least favorite part, what do you want to learn more. And they were able to label different parts of station 3, somebody said, or they really enjoyed the volcanoes and learning about that part of the lesson.

Student engagement was important for Linda and Alana for two reasons. First, the high level of student engagement affirmed their teaching decisions. When they began planning the field trip, they both felt unsure about how they would engage students in exploring measurement at the museum. They took 60 students (both third-grade classes) on the field trip, and based on their difficulties with classroom management, they had reason to expect trouble if the museum activities were not engaging. In her practicum journal, Alana described their struggles:

After spending almost ten minutes re-arranging seats so that children who were misbehaving with each other were not sitting next to one another, we were able to get the lesson started. At this point the class was riled up and energetic, which made it difficult to pair them off in groups; almost everyone seemed to have a problem with his or her assigned partner.

As evidence of student engagement during the museum visit, Linda noted that almost all of the students completed the trip booklets, that students worked together, and that many created detailed drawings and descriptions of the properties of the rocks. In their museum presentation, Linda and Alana cited several examples of such work. One student noticed that her rock was shaped like a rhombus, and another student described the texture of his rock as rough, delicate, and bumpy. Gauging success by student engagement at the museum was consistent with how Alana and Linda measured success in the classroom.

Second, Linda and Alana indicated that one of their motivations for the trip was to allow the students to have fun. In her practicum journal, Alana had written, "However once everyone got into the lesson, they seemed to have fun with it and every pair competed the assignment by writing down their results in their science notebooks." Thus, Alana considered students' emotional tone and their ability to complete their work and give detailed explanations to be evidence of student engagement that facilitated learning. It is also important to note that over time, students' behavior did improve. For example, a month after she'd described the difficulties she and Linda had had with classroom management, Alana wrote:

...this activity was the most successful to date in terms of keeping all students engaged and behaving...Students in both classes arrived quietly and were sent to work immediately with only a three or four minute modeling period at the beginning to make sure everyone knew what was expected of him or her. It seems that the students are now beginning to realize that our science class is more about getting up and doing activities rather than sitting at a desk.

A second form of evidence of student learning that the teachers cited was that students enhanced their skills in making hand measurements. The video of the museum visit shows Alana showing some students how to position their hands one

after the other to obtain more accurate measurements, as they had been taught to do earlier. As a result of her instruction, students began positioning their hands more carefully to make the measurements. She explained:

In my group, at first the students measured inaccurately, not trying very hard to measure the rocks precisely with their hands. However, after I reminded them how to measure properly, they spent more time with each of their rocks, measuring properly as best they could and recording the results.

Thus, at first students did not take their measurements seriously. Alana had encountered a similar situation in the classroom when Linda and she first tried implementing aspects of the play-debrief-replay model. Describing that situation, she wrote:

It seemed that certain students . . . were not taking the activity seriously because we were allowing them to get out of their seats and measure the table with a friend. This could well be due to the transition from standard, seated direction to the “play” model . . . some of the children might not be used to their newfound “freedom.”

A little later in the semester, Alana noted similar behavior of students and attributed it to the repetitive nature of the measurements students were making inside and outside the classroom. She wrote:

The main issue we encountered in this lesson was keeping the students interested in the topic at hand. We felt that they still needed practice with the tape measure, a tool many of them had never used before by themselves. However, after multiple months of measuring different objects, both in the classroom and out of it, it became clear that the two third-grade classes were getting restless about the topic of measurement.

One of the constraints of partnering with this school is that teachers there are required to cover the assigned units and to use the materials they have been given. Although there is some room to modify lessons, and Alana and Linda did incorporate more play into the hand-on activities, the reality is that students were making many of the measurements—of each other, of their desks, of various objects in the classroom—with no real purpose other than to practice the skill. As a result it is not surprising that at first, some students were not taking the measurements seriously in the museum either. Thus, Alana and Linda needed to help students make the connection between measurement and the real world, because the measurements the students were making as required in the unit were decontextualized. An example of a more authentic purpose for measurement might be to determine which classroom plants, being raised under different conditions, were growing the fastest, and by how much. Students might also want to know who among them in the class

had grown the most by the end of the year, and therefore take monthly measurements to collect the data needed to answer that question.

At the museum, the teachers also noticed that students learned to see measurement in other parts of the exhibit. For example, students realized that the rings in the cross section of the petrified tree were each about one centimeter wide. Other students began measuring the tables and doors. Linda wrote:

And that also kind of showed us evidence of them relating the measurement to the real world, they were not just using the rocks, they were saying the computer or this table, in the exhibit or whatever, they were transferring their learning to the real world which is real interesting.

Other measurements that the students noticed included a seismograph showing the intensity of local tremors in the Earth, and the height of layers in a glacier core. Alana noted that the seismograph was a highlight of the trip for her. She wrote:

I was able to engage them in a short discussion about earthquakes and the seismograph as a kind of measurement by asking questions to help them better understand the machine: Do you know what an earthquake is? How do you think this machine measures vibrations underground? Why do you think that we do not always feel earthquakes? By having this question-and-answer session at the actual machine as it was updating in real time, the students were able to see that a seismograph is a different kind of measurement while learning a bit about earthquakes. A similar moment occurred at the petrified tree, where I explained that tree rings can be read like a timeline, with each ring representing a year in the life of the tree.

Another form of evidence of learning that Alana and Linda noticed was that students were asking many questions. For example, Alana wrote:

...students were asking questions about the rocks that they found particularly interesting or cool. These questions were either answered by reading aloud the labels or asking a docent to explain them. When we approached the iron-banded rock, striped with black and red bands, the docent brought out a magnet and explained to the children that the iron is magnetic, how the rock became banded over time, and how the bands represent the presence of certain molecules in the atmosphere during the earth's early years. The students then all discussed how old the earth must really be and how it was cool that the rock could hold up a magnet. They then measured the height of the rock using their hands. The experience at this particular rock highlighted self-guided learning and the importance of exploring

what you find interesting, with some help and information provided by someone who is knowledgeable about it.

Thus, having begun by wondering how they were going to incorporate measurement into a field trip at the museum, Linda and Alana emerged with the sense that the possibilities were limitless. As Alana concluded:

A unit on measurement in science lab lends itself to an almost endless array of possibilities for a museum field trip, since measurements of all kinds can be found in almost every aspect of science learning. It is for this reason that we chose to focus our field trip on a large exhibit that mainly addresses geology, the creation of Earth and the many geological features that we see around us. While learning about rocks may seem fairly abstract on the surface when considered in relation to measurements, this exhibit provided the perfect hands-on opportunity for our third-grade students to learn about an interesting new topic while practicing and solidifying skills that they have previously been learning in science lab.

At the conclusion of the teachers' presentations, the museum educator, Louise, told Linda and Alana:

You really made very creative uses of the halls, in ways that are very interesting and refreshing....to see how you're using the halls, I love...I mean I could point out something in everybody's presentation. I knew you were going to go for the petrified wood when we were talking together in the hall, and I liked the way you used that.

Louise has been an educator at the museum for many years. Her assessment of Linda and Alana's field trip design makes a strong statement about our success in scaffolding teacher learning in ways that would support creative use of resources like the museum. In the following section, we elaborate on some of the important linkages we see in this case between teacher learning, teacher practices, and student achievement.

DISCUSSION: EVALUATING EVIDENCE OF TEACHER LEARNING

This case begins to trace linkages between seminar activity structures and the goals teachers begin to incorporate into their teaching. For example, the first practicum assignment helped Linda and Alana formulate the goal of more explicitly positioning students as scientists, and this goal was evident in their reflections and in the design of their lessons for the remainder of the semester. Another facet that resonated with them was the role that play could have in engaging students in learning science. Linda and Alana consistently experimented with this idea across the semester, although constraints related to classroom management interfered with fully

implementing a play-debrief-replay model in their classroom. Their field trip lesson incorporated aspects of play or free-choice time into many activities at the museum. In addition, the student interviews for the second practicum assignment helped Linda and Alana formulate the goal of helping students contextualize their understandings of measurement. Their struggle to create a field trip connected to measurement at a natural history museum served to transform their understanding of the array of contexts available for teaching measurement.

Developing the field trip unit, with pre-visit, visit, and post-visit lessons, is required for the course and in many ways serves as the culminating activity for the teacher teams. This case provides clear evidence of teacher learning from the seminar assignments, from the museum, and from students. The teachers clearly structured their field trip lesson with a clear plan of action, as well as a combination of structured and unstructured student engagement strategies. Alana's reflection shows that the use of this approach was intentional:

The mix of structured and unstructured engagement, as outlined by James Kisiel in "An Examination of Field Trip Strategies and their Implementation within a Natural History Museum," (Kisiel, J. (2006)) worked well in our particular situation because we had so many students.

Although the unit clearly demonstrates many aspects of teacher learning, one key focus of the seminar—the notion of equity and ensuring that all students are learning—was not as well-developed. For example, the idea of using checklists to evaluate students' skills with measurement arose in several of Alana's reflections on classroom lessons:

With so many pairs running around the room, it was difficult to ensure that both students were sharing the measuring responsibilities. A future assessment to guarantee that all students know how to use the meter stick would be, as Wasserman suggests (Wasserman & Ivany, 1996), to go around to each student one by one as they are measuring objects and have each student show me how they do it, without the aid of a partner. I could keep a checklist with me and check off who is comfortable with the meter stick and who needs more practice.

However, the team never incorporated this idea into their instruction. The field trip had a clear plan of action for the class as a whole, but there were no indications in the lesson plan, the reflections, or the museum presentation that Linda or Alana considered how they might need to adapt the overall plan for individual students' needs. Although most students completed the booklets, they serve more as a record of what students did than of what they actually learned. In addition, no mention was made of the few students who did not complete the workbooks, and no discussion of why they might not have done the work. Finally, in the two formal assessments

that the team administered—a quiz and a performance-based assessment in which students had to rank three objects according to mass, predict the mass, and then measure and record the actual mass—there were no modifications for individual students' needs.

CONCLUSIONS

This study documents a set of practices designed to support teacher learning that spans formal and informal science learning contexts. From the findings we can begin to draw clear linkages between what and how teachers are learning, some of the impacts on their practices, and some of the impacts on student learning. We can also see instances where teacher learning falls short of teacher education goals, which may have a negative impact on student learning, particularly from an equity perspective. One significant finding that provides a more nuanced look at teachers' strategies during museum field trips is the role of structured versus unstructured strategies at meso and micro levels of instruction (Kisiel, 2006). We found that at the meso level, teachers had an overall plan that primarily called for structured student engagement strategies, in the form of a workbook, rotating stations, and writing prompts. However, they also incorporated unstructured student engagement strategies, both in the form of a brief play period when students first arrived at a station in the museum and in giving the students free choice of which rock they would observe more closely and measure. In addition, at the micro level of student-teacher interaction, many of the conversations between students and teachers could be classified as unstructured engagement, with teachers responding to students' interests, helping students interpret exhibits, connecting concepts to the classroom curriculum, facilitating student thinking, reading labels, orienting students to the next exhibit they would be seeing, and facilitating free exploration.

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