Models of Inquiry-based Science Outreach to Urban Schools

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ABSTRACT

A primary obstacle to urban precollege geoscience education is limited access to inquiry-based geoscience experiences that are engaging and relevant to students' lives. Opportunities are reduced by the common misconception that the geosciences are less relevant to urban audiences and by the financial limitations of many urban school districts. The Paleontological Research Institution (PRI) developed two outreach programs for urban elementary school classrooms. *Collections Connections* engaged students in the natural sciences through the collection, curation, and exhibition of natural objects found in a local urban park. *Devonian Seas* involved students in authentic paleontological research through data collection and analysis of fossil samples. Grant-supported outreach programming reduces financial obstacles to participation and allowed the PRI to reach diverse audiences that may not otherwise have contact with museum educators. Evaluations of the PRI educational programs have identified four pedagogical approaches integral to successful outreach in urban elementary schools, and precollege classrooms more broadly: 1) providing students with opportunities to observe real fossil specimens catalyzes learning; 2) local examples connect classroom content to students' everyday lives; 3) interdisciplinary topics are a springboard for teaching across curricula; and 4) authentic research experiences teach students that science is something they can do.

INTRODUCTION

We live in an increasingly urban world. In fact, nearly half of all people, globally, currently live in cities (United Nations, 2004). By 2030 this is projected to increase to nearly 60%. In the United States 80% of the population now resides in urban areas. Despite the large numbers of students educated in urban schools, only recently have geoscientists begun to teach students in urban areas about the geoscience issues affecting their communities (e.g., Barstow and Haddad, 2002; O'Connell et al., 2002). This is unfortunate because urban students with fewer experiences with geoscience may assume it is less relevant to their lives. As urbanization continues, studies are needed that detail effective strategies for teaching geoscience in an urban context (e.g., Kean and Enochs, 2001; Wetzel, 2002).

Efforts to improve urban geoscience education are also essential to enhancing the diversity of the geosciences. Demographic data reveal a clear disparity between the representation of many ethnic groups within the U.S. population and within the geosciences profession (Table 1). For example, African-Americans compose roughly 12% of the U.S. population, but only 1% of employed geoscientists with a doctoral degree. Similarly, Hispanics make up roughly 12% of the population though only 2% of Ph.D. geoscientists. Over 85% of geoscientists currently employed with a Ph.D. in the U.S. are White, non-Hispanic. This pattern of under-representation is also apparent at the undergraduate level (Table 1).

A primary way to increase the involvement of minority groups in the geosciences is to provide experiences with inquiry-based geoscience education during elementary and secondary school. Studies have shown that students with positive early experiences with science are more likely to continue in science (e.g., Nazier, 1993). As approximately 91% of minorities in the U.S. reside in urban areas, efforts to enhance geoscience diversity necessitate increasing effectiveness of educational strategies in urban settings (United States Census, 2000).

At the Paleontological Research Institution (PRI) we have concentrated on providing urban students with access to inquiry-based science experiences through museum educational outreach. In this paper, we describe three primary obstacles to improving urban geoscience education and then discuss two of the programs we have developed that have been offered to urban elementary school classrooms in central New York. We describe the goals and structure for each program and present evaluation data gathered from participants. Our findings suggest four best practices that have been integral to our programs and which can be employed in other urban outreach efforts.

OBSTACLES TO URBAN GEOSCIENCE EDUCATION

A variety of challenges exist to engaging students from urban school districts in the geosciences. These include: 1) the perception that urban environments are unnatural; 2) financial limitations in lower income urban school districts; and 3) limited English proficiency for a significant number of students in urban classrooms.

Perception of urban environments as unnatural - The misconception that the geosciences, and natural sciences more broadly, are less relevant in urban settings pervades popular thinking and poses a challenge to urban geoscience education. This sentiment is rooted in historical definitions of nature that have tended to restrict the study of natural phenomena to 'wild' areas and other rural settings (e.g., Cronon, 1995; see Berkowitz et al., 2003 for discussion of the emerging field of urban ecology). Some teachers with whom we have partnered have verbalized their belief that urban students live in greater isolation from natural phenomena than rural students, who they perceive to be 'surrounded' by nature. While urban environments may pose unique challenges to some traditional field-based geoscience activities, these are not insurmountable. For example, Haywick (2002) and Wetzel (2002) note the general paucity of accessible rock outcrops within urban

	% geoscientists employed with a Ph.D.	% of undergraduate geoscience majors	% within U.S. Population
African-Americans	< 1%	1%	12%
Hispanics	2%	3%	12%
Asian/Pacific Islanders	8%	2%	4%
American Indians	< 1%	< 1%	2%

Table 1. Statistics on Ph.D. Employment in the geosciences, undergradute geoscience education, and demographics of the U.S. population by minority group. Data available from the National Science Foundation Geoscience Diversity Initiative (National Science Foundation, n.d.).

areas but provide suggestions for alternative approaches. Many geoscience phenomena are manifested in urban settings. While some of these have been used in construction or landscaping, materials such as rocks, soils, and gardens as well as urban floras and faunas can all be used creatively in urban geoscience activities.

Limited financial resources - Financial limitations in some urban school districts pose a challenge to providing students with an adequate education (United States General Accounting Office, 2002; The Education Trust, 2002; 2003). The case of The Campaign for Fiscal Equity vs. New York City (2003), for example, ruled that students in the New York metropolitan area were not receiving their constitutionally mandated basic education. While per-pupil spending differences between inner city and suburban schools have been shown to vary among metropolitan areas, inner city schools typically have older infrastructure, larger class sizes, less experienced teachers, and fewer educational resources (United States General Accounting Office, 2002). When per-pupil spending is adjusted for a variety of educational costs (e.g., educating non-native English speakers), school districts that serve areas with high-poverty consistently spend less per-pupil than those located in low-poverty areas (The Education Trust, 2002; 2003). In other words, students in many urban public schools have more limited access to school resources and perhaps fewer opportunities for scientific enrichment than their peers in other school districts.

In our experience, outreach program fees are covered in a variety of ways: grant support, parent-teacher organizations, individual teachers or parents, and by the school district. In a lower income community, far fewer external sources of financial support are typically available for science enrichment programs. Limited financial resources may pose a primary obstacle to participation in some in-school and extracurricular enrichment activities that explore the natural environment (e.g., field trips).

Limited English proficiency - In many urban schools, classrooms contain a significant proportion of students who do not possess certain basic English reading and writing skills (United States General Accounting Office, 2002). This is due to a variety of factors, including the presence of students who are learning English as a second language. Within the public school system in New York State there are approximately 200,000 students considered to have limited English proficiency; these students come from over 135 different language backgrounds (New York State Education Department, n.d.). Effective education of students with limited English proficiency requires additional resources, (e.g., teachers, tutors, books), yet these resources are not often accounted for in school budgets (United States General Accounting Office, 2002). In our experience, it is not uncommon to visit classrooms in which recently immigrated students are combined with native English speakers in the same classroom without obvious sources of language support. Beyond financial challenges, limited English proficiency poses an obstacle to conventional methods in science education which rely heavily on assimilating information through lecture and textbook learning.

These three obstacles may be overcome, in part, through museum educational outreach. The development of grant-supported outreach programs can reduce financial obstacles to participation by bringing educational resources directly to participants. Through the incorporation of local examples, outreach programs can also help to eliminate misconceptions about the nature of urban environments and help students to connect geoscience classroom content to their lives. Furthermore, project-based outreach programs provide opportunities for students of a wide variety of learning styles and backgrounds to participate in inquiry processes.

EDUCATIONAL OUTREACH AT THE PRI

At the PRI, we provide educational programming to students from a broad range of socioeconomic backgrounds. These programs draw on students' intrinsic interest in fossils as a starting point for covering scientific processes and content across their curricula. Our programs are largely underwritten by state, federal, and corporate grant support, allowing us to alleviate some of the financial hurdles to participation and engage students that may not otherwise have access to such activities.

Demographics of schools served by the PRI outreach programs - Since 1999, we have offered outreach programming to schools located within an approximately 160 km radius of Ithaca, New York, with the majority of programs concentrated in the Ithaca, Syracuse, and Utica city schools and surrounding rural and suburban districts. Syracuse and Utica are two of the largest urban areas within central New York, with metropolitan populations of approximately 732,000 and 300,000, respectively (United States Census, 2000). In our outreach area, the number of students eligible for free and reduced-price lunch (a proxy for family income) is generally greatest among urban schools, reaching up to 75% of the student population in some instances (New York State Education Department, 2000). Our outreach area includes urban schools where 5 to 9% of students are considered to have limited English proficiency (New

Introduction	1. Introduction to *Collections Connections*
Field Work	2. Field work in local urban park
	3. Sorting and classifying specimens
	4. Mapping
Study & interpretation of specimens	5. Interpretation of geological specimens
	6. Interpretation of biological specimens
Museums	7. Introduction to natural history museums
	8. Building classroom natural history collections
	9. Building classroom exhibts
Virtual Museums	10. Marking a virtual museum exhibit online
	11. Viewing class website

Table 2. General outline of *Collections Connections* programming.

York State Education Department, 2000). Between 1999 and 2003 we offered approximately 500 programs at over 100 schools, involving over 5,000 students; roughly half of the programs were offered in urban schools. These programs were developed for a wide range of educational levels (K-12), though most were offered to elementary school classes. The *Collections Connections* and *Devonian Seas* programs were developed explicitly with urban classrooms in mind and are discussed here.

Collections Connections - The *Collections Connections* program was designed to teach urban elementary school students about natural history through the process of creating, interpreting, and exhibiting a collection of natural history objects gathered from around their neighborhood (Figure 1). Creating a classroom museum from collected objects is an effective pedagogical strategy as it increases student awareness of their local environment, uses familiar and inexpensive objects as a basis for science education, exposes students to a variety of learning styles, and links science to other aspects of the curriculum (Ross, 2000; Russell, 1998). *Collections Connections* was pilot tested in fifth grade classrooms at Beverly J. Martin Elementary School, located in downtown Ithaca. The program involved 2 fifth grade classrooms each school year from 1998-2000 and was supported though a grant from the Shell Foundation. The grant enabled the PRI to offer an extended series of about 11 sessions for each class, and to bring the classes to the PRI for a tour of the exhibits and collections (Table 2.)

Classes participating in *Collections Connections* were introduced to the program through a field trip to the PRI and an interactive presentation on natural history and museums. After this introduction students went on a field trip to a small (1 square city block) urban park located a few blocks from Beverly J. Martin Elementary School. During this session, students collected and documented natural history specimens (e.g., rocks, twigs, and leaves) found in the park and along the sidewalks in transit to and from their school. A specimen label that contained locality information was created by the students for each object they found. This portion of the program emphasized the development of student observational skills through the process of collecting and studying natural objects. Student collections then served as a jumping off point for teaching about classification and mapping during subsequent sessions.

Students were asked to classify objects according to a system of their choice (e.g., texture, shape, organic/inorganic), and then contrast their classification scheme with those generally employed by scientists. Students then mapped their objects on a local city map and were asked to discuss why the location of their specimens was an essential piece of information for the interpretation of the nature of their neighborhood. Once classified, students' specimens were the source of discussions during follow-up sessions on regional geologic history, Earth processes such as weathering, and the natural urban environment. Students invariably also collected pieces of manmade materials (e.g., asphalt and brick) during their field trip. Rather than invalidating these finds as somehow outside the focus of natural history, these were instead incorporated into a discussion of the natural origins of manmade objects and their place in the natural history of their neighborhood. Several sessions were devoted to discussing the scientific meaning of their specimens and how they might be used within the context of a classroom museum exhibit to tell the story of the local environment.

In subsequent sessions, students worked in small teams to write exhibit text, illustrate their specimens, and interpret their findings for younger student visitors who took classroom museum 'tours.' During this process, students elected to participate in certain areas in which they had interest and strength, thus engaging them in activities in which they had confidence. They could elect to work as curators, exhibit designers, or exhibit developers. For example, a student with strong organizational skills might choose to play a role as curator within the classroom museum, a student with strong written communication skills may write labels as an exhibit developer, and a classmate who enjoys drawing might create artwork as an exhibit designer. Communication was especially important during this portion of the program, and could be accomplished in a variety of different ways (i.e., through drawing, writing, or speaking). This format provided opportunities for participation by all students including those with limited English proficiency who could play important roles in the exhibit "teams" as curators and exhibit designers.

To enable students to see their experiences within a broader context and explore the world of other museums, students visited museum websites in a school computer lab. In the first year, the culmination of the project was creating a virtual museum exhibit of their classroom specimens with digital images and interpretive text (Ross, 1999). In the second year, capstone experiences included field trips to the PRI and then to the American Museum of Natural History in

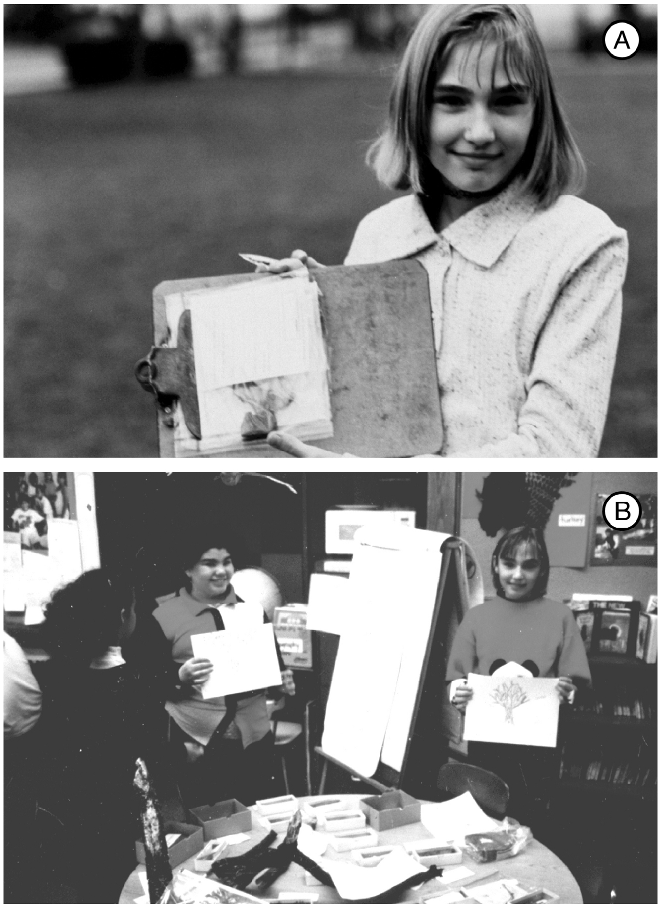

Figure 1. Fifth grade students participating in *Collections Connections*. The program engaged students in all the steps of making a museum, from specimen collection and identification, to interpretation, and exhibition. 1A. Student collecting natural history specimens near her school and recording locality information. 1B. Students displaying their classroom museum, complete with exhibit labels and interpretive artwork.

New York City. These field trips served to reinforce important concepts about museums and collections, and provided students with additional contact with natural history specimens (e.g., examining the skull of a Tyrannosaurus rex, and searching for fossils in local Devonian-age shale).

Collection Connections was developed to be an inexpensive educational experience that drew upon local resources and trained teachers to undertake natural history projects in their surrounding urban environment. The project was intended, in part, to make teachers themselves aware that the varieties of building stone, gravel, cement and asphalt around them each have geoscience significance and can be connected to an inquiry-based curriculum. Moreover, if teachers run the project for several years their classroom will gradually accrue its own set of interpreted rocks and related objects that can be used in classroom activities. Most significantly, teachers who begin to look for the nature in their neighborhood may begin to integrate other urban geoscience observations such as landscapes, weather patterns, and other phenomena into their teaching.

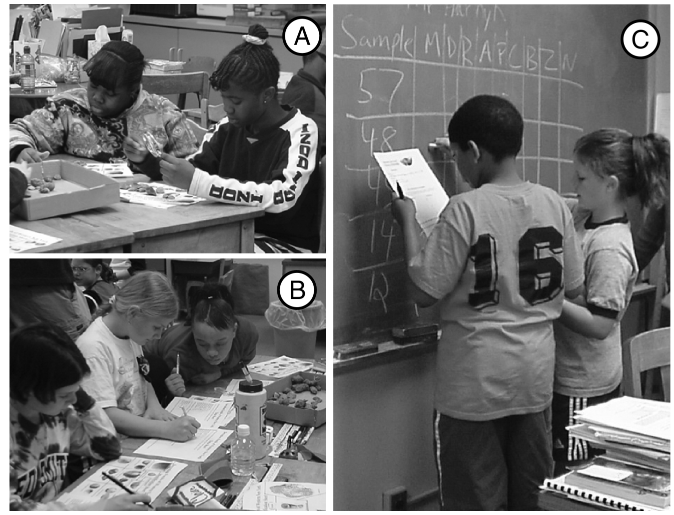

Figure 2. Fifth grade students participating in *Devonian Seas*. The program engaged students in authentic paleontological research through data collection and analysis. 2A. Students identifying Devonian fossil specimens. 2B. Students recording taxonomic assemblage data. 2C. Students compiling class data.

Devonian Seas - Like *Collections Connections*, the *Devonian Seas* project was designed to engage students directly in scientific processes such as classification and hypothesis testing. *Devonian Seas* differed, however, in its primary focus. Where *Collections Connections* took students through the process of collecting and interpreting natural history specimens, *Devonian Seas* was designed to engage students in authentic paleontological research using specimens collected by teachers during educator workshops led by the PRI (Harnik and Ross, 2003; Harnik; 2002). Such collaboration provides students and teachers with valuable inquiry-based experiences and scientists with important paleontological data (Harnik and Ross, 2002; Harnik, 2002; Lawrence, 2001; Thompson, 2003). Involving students at all levels in authentic research is a critical component of many recent educational reform recommendations (e.g., Handelsman et al., 2004; National Research Council, 1996). For example, the National Research Council (1996, p. 173) recommended that "for students to develop the abilities that characterize science as inquiry, they must actively participate in scientific investigations." Research experiences can play a powerful role in shaping student interest in science, but have traditionally been restricted to undergraduate and high school students who have demonstrated an aptitude for science (e.g., Council on Undergraduate Research).

Devonian Seas was initiated in spring 1999 with the goal of engaging fourth through ninth grade students in research on the Devonian marine fossils of central New York. Since 2001, this partnership has involved approximately 100 classrooms per year in Syracuse, Utica, and surrounding rural schools. Approximately 3,000 students have participated to date, with roughly 50% of these from urban schools. *Devonian Seas* has been supported by grants from the National Science Foundation Geoscience Education program and the GE Fund, which have minimized the cost incurred by participating schools. A nominal mileage reimbursement

	Collections Connections	Devonian Seas
Audience	5th Grade	4th-9th Grade
Format	11 45-minute sessions	1 60-minute sessions followed by ~ 60+ minutes of classroom research
Primary Focus	Local natural history; classroom museums	Regional paleontology; participation in authentic research
Educational Outcomes	Understanding of scientific processes; connections between art and science	Understanding of scientific proceses; how to document biotic change in the past
Affective Outcomes	Students, through using variety of skills, see how they could participate in museum science	Students, entrusted as collaborators, see themselves as scientists

Table 3. Comparison of *Collections Connections* and *Devonian Seas*.

payable to the PRI ($40-85 depending on travel distance) was charged per day of educational programming at each school.

For some teachers, involvement in *Devonian Seas* began with a 3-5 day workshop offered during the summer for which participants received in-service credit through the local school district. Field-based workshops served four primary purposes: 1) to introduce teachers to inquiry-based approaches in geoscience education; 2) to provide direct experience with the research questions and methods of the *Devonian Seas* project; 3) to collect fossil materials otherwise unavailable in urban settings; and 4) to engage teachers directly in geoscience research. During these workshops, teachers and staff from the PRI collected fossil samples for use in classroom research, created measured stratigraphic sections, participated in *Devonian Seas* classroom activities, and discussed inquiry-based science pedagogy.

Student involvement in the project began with a hands-on classroom program led by a scientist-educator from the PRI. These programs were offered each school year between October and June and were generally 60 minutes in length. During this introduction the students' role as scientists within the partnership was made clear. Students participated in reconstructing the geologic history of central New York through examination of sedimentary rock samples and fossil specimens from the PRI teaching collection. By making observations and proposing hypotheses within a guided-inquiry setting, students became familiar with the geologic history of the region and the inquiry-processes they would employ later during their research.

The next phase of the project consisted of classes collecting data on the abundance of different fossil taxa found in a bulk sample of Devonian marine sedimentary rock. Teachers generally facilitated this classroom-based research portion of the project. Small groups of students worked together to identify and count fossil specimens using identification sheets. Students recorded their data and then analyzed and interpreted their findings with the guidance of their teacher and the PRI scientist-educator (Figure 2). Discussions of their data informed student understanding of the geologic history of New York and of past biotic and abiotic change. On average classroom research took an hour, though several classes were known to extend data collection over several weeks of occasional 30-60 minute sessions. Completed data sheets were submitted in hard copy format to the PRI along with the fossil samples, student questionnaires, and post-program evaluations from participating teachers; an online form is in development that will allow students to submit their data electronically and see their contributions in a broader context (http://www.priweb.org).

Devonian Seas was designed to be accessible to different learners through its emphasis on hands-on activities involving the comparison and interpretation of fossil forms and through the use of image-rich educational materials. Providing students with authentic fossil samples on which to conduct research in the classroom also circumvented challenges associated with school field trips while still offering students opportunities for first-hand exploration of geoscience materials. Small-group research collaborations allowed each student to play an active role in aspects of data collection and analysis.

EVALUATION OF OUTREACH PROGRAMMING

Both *Collections Connections* and *Devonian Seas* have been evaluated by participating teachers and students using internal and external evaluation tools. Internal evaluations employed post-program, semi-quantitative questionnaires completed by participating teachers as well as surveys with more focused questions about program content, activities, and areas for improvement. External evaluations of *Devonian Seas* were conducted by Maria Lawrence and Molly Loomis of the Program Evaluation and Research Group (PERG) at Lesley University (Lawrence, 2001) and Stephanie Thompson of Seavoss Associates (Thompson, 2003). External evaluations were administered in both rural and urban schools.

Collections Connections - *Collections Connections* was evaluated in three ways at the end of each year through: 1) teacher surveys; 2) student surveys; and 3) student feedback gathered by teachers in open-ended classroom discussion. In addition, the PRI outreach educator (Ross) kept a journal during pilot tests and met with the teachers to discuss his observations and impressions. The evaluation focused on qualities such as student attitudes, interests, and awareness, in keeping with the overall goals of the series.

In the surveys, students were asked what they liked most and least, and what they found to be too difficult. Many students reported that they most liked the programs in which they created labels for specimens and made the exhibit, or best liked the activity to collect specimens in the local park. They liked least discussions of the science behind the objects, which students perceived to be overly lengthy. This suggests to us the need for more interactive and tactile approaches for these sessions. The process of creating the labels and museum exhibits required considerable coordination by the teacher and the PRI educator and necessitated teamwork among the students. While teachers and the PRI educator observed that this process was at times chaotic while students developed a system for working together, students indicated that they enjoyed the freedom to work independently from their teacher that led to an accomplishment that was readily seen by all (the exhibits). Few students reported that any aspect of the activity was difficult, but among those that did, the "rocks" part (identifying and interpreting the history of the rocks in the collection) was considered more difficult than other topics.

Personal observations made by the PRI outreach educator (Ross) revealed that students took a special interest in display of specimens that they had personally collected and frequently pointed out the particular specimens in the collection and exhibits that they had found. Teachers anecdotally reported that some students who were not otherwise academically active became more engaged with certain activities such as collecting objects or setting up exhibits. Many of the students had been to an art museum on a school field trip, but few had been to a natural history museum other than the PRI. The teachers frequently remarked to the PRI outreach educator during the series that most of the students in the class would not otherwise have any firsthand contact with museums or scientists. The teachers themselves were surprised at the number of educational museum resources available on the Internet.

Devonian Seas - *Devonian Seas* was evaluated through: 1) student and teacher surveys; 2) classroom observation by external evaluators; and 3) student and teacher interviews/small-group discussions with external evaluators. Participating teachers have indicated in the interviews and post-program surveys conducted by PERG and Seavoss Associates that the program satisfies their curricular goals and that their students enjoy and are actively engaged in the project (Lawrence, 2001; Thompson, 2003). One teacher commented during a post-program classroom interview: "I thought it was excellent. It was so good in so many ways… it gave kids a very good idea of it [paleontological research], and it made it real for them" (Lawrence, 2001, p. 33). Lawrence (2001) compared and contrasted the educational outcomes of *Devonian Seas* with other classroom outreach programs (e.g., *Dinosaur Science*) offered by the PRI, and found that participation in authentic research in the context of *Devonian Seas* engages students in inquiry-processes in a way that goes beyond other more traditional hands-on classroom programs. Thompson (2003, p. 9) also documented similar sentiments about authentic inquiry and quoted a teacher as saying that "answers are not always clear-cut," and that participation in *Devonian Seas* helped students to understand this. In addition, both Lawrence (2001) and Thompson (2003) found that students participating in *Devonian Seas* were aware that they were gathering real scientific data in collaboration with the PRI and took that responsibility very seriously. One fourth grade participant commented on a post-program survey, "there was a greater level of trust in us than I expected," while other students noted that this project was different from other classroom activities because this was real research and they (the students) were real scientists (Thompson, 2003). In an illustration of student awareness, Lawrence (personal communication) reported that a fifth grade student whose data sheet had been overlooked accidentally, told their teacher several times, 'they need my data,' until it was mailed to the PRI.

DISCUSSION OF EVALUTATION RESULTS

Collections Connections - The teacher evaluations suggest that future series might focus on a narrower topic. One of the challenges of working with a classroom only once or twice a week is that each session needs to devote time to reviewing material so that all students start each class engaged and with comparable background. Thus, it is important to work with teachers to promote ongoing maintenance of student interest and knowledge throughout the course of the program. Additionally, teachers perceived a need for more examples from which students can work, ranging from how to identify rocks to how to write the text for labels. Teachers seemed more concerned about themselves and their students knowing vocabulary, correct categorization, and factual information than was intended by the PRI educators. In fact, it became evident that a future goal should be to increase the awareness among participating teachers that natural history in general, and geology in particular are inquiry-based approaches linked to many other areas of human inquiry and not simply collections of facts and names to be memorized. It is important that teachers work collaboratively through the project, and that teachers receive opportunities for professional development before the series begins.

Devonian Seas - Primary areas for improvement within *Devonian Seas* center around improving project materials (e.g., identification keys) and developing ways to provide feedback to students after data collection has been completed (Thompson, 2003). The *Devonian Seas* project was designed to involve a relatively minimal time commitment on the part of participating classes, to allow it to be integrated with full class curricula, and adopted by large numbers of classes. Now the challenge for the PRI educators is to provide additional opportunities for students to work with data and learn about the results of their research after they complete the required components of the project. Some students expressed frustration working with rock samples that contained small, fragmented, or sparse fossils. Future classroom presentations by the PRI educators need to clearly outline some of the challenges of working with fossil materials that are poorly preserved (e.g., not being able to identify all fossils in a sample), in part, to adjust student expectations of the research process. The introductory program should make it clear to students that scientists also find it challenging to identify fragmentary fossils and at times are unable to gather data from every partially preserved specimen.

FOUR BEST PRACTICES

Evaluations of *Collections Connections* and *Devonian Seas* have highlighted four pedagogical best practices for programming in urban schools that are closely aligned with recommendations from American Association for the Advancement of Science (1993), National Research Council (1996), and Barstow and Geary (2001). These best practices may be particularly effective in urban classrooms as they validate student contributions and background knowledge, draw on interdisciplinary topics of interest, and provide students with access to experiences they might not otherwise have had.

1. Access to authentic materials - Providing students with opportunities to touch and observe real fossils to which they may not otherwise have exposure can be a powerful catalyst for learning. The comments of one fourth grade student are representative of much of the feedback we receive from program participants. "Thank you for coming to our classroom. We all loved the fossils especially the shark tooth and the wooly mammoth. I think paleontologists are cool people because they can discover new animals and plants." Hands-on experiences with real fossils can engage students who might not otherwise be active classroom participants by drawing upon their interests and by entrusting them to handle materials of scientific and cultural value. In addition, a hands-on approach provides opportunities for students of different learning styles, including those with limited English proficiency, to actively engage in scientific processes and content.

2. Use local examples - Using local examples connects classroom curricula to students' lives in a way that textbooks often do not. Incorporating local examples into classroom activities increases student confidence as it draws upon student experiences and background knowledge while demonstrating the connection between classroom curricula and student experience. This is reflected in the following fifth grade *Devonian Seas* participant's comments about the geologic history of their city: "I did not know that Syracuse was (once) an ocean with warm water. I thought it was always land before. I also did not know there was a difference in shells today than when Syracuse was an ocean." Drawings created by *Collections Connections* participants also demonstrate an investment and interest in the objects they personally collected and described and in the natural history of their urban neighborhood.

3. Incorporate interdisciplinary approaches and topics of interest - Using interdisciplinary approaches and topics of interest can be a springboard for teaching across curricula. Students who may picture science stereotypically as involving white coats and lab research, may feel more engaged when they learn that science can include approaches such as art, writing, and fieldwork. In *Collections Connections*, for example, students go into the 'field' and create their own collections of natural history specimens for which they later create interpretive exhibit labels and graphics. Exciting content, such as paleontology, that is interdisciplinary in nature, can also be used to reach a variety of content and process standards (e.g., Beaty and Fountas, 1992; Cook and Johnson 1996; Munsart, 1993; Scotchmoor and McKinney, 1996). For example, one fourth grade student commented, "I don't really like science or rocks, but fossils are my thing so this was great!" Furthermore, local examples can serve as an excellent means for meeting cross-curricular content standards. Students in the PRI outreach programs made connections between science and social studies/regional history through their interpretation of collected materials such as asphalt in *Collections Connections* and their reconstruction of the ancient marine environments of New York in *Devonian Seas*.

4. Engaging in research - Participation in authentic research teaches students that science is something that they can do (e.g., Hansen et al., 2003; Jarrett and Burnley, 2003). This type of experience can empower students to take an active role in their learning as reflected in this quote from a fifth grade student: "The coolest part of the exercise was that we were the scientists uncovering the evidence that we used to classify them." Another 5th grade student commented that the best part of the activity was "looking at the fossils because it gave me a head start on my career." Research collaborations involving scientists and precollege classes help to teach students about inquiry through direct hypothesis testing and data collection, and provide students with scientific role models. Students feel entrusted within such research partnerships and take their role as scientific collaborators seriously.

CONCLUSIONS

We must be committed to improving urban geoscience education in order to teach students about the environmental issues facing their communities, increase diversity within the geosciences, and provide equitable access to high-quality, inquiry-based science education. The *Collections Connections* and *Devonian Seas* programs provide two effective models for engaging urban students in the geosciences through museum educational outreach. These programs created opportunities for students to take ownership and responsibility for tangible, authentic, and exciting geoscience projects. Both outreach programs were hands-on and inquiry-based (Table 3). Both were also structured around students developing their own questions and hypotheses, and interpreting data individually and in small groups. These programs were also unified in their focus on engaging students in observation of regional and local natural history materials. Given the similarities between these two programs the question arises as to whether there are certain contexts in which one approach might be preferred over the other.

Though similar in goal, the two outreach approaches differ in their structure, content, and associated activities (Table 3). *Collections Connections* was designed as a series, which featured longer-term interaction with the PRI educator and more in-depth inquiry and content. This format was more time-intensive for both the PRI educator as well as the participating classes, which meant that relatively few classrooms were able to participate. In contrast, *Devonian Seas* was designed to be a relatively small time commitment for both classroom teachers and the PRI educators. This promoted the involvement of large numbers of students by facilitating easy integration into an already full curriculum and limited museum educator hours. Such a format necessitates the development of innovative ways to follow up with participating classes to provide feedback on student data and project research.

Collections Connections, through its focus on involving students in all aspects of collection creation and exhibition, connected students closely with their local urban environment and engaged students in using a diverse array of skills applied to understanding and communicating natural history. Our experiences show that students in urban neighborhoods can find objects for a natural history collection and will take personal interest in them. The identity of the specific objects in this case is less important than the process of learning about the objects and sharing that information with others. In *Devonian Seas*, students were also involved in finding objects by using materials provided by the PRI. *Devonian Seas* participants came to see themselves as scientists through their direct engagement in research and collaboration with the PRI staff. Perhaps future work could investigate ways to integrate these two approaches into a multi-stepped program for classes willing to commit a greater portion of their school year. Engagement in paleontological research could be undertaken first, after which students could create collections from their own neighborhood that would then be interpreted using the research approaches with which they had gained familiarity.

In closing, the following overarching point must be made: while this issue of the Journal of Geoscience Education is focused on ways to improve urban geoscience education, many of the approaches presented here are not only suited for urban classrooms. In fact, the best practices discussed here are broad guidelines for engaging any audience in scientific inquiry.

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