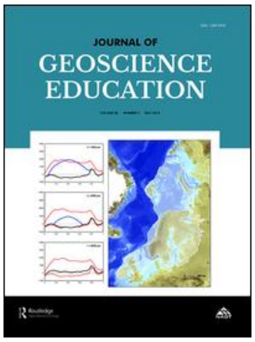

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ABSTRACT

All across the nation, Earth science knowledge among both students and their teachers in middle and high schools has been substandard, and particularly so for underrepresented minorities in science, technology, engineering, and mathematics (STEM) education. In New York City, a geoscience program was, therefore, developed to assist in ameliorating this problem. For middle and high school students and teachers, the program (1) provided pedagogical, research, and inquiry-oriented geoscience experiences; (2) offered pedagogical and research standards-based professional development in Earth science for teachers; (3) promoted geoscience inquiry and engagement via a three-dimensional, online virtual environment in which geoscience concepts were demonstrated, taught, and explored; (4) afforded students and teachers exposure to the geosciences through geoscience events and seminars; and (5) sponsored community-based geoscience outreach activities. Results from the program have shown noteworthy increases in students' understanding, participation, appreciation, and awareness of the geosciences. Altogether, the initiatives above combined geoscience learning opportunities, exposure, and research experiences with eager cohorts of geoscience learners to produce holistic, engaging stimuli for the scientific and academic growth and development of grades 8–12 student and teacher participants. [DOI: 10.5408/13-101.1]

Key words: academic support, diversity, geoscience research experiences for high school teachers and students, program design, underrepresented minorities, virtual worlds

INTRODUCTION

Recent reports and studies have pushed the nation's science, technology, engineering, and mathematics (STEM) crisis to the very forefront of educational reform discussions and strategic planning and have easily made the argument that this crisis threatens not only the United States' global competitive edge, but its national security as well. The American Competitiveness Initiative of the Bush Administration (Domestic Policy Council, 2006), the Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future report of the National Research Council (Institute of Medicine, 2007), the Obama Administration's Educate to Innovate Initiative (The White House Office of the Press Secretary, 2009), the new $100 million government/private industry initiative to train 10,000 STEM teachers and to graduate one million additional STEM students over the next decade (The White House Office of the Press Secretary, 2012), and the report to President Obama from the President's Council of Advisors on Science and Technology (2010) are just some of the landmark studies that have propelled this crisis into the national spotlight.

The American Geological Institute (2011) emphasized that the United States is facing a critical shortage of geoscientists at a time when the demand for them is actually increasing, and that the geoscience workforce is predominantly comprised of Caucasian males who are near, at, or past the retirement age. The imbalance in the age demographic is a concern. The study reported that the percentage of geoscientists between 31 and 35 years of age is less than half the number of geoscientists between 51 and 55 years old. Jackson (2003) purports that the decline in the number of students in the geoscience pipeline, coupled with increasing rates of retirement among persons trained in the early 1960s, points to a potential resource crisis and deficit, particularly as fewer students from underrepresented groups (African-American, American Indian or Alaska Native, Hispanic or Latino, Native Hawaiian, or other Pacific Islander) pursue advance studies in the geosciences.

During this century, the ethnic demographics of the United States are expected to reverse so that the current minority population is anticipated to become its majority. This population-shift forecast raises grave concerns in light of the underrepresentation of the current minority population in the STEM disciplines in general and in the geosciences in particular. In 2009, a National Science Foundation report (NSF; 2009) documented that 22.7% of the traditional college age students (18–24 years of age) in the United States were from underrepresented minority (URM) groups. However, these students earned only 13.7% of all bachelor's degrees in the STEM disciplines. The American Geological Institute (2011) reported that, compared to other science and engineering fields, the geosciences confer the lowest percentage of bachelor's degrees to URMs. The study also reported that the percentage of geoscience degrees earned by underrepresented minorities is less than 10% at the bachelor's, master's, and doctorate levels combined. Gates and Mirkin (2012) further highlighted this ethnicity and diversity attainment gap in the geosciences at the national level. In a more recent study on the status of recent geoscience graduates, the American

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Geological Institute (2013) reported that, although the gender gap appears to be closing at the bachelor's and advanced degree levels, minorities are still severely underrepresented in geoscience departments.

The American Geological Institute (2011) noted that, over the past 18 years prior to the study, only 11%–15% of seventh and eighth graders formally take a year of Earth science and between 1993 and 2006 only a few K–8 teachers had geoscience degrees. The report highlighted that teachers most commonly possess degrees in fields other than science and engineering. For the past 26 years, approximately only a quarter of high school students enrolled in an Earth science course. Consequently, while enrollment rates in physics and chemistry courses have been increasing, the enrollment rate for Earth science has remained stagnant. Projected market demand and current enrollment trends suggest that, within the next decade, the United States may experience a serious shortfall in the number of engineers and scientists needed to fill jobs. For the United States to remain competitive in this global technological society, it must take serious steps to create a diverse, well-trained, multicultural STEM and geoscience workforce. The ability to attract more minority geoscience students, including young women, is a significant challenge faced by the academic community and corporations with a stake in the nation's technological future (Collins, 2003).

Like that of the nation, formal and informal geoscience academic outcomes in New York State remain inadequate. In New York City, for example, middle school students are required to take the Intermediate Level Science Test (ILST) of which Earth science is a component, while high school students have the option of taking the Earth Science Regents exam. Both exams are part of the Earth Science Core Curriculum that supports the New York State Learning Standards for Mathematics, Science, and Technology. Students are generally tested on their major understandings, skills, and real-world applications drawn from the following eight subject areas: Size, Shape, and Composition of Earth; Mapping; Rocks and Minerals; Weathering, Erosion, Deposition, and Landforms; Earthquakes and Plate Tectonics; Earth History; Meteorology and Climate; and Astronomy. In a recent 2011–2012 ILST report (New York State Education Department, 2012), the statewide pass rate for students who scored at Level 4 (the highest level) was 24%. However, the mean ILST Level 4 pass rate for African Americans was 7% and that for Hispanics was 10%. Comparably, for high school students taking the New York State Earth Science Regents exam (New York State Education Department, 2013), only 8% of African Americans and 12% of Hispanic students scored at or above 85. These statistics reflect the overall bleak state of the geosciences in New York, particularly among underrepresented minority students.

SUCCESSFUL GEOSCIENCE INITIATIVES

Many research-based, best-practice initiatives to enhance access and success in the geosciences for underrepresented minority groups have been successfully implemented. Levine et al. (2007) determined that these geoscience initiatives were successful in part because they (1) integrated outdoor activities and experiences; (2) included field trips; (3) provided early research experiences; (4) utilized place-based teaching; and (5) fostered a geoscience departmental culture that had social and cooperative structures that students found inviting and supportive. Indeed, the entire Special Issue: Broadening Participation in the Earth Sciences of the *Journal of Geoscience Education* (Riggs & Alexander, 2007) is replete with studies that focus on successful strategies for diversifying the geosciences.

Silverstein et al. (2009) found that engaging New York City high school teachers in research helped to improve their students' achievement in science. The study also determined that there was a critical need for professional development to improve the teachers' scientific knowledge, pedagogical skills, and confidence. Colleagues at the University Corporation for Atmospheric Research (UCAR) Significant Opportunities in Atmospheric Research and Science (SOARS) program (Pandya et al., 2007) set forth the following eight design principles that have proven successful in recruiting and retaining minorities in STEM: (1) institutional leadership, (2) targeted recruitment, (3) engaged faculty, (4) personal attention, (5) peer support, (6) enriched research experience, (7) bridging to the next level, and (8) continuous evaluation. From their multifaceted geosciences seminars and career workshops outreach model for enhancing diversity in the geosciences, Stokes et al. (2007) in Buffalo, New York, found that having underrepresented minority students make presentations at Buffalo Public School events increased the effectiveness of the Buffalo Geosciences Program's (BGP) outreach efforts. Due to the BGP's initiative, the number of underrepresented minority students enrolled at the local higher education institution reached all-time high levels. At the University of Texas–El Paso, Miller and colleagues (2007) conducted a two-week geoscience summer program for Hispanic American high school students with strong interests and abilities in science and math. The program proved to be a highly effective strategy for inspiring interest in the geosciences. Short-term indicators show statistically significant positive changes in attitudes towards the geosciences while long-term indicators (survey results that tracked the participants' college careers) show a 55% retention rate in the geoscience pipeline. Additionally, Murray et al. (2012) found underrepresented groups of at-risk middle and high school students in the Detroit area who participated in geoscience research with their teachers and university faculty increased their awareness of the geosciences and their interest in pursuing a geoscience careers.

A PARADIGM FOR DIVERSIFYING THE GEOSCIENCES

City Tech's Geoscience Initiative

New York City College of Technology (City Tech), a comprehensive college and a designated Hispanic-serving institution, was awarded a National Science Foundation Opportunities for Enhancing Diversity in the Geosciences (OEDG) Program Track 1 Grant. The primary goal of the project was to increase participation in the geosciences of African Americans, Hispanic Americans, Native Americans, and Native Pacific Islanders. The grant, entitled *Creating and Sustaining Diversity in the Geosciences Among Students and Teachers in the Urban Coastal Environment of New York City*, focused on advancing public literacy in Earth system science by pursuing the following four objectives:

1. Equip educators with the tools to understand and convey knowledge in the geosciences;

TABLE I: Student, teacher, and class participants by institution.

Public Schools	Percentage of African Americans & Hispanics at Institution[1]	Number of Student Participants	Number of Teacher Participants in Geoscience Activities and Research	Number of LE Classes Participated in Geoscience Exposure Events	Number of LE Classes Participated in Virtual Explorations
MS394	96.1%[2]	76	3	2	–
UAI	92.0%[3]	56	2	2	–
City Poly	87.3%[1]	72	3	3	1
Westinghouse	94.7%[4]	1	1	–	–
Total		205	9	7	1

[1]New York State Education Department (2013c).
[2]New York State Education Department (2013a).
[3]New York State Education Department (2013b).
[4]New York State Education Department (2013d).

2. Engage students and teachers in general geoscience research;
3. Create geoscience academic pathways and enhance existing Earth science pedagogy to improve performance in the geosciences; and
4. Disseminate basic geoscience knowledge and raise public awareness to the critical nature and vulnerabilities of the environment.

Participants

The participants of the program belong to the urban coastal City of New York, and they have been impacted and have unique ties to the city's geophysical encounters of climate change, sea-level rise, coastal storms, coastal flooding, urban heat island, and extremes in heat and precipitation. The coastal location of this urban city provides a distinctive laboratory for geophysics, and, therefore, the awareness of these phenomena should be heightened for these participants. All the participants of the project experienced this urban coastal city's recent encounters with hurricane Irene, an earthquake, and Superstorm Sandy. Therefore, as the city begins to rebuild for resilience and sustainability, the knowledge (or at least the awareness) of the geosciences for these participants is paramount and extremely relevant.

To execute this project successfully, critical nexuses with minority-serving public schools (particularly those schools in which Earth science is not taught) and external partnerships with extant geoscience programs and initiatives were forged.

Public Schools

The following four minority-serving public schools participated in the project:

1. Mary McLeod Bethune Middle School 394 (MS 394);
2. The Urban Assembly Institute of Math and Science for Young Women (UAI), a public middle and high school for young women interested in mathematics and science;
3. City Polytechnic High School of Engineering, Architecture, and Technology (City Poly); and
4. George Westinghouse Career and Technical Education High School (Westinghouse), a public vocational school that offers instruction in skilled trades.

None of the four schools offers Earth science in its curriculum. Therefore, with the exception of Westinghouse High School, which had a science teacher and a student as participants in the project, Living Environment (LE) classes from each school were selected to participate in the project's geoscience activities as shown in Table I.

For all four schools, commitment from principals, senior administrators, and/or parent–teacher association coordinators was critical to garner full participation of the students. Without this strong support, the coordination between the science teachers, the students, the parents, and the project would not have been efficient and effective.

External Partnerships

Establishing external partnerships was essential to obtaining the resources needed to equip educators, impart geoscience knowledge, raise geoscience awareness, and provide opportunities in the geosciences. The following national organizations were partners in this project:

1. The Brookhaven National Laboratory (BNL), a national laboratory operated by Brookhaven Science Associates for the U.S. Department of Energy;
2. National Oceanic and Atmospheric Administration, Cooperative Research Sensing Science and Technology Center (NOAA-CREST), a multidisciplinary center involving several institutions of higher education focusing on remote sensing research applied to Earth, atmospheric, environmental, and marine sciences;
3. National Aeronautics and Space Administration, Goddard Institute for Space Studies (NASA GISS), a laboratory in the Earth Sciences Division of NASA's Goddard Space Flight Center and a unit of the Columbia University Earth Institution;
4. New York City Research Initiative Program (NYCRI), an education arm of NASA GISS that provides geoscience research and geoscience enrichment opportunities for high school students and teachers and for both undergraduate students and their professors; and
5. The Global Learning and Observations to Benefit the Environment (GLOBE) program, a K–12 initiative that engages students and their teachers in local and international research projects about global environmental change.

TABLE II: Program partners' roles and outcomes.

Partners	Roles	Outcomes
BNL NOAA-CREST NASA GISS	**Provided:**	**Participants:**
	Indoor/outdoor hands-on geoscience activities	Gained geosciences knowledge
	Laboratory tours	Found geoscience concepts interesting
	Presentations by renowned scientists	Expanded their understanding of the geosciences
	Presentations by high school research interns	Enjoyed learning about the geosciences
	Earth Day activities	Understood the relevance of the geosciences to their daily lives
NASA GISS NYCRI	Summer research programs for high school teachers and students	Gained geoscience research skills and experience
GLOBE	Teacher certification training in global environmental studies	Demonstrated that geoscience content contributed to their understanding of the geosciences
	Inquiry-based student research activities	Indicated that geoscience materials were useful for their professional development
		Received training in geoscience pedagogy and geoscience content

These national establishments provided vibrant and robust geoscience activities that aligned well with the expected outcomes of the program. Each partner played a unique role in achieving the objectives of the project as shown below in Table II.

Project Timeline

Figure 1 below depicts the project's two-year timeframe. The first year of the project was used primarily for planning and designing, and the project's second year was used primarily for implementing and testing. During the first year of the program and prior to its actual beginning, Internal Review Board (IRB) certifications from both the New York City Board of Education and from City Tech were obtained. Schools were selected, agreements were made, partnerships were forged, the virtual geoscience design team was assembled, and the geoscience exposure trips and the community outreach events were organized. During the second year, the summer geoscience research projects started, the virtual geoscience modules were piloted, the geoscience exposure trips continued, and the project was assessed and disseminated.

Critical Components of the Piloted Geoscience Program

The entire project—its goals, its objectives, its expected outcomes, and its activities—are all in concert with the best practice ideas that are mentioned above for successful geoscience initiatives. For example, Table III below shows how the five main activities of the project, namely: (1) professional development; (2) summer geoscience research; (3) virtually exploring the geosciences; (4) geoscience exposure events; and (5) geoscience community outreach programs were imbued and synergized with various elements of the SOARS program's best-practice ideas and initiatives. This alignment and mapping provided a framework that allowed for project tracking and evaluation via formative and summative assessments.

The five programmatic activities as outlined and aligned in Table III above are described below.

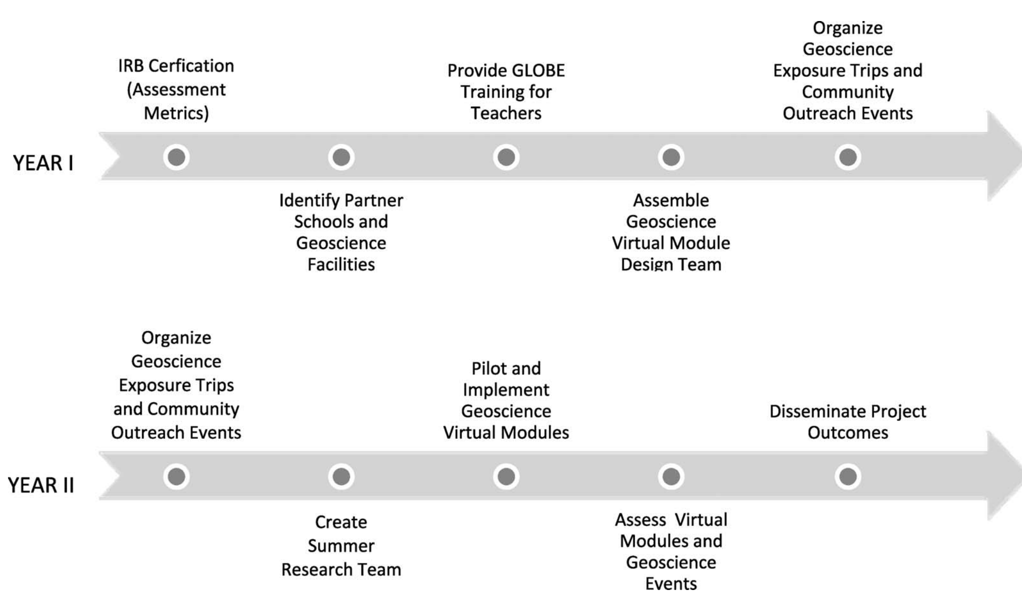

FIGURE 1: Chronological activities of the geoscience program.

TABLE III: Aligning program objectives, activities, outcomes, and assessment with SOARS best-practice STEM design principles.

Program Objectives	SOARS[1] Literature-Based Design Principles	Activities	Outcomes	Assessment Methods
Equip educators with the tools to understand and convey knowledge in the geosciences	Engage faculty	Professional development	Teachers increased:	Satisfaction surveys
	Institutional leadership		■ Understanding of the geosciences	
			■ Pedagogical skills	
Engage students and teachers in general geoscience research	Personal attention	Summer geoscience research	Teachers and students increased:	Interviews
	Peer support		■ Engagement in the geoscience	
	Enriched research experience		■ Geoscience research skills	
			■ Scientific communication skills	
Create geoscience academic pathways and enhance existing Earth science pedagogy and learning	Targeted recruitment	Virtually exploring the geosciences	Students increased:	Pre- and post-knowledge test
	Bridging to the next level		■ Understanding of the geosciences	
			■ Interests in the geosciences	Module feedback
			■ Knowledge of the geosciences	Surveys
Evaluate and disseminate basic geoscience knowledge and raise public awareness of the critical nature and vulnerabilities of the environment	Continuous evaluation	Geoscience exposure events	Students increased:	Satisfaction surveys
			■ Understanding of the geosciences	
		Geoscience community outreach programs	■ Interests in the geosciences	Feedback surveys
			■ Knowledge of the geosciences	
			■ Applicability of the geosciences	

[1]Pandya et al. (2007).

Professional Development

For teachers, especially of Earth science at both the middle- and high-school levels, the need for professional development to increase their science knowledge and pedagogical skills is critical (Silverstein et al., 2009). Additionally, access to resources and opportunities in the geosciences is urgently needed to support both their learning and their classroom experience. As part of this project's initiative, science teachers in the New York metropolitan area participated in a three-day GLOBE training and certification workshop at Queens College in New York City. The content of the three-day GLOBE certification workshop included the Atmosphere, Seasonal Change, Hydrology and Land Use Protocols, Earth Systems Science, GPS Use, GLOBE Database Entry and Retrieval, GLOBE Website Navigation, and Inquiry-based Student Research activities.

After the completion of the workshops, the teachers were awarded GLOBE certification. This certification permits them to participate in international GLOBE projects in which their students can contribute to worldwide research with other GLOBE collaborators. Additionally, the geoscience instruments (thermometers, flow meters, rock and mineral sets, water testing kits, barometers) used in the workshop activities were given to the participants so that they may utilize them in their classrooms and in pedagogical practices with their students thereafter.

Summer Geoscience Research

The National Research Council (2011) reported that high school students who had STEM research experiences were more likely to complete a STEM major in college than their counterparts who did not have such research experiences. The report further stated that professional development and research experiences are critical for teachers as they strive to develop their knowledge, experience, and pedagogical skills in STEM. To this end, the NASA GISS NYCRI program provided summer geoscience research experiences for three high school teams, with each team comprised of a teacher and an underrepresented minority student. Therefore, a total of six project participants (three teachers and three high school students) conducted state-of-the-art geoscience research at NASA GISS. The teams spent six weeks in the summer working with NASA research scientists, college professors, and college students.

The research enrichment experience included geoscience content and research seminars, visits to various geoscience research laboratories, visits to informal education institutions, and participation in local and regional research summits. Each of the three teams made both oral and poster presentations at an annual end-of-summer STEM symposium. The symposium usually has over three hundred participants from government agencies, from colleges, and from high school students in and around the New York City metropolitan area. The research projects that were completed and presented by the teams from this project were (1) Image Compression and Image Processing, (2) Satellite Retrieved Earth Surface Temperature: Averaging Process and Validation, and (3) Using Neural Network Techniques to Predict Surface PM2.5 Levels from Optical and Meteorological Data.

Virtually Exploring the Geosciences

To meet New York State and City Earth science standards, students must demonstrate geoscience understanding by correctly using geoscience concepts to describe observations, to make predictions, and to explain these concepts in multiple ways (verbally, written, and via diagrams, graphs, and charts). These components of geoscience understanding—interpreting, explaining, and

FIGURE 2: An example of using a virtual world to explore geophysical phenomena.

representing—are required to meet established standards that call for teachers to frame questions that elicit deeper student understanding of cause and effect. Students should also be able to identify and control variables in experimental and nonexperimental research settings, as well as to work individually and collectively in teams to assemble, synthesize, analyze, and share information and ideas.

In aiding students to meet the standards and requirements above, this project used the student-friendly virtual world to explore geophysical phenomena. The virtual vista of Second Life, a three-dimensional online virtual world, was used to provide students with a real-world inquiry-based geoscience exploration within a classroom setting. Studies have shown that computer-supported collaborative learning is one of the most promising ways to improve teaching and learning because academic success is socially motivated (Lipponen, 2002). Such collaborations can be effected via learning in online virtual worlds in ways that keep students engaged (Atkinson, 2008; Lansiquot, 2013; Russell, 2007). In Second Life, students were able to explore geoscience concepts by, for example, exploring the geophysical phenomena of sea breeze and orographic lifting on a peninsula and by making meteorological measurements as they ascend a virtual mountain (see Fig. 2).

Mountain Weather and Sea Breeze Virtual Modules

For the mountain weather module of orographic lifting, students were provided with an instrument that measures altitude, atmospheric pressure, relative humidity, temperature, and dewpoint temperature. As they ascended the mountain, they then had to figure out why, where, and how cloud formation occurs. The students were guided to grapple with the concepts of why windward sides of mountains have precipitation and lush vegetation and why leeward sides of mountains are rainfall deficient and often desert-like.

Building on the mountain weather virtual module lesson, the sea breeze lesson engaged students in the following concepts: (1) differential heating of land and water, (2) buoyancy and rising warm air that produce localized circulation, (3) the genesis of regional atmospheric low pressure and high pressure areas, and (4) air flow from regions of high pressure to regions of low pressure. Consequently, the sea breeze virtual module begins with exploring wind patterns, thereby providing students with an opportunity to explain these meteorological concepts. This is then followed by students using instruments to measure atmospheric pressure and air temperature and then graphing the collected data. These activities afforded the students a second opportunity to explain these concepts. Students then used pressure blocks to explain local atmospheric phenomena related to such concepts as sea breeze, day/night wind patterns, and peninsular versus coastal winds.

In order to improve student learning and to promote successful outcomes, students were first taught the geophysical concepts involved in the modules; they were then subdivided into teams of two or three students and given initial geoscience module exploration instructions and guided questions. They then went off on their virtual field campaign of exploration and data collection. After the field campaign, the students were expected to apply geophysical concepts to interpret, explain, and present the collected data.

Geophysical concepts, individual exploration, team fieldwork, and data synthesis and analysis were all indispensable to these inquiry-based learning activities. This virtual world geoscience learning paradigm is highlighted in Lansiquot et al. (2014). The geoscience virtual modules were created by this project with a team consisting of a geoscience faculty member, a postdoctorate scientist, a technical writing specialist, a learning specialist, a mathematics educator, and two high school science teachers. Material from this project will be available at the project's website. Until the website is fully operational, interested parties may contact the lead author for information.

Geosciences Exposure Events

Exposure trips allow students to experience the geosciences with an understanding and an awareness that goes beyond the classroom. The lectures and workshops from the visited STEM facilities provided firsthand experiences in understanding the geosciences. On these trips, students and teachers engaged in hands-on environmental science activities, held conversations with leading geoscientists, participated in guided tours of state-of-the-art laboratories, and engaged with interactive exhibits that demonstrate geoscience principles.

The state-of-the-art facilities visited by participants were selected based on their direct involvement and contribution to the geosciences. Furthermore, the affiliation of these facilities with institutions of higher learning provided easy access to STEM opportunities for the high school and middle school students and their teachers. The students were not only exposed to the geosciences, but they were also exposed to college settings that had academic and extracurricular STEM programs.

Community Outreach Programs

Community outreach programs for the geosciences are valuable and effective in attracting both students and the general public to the geosciences. In Buffalo, New York, Stokes et al. (2007) deftly used community outreach as an effective tool for generating awareness of and interest in the geosciences. Similarly, in its bid to raise awareness to the geosciences, the Virginia Polytechnic Institute and State University through its Department of Geosciences (http://www.geos.vt.edu) has for many years run a highly successful geoscience outreach program. This City Tech program was also engaged in geoscience community outreach events. The events focused on raising public awareness to the geosciences and on presenting information about geoscience careers. Some of these events included "Exploring Careers in the Geosciences," "Learning Geosciences by Doing Science," "NOAA-CREST Day: Celebrating Earth Day," "Climate Science and Climate Change," "Climate Change: Sea Level Rise—Brooklyn Under Water," "Superstorm Sandy," and "Probing and Understanding the Environment: Climate Change." Presentations by world-renowned geoscientists attracted much attention from the community. Dr. James Hansen, the then-director of the NASA GISS, delivered an extremely enlightening public presentation entitled, "Speak Truth to Power: Human-Made Climate Change—A Scientific, Economic, and Moral Issue," and Dr. Charles Vörösmarty, professor of civil engineering and a Distinguished Scientist with the NOAA-CREST of The City University of New York's Environmental Crossroads Initiative at the City College of New York, electrified students and the general public with a lecture entitled, "A Precious Resource Running Dry: The Coming Fresh Water Crisis." All of the geoscience community outreach events were instrumental in spreading and raising awareness of and interest in the geosciences among young students, their teachers, and the general public.

ASSESSMENT METHODS, LIMITATIONS, AND RECOMMENDATIONS

Assessment Methods

The project's five components were assessed by way of pre- and posttests, surveys and/or interviews (Table III). A satisfaction survey was administered for the professional development component soliciting (1) how much a workshop presenter's knowledge and ability contributed to the participants' understanding of the geosciences, (2) the usefulness of the content, and (3) whether or not that component met the expectations of participants and, therefore, warranted a recommendation to other potential participants. Teachers participating in the summer research component of the program were interviewed. The virtual exploration of the geosciences component of the project incorporated a pre- and post- knowledge test of the geoscience concepts learned through using Second Life, and a module feedback survey was conducted. A paired sample t-test was also used to statistically show significance in knowledge gained. For the geoscience exposure events component, a satisfaction survey was given to the participants after each geoscience exposure event. A t-test was conducted to show statistical differences in middle and high school students' responses, and two community events with presentations by renowned geoscientists were assessed with feedback surveys.

Assessment Limitations

The primary goal of the project was to create a model program to pilot several geoscience activities that would effectively increase the interest, awareness, and support of the geosciences among the underserved populations. Gauging the effectiveness of these activities is paramount; however, a complete assessment was limited by the following two critical hindrances:

1. A two-year study, with a first year for planning and designing and a second year for testing and implementing, is insufficient to conduct and produce

TABLE IV: Teacher's mean responses from the GLOBE workshop. Survey scale with 1 = strongly disagree and 5 = strongly agree.

Statement	Mean ($n = 5$)
1. Program was well organized.	4.8
2. Presenter's knowledge of the content contributed to my understanding.	5.0
3. Presenter's ability to communicate contributed to my understanding.	5.0
4. Program was consistent with the description in the announcement.	4.6
5. Material presented was useful for my professional development.	4.0
6. In general, I was satisfied with the content of the program.	4.8
7. The program met or exceeded my expectations.	4.6
8. I would recommend those or other similar programs to my colleagues.	5.0

a proper longitudinal measure of the effectiveness of the geoscience activities. For example, the impact of the summer research experiences for high school teachers and students, the demonstration of knowledge gains on standardized Earth science exams, and the "pipelining" of the students to geoscience majors and careers cannot be measured in the allotted timeframe.
2. Inflexible middle and high school curricula scheduling retarded implementation of new pedagogical geoscience knowledge and activities.

Assessment Recommendations

To ensure a viable geoscience learning model that can be established for replication, the following are recommendations proposed to overcome the assessment limitations outlined above:

1. An increase in the number of science teacher and student participants would enable the use of statistical analyses to measure the effectiveness of the interventions;
2. A longitudinal study designed to understand to what extent the knowledge gained by the teachers from the professional development component enhanced geoscience competency among the students; and
3. A longitudinal study to measure the attitudinal change and impact of the geoscience activities.

RESULTS

The assessment results for each of the geoscience components are described and reported below.

Professional Development

For professional development, there were five high school science teachers who participated in the GLOBE workshops. A five-point Likert scale was used to solicit their responses, with 1 indicating "strongly disagree" and 5 indicating "strongly agree." The participants unanimously felt that the presenter's knowledge contributed to their understanding and that the presenter's ability to communicate also contributed to their understanding. They agreed that the material was useful for their professional development. One teacher remarked, "I am surprised at the level of student engagement it [the GLOBE material] encouraged." Their survey responses are summarized in Table IV.

Summer Geoscience Research

Feedback from the summer research experiences was overall positive, as this high school teacher highlighted his experience:

> *"My experience, as well as [that of] my high school student, was very educational and rewarding. Having two engineering degrees, I was able to implement my knowledge and experience to help guide and mentor my own student as well as two undergraduate students also involved in the program. I feel that my student received the most benefit from this project. She was able to see firsthand what it is like being in the "real world." She was held accountable, and she was given responsibility for contributing to our research paper, as well as presenting our initial data to the other research groups and [to] NASA representatives."*

Virtually Exploring the Geosciences

The findings from Lansiquot et al. (2014) highlighted the statistically significant differences in pre- and posttest scores on both the mountain weather, $t(17) = 4.9$, $p < 0.01$, and the sea breeze modules, $t(16) = 2.6$, $p < 0.05$. These results suggest that the virtual exercises increased the high school participants' understanding of these two geophysical phenomena. The students also reported gaining a better understanding of, and interest in, these concepts. Responses from the module feedback survey (1 = strongly disagree, 7 = strongly agree) showed that participating students strongly felt that they had a better understanding of mountain weather ($M = 5.88$) and sea breeze ($M = 6.00$) and that the geoscience concepts were interesting ($M = 6.24$ and $M = 5.53$, respectively). They also reported that they had learned something new about the geosciences ($M = 6.35$, $M = 6.06$) and that they did not find the modules too challenging ($M = 4.35$, $M = 4.63$).

Geosciences Exposure Events

An exposure trip satisfaction survey distributed after each event consisted of eight questions regarding the organization and expectations of the trip, learning and understanding of the geosciences, and geoscience interest level. A seven-point Likert scale was used to solicit responses with 1 indicating "strongly disagree" and 7 indicating "strongly agree." The mean responses and t-test results comparing the middle and high school students' responses for each exposure trip events are summarized in Table V.

The overall results show a higher mean response rate for the middle school students when compared to the high school students. Statistically significant differences between the middle and high school student responses are also shown in Table V for questions addressing (1) learning something new about the geosciences and how relevant and

TABLE V: Mean responses and *t*-test results from the satisfaction survey of the BNL, NOAA-CREST, and NASA GISS geoscience exposure events. Survey scale with 1 = strongly disagree and 7 = strongly agree.

	BNL		NOAA-CREST		NASA GISS	
	Middle School	High School	Middle School	High School	Middle School	High School
	($n = 28$)	($n = 25$)	($n = 22$)	($n = 26$)	($n = 76$)	($n = 128$)
1. The trip was well organized.	6.86[1]	5.16[1]	6.14	5.46	6.26[1]	5.85[1]
2. I learned something new about the geosciences on this trip.	6.71[1]	5.52[1]	6.18	5.65	6.09[1]	5.58[1]
3. The geosciences concepts presented were interesting.	6.21[1]	4.80[1]	6.23[1]	4.88[1]	5.49	5.11
4. The trip helped me to understand more about geosciences.	6.18[2]	5.40[2]	6.41	4.85	5.64	5.30
5. I enjoy learning about the geosciences.	5.78	5.16	5.68	4.85	5.28	4.89
6. I would like to come to visit the site again.	6.12[1]	4.72[1]	6.00	4.62	5.53[1]	4.76[1]
7. I can use the materials I learned from this trip and apply them to my life.	5.63[1]	4.20[1]	5.82	4.96	5.76[1]	4.86[1]
8. The trip met my expectations.	5.71[1]	4.32[1]	6.05[1]	4.69[1]	5.63[1]	4.85[1]

[1]Significant at the 0.01 level (2-tailed).
[2]Significant at the 0.05 level (2-tailed).

applicable for their lives the geoscience information is are shown for the BNL and NASA GISS events, (2) how interesting the presented geoscience concepts were for the BNL and NOAA-CREST events, and (3) how the trip met their expectations for all three sites.

A few student responses from each school are highlighted below.

Middle School 394

"What I liked most [at BNL] was doing the hands-on project with the clouds. It made learning more interesting."

"I liked everything about the [NOAA-CREST] trip, especially the globe and the sensory science."

"I liked how the college students made their presentations and explained to us their perspective on the NASA GISS organization and the geosciences."

City Polytechnic High School of Engineering, Architecture, and Technology

"I liked the information about global warming that is not really presented on TV. It also gave me a challenge to be like the scientists [at NASA GISS]."

Urban Assembly Institute of Math and Science for Young Women

"I like the nano science department [at BNL]; I really enjoyed that part because he explained in great detail for a person my age."

"I like when we went to the [BNL] pond site, and we were measuring the temperature of the soil and the air."

"The best part of the [NOAA-CREST] trip was the Jeopardy game on geoscience."

Overall, student feedback from exploring the geosciences through either a virtual environment or an exposure trip has been positive. Students have (1) gained an understanding of the geosciences, (2) learned something new about the geosciences, (3) found the presented geoscience concepts interesting, and (4) enjoyed learning about the geosciences. Based on overall responses, the geoscience exposure trip experiences were particularly more gratifying for the middle school students than they were for the high school students. This critical result supports Osborne and colleague's (2009) study stressing the urgency of engendering a science interest in students between the critical ages of 10 to 14.

Community Outreach Programs

Feedback surveys were distributed after Dr. James Hansen's "Speak Truth to Power: Human-Made Climate Change—A Scientific, Economic, and Moral Issue" lecture and after Dr. Charles Vörösmarty's "A Precious Resource Running Dry: The Coming Fresh Water Crisis" presentation. Similar to the exposure trip satisfaction survey, a seven-point Likert scale was used to solicit responses with 1 indicating "strongly disagree" and 7 indicating "strongly agree." The mean responses from the presentations are summarized in Table VI.

The community feedback regarding the geoscience presentations has been overall extremely well received. Strong responses indicated that the participants learned more about the geoscience concepts presented and that their awareness and understanding of these topics were heightened.

DISCUSSION

Engaging underrepresented minority students in geoscience experiences, knowledge, and opportunities is a daunting challenge in general and an acute problem, in particular, for those in their formative years of learning. With the geoscience workforce gap between supply and demand widening, meaningful, sustainable, and innovative geoscience transformation is critically needed. However, despite the bleak national results and outlook in geoscience education at all academic levels, hope for the geosciences yet abounds. This hope, however, must be predicated upon

TABLE VI: Mean responses from community outreach programs. Survey scale with 1 = strongly disagree and 7 = strongly agree.

Dr. James Hansen	Mean (SD)	Dr. Charles Vörösmarty	Mean (SD)
	($n = 69$)		($n = 64$)
1. The lecture was well organized.	5.8 (1.8)	1. The seminar was well organized.	6.0 (1.2)
2. The lecture was useful.	6.0 (1.7)	2. I learned something new about the geosciences in this seminar.	6.1 (1.2)
3. I enjoyed learning about the scientific, economic, and moral issues of human-made climate change.	5.9 (1.7)	3. The geoscience concepts presented were interesting.	5.7 (1.4)
4. The lecture heightened my awareness to the importance of climate change.	5.8 (1.8)	4. The seminar helped me to understand more about geoscience.	5.7 (1.3)
5. I was made more aware of the role I can play in mitigating and adapting to climate change.	5.5 (1.7)	5. I enjoy learning about the geosciences.	5.3 (1.5)
6. I would attend another geosciences lecture in the fall.	5.8 (1.8)	6. I would like to attend another similar seminar again.	5.2 (1.6)
7. This lecture met my expectations.	5.9 (1.7)	7. I can use the materials I learned from this seminar and apply it to my life.	5.4 (1.6)
		8. The seminar met my expectations.	5.3 (1.5)

and rooted in a radical geoscience paradigm shift that focuses seriously on thoroughly repairing the nation's severely leaking geoscience personnel pipeline, and the repairs must include (and perhaps begin with) our youngest scholars. A geoscience program like the one described in this manuscript may be duplicated and implemented elsewhere, for not only is it rooted in best practices, but it is also modular and portable. Therefore, it lends itself to being scaled up (adding more participants, more partners, more geoscience virtual modules, administered over a longer time frame) or scaled down (reducing the number of participants, reducing the number of partners, reducing the number the exposure trips, selecting and engaging in only some of the five primary activities of this project, partnering with local organizations that are not necessarily federal agencies). The geosciences must intentionally be made accessible, affordable, and attractive to URM students. Focus must also be placed on reducing both the gender and age disparities within the field, and the national spotlight must shine on community colleges where there has been a growth in geoscience majors and also shine on the nation's dire need to fill the ever-growing workforce as this century marches on. With grave concerns about renewable energy, climate change, and green, sustainable infrastructure and living, it is imperative that students from all walks of life are brought under the lucrative geoscience umbrella of inclusion and active participation. The future of our nation depends on this needed groundswell of geoscience endeavors and participation, and it must begin early in schools and be sustained via student support, internships, and workforce transitions. A multitiered paradigm that holistically enlists and scaffolds industry; local, regional, and national agencies; academic institutions; parents; and students as a vibrant, dynamic entity to advance the geosciences should be considered.

CONCLUSION

This paper describes the piloting of a geoscience education program that is built upon best practices and that targeted grades 8–12 minority students in the urban coastal region of New York City. The successful implementation of this geoscience project was based on the need for geoscience awareness and knowledge among those involved: grades 8–12 students, grades 8–12 teachers, and the public. The five modular components of the project (professional development, summer geoscience research, virtually exploring the geosciences, geoscience exposure events, and geoscience community outreach programs) can either be sectional or integrated. Additionally, they are relatively easy to implement, thus establishing and maintaining the critical nexus and indispensable partnership between organizations (national and regional) and educators. Teachers were excited at the prospect of enhancing their own learning and then to use that knowledge to stimulate new geoscience classroom activities. Moreover, students were excited to learn about the geosciences by exploring the familiar and user-friendly territory of the virtual environment and by working in learning communities as they explored the geosciences in the virtual environment. This mode of learning fostered student interaction, allowed for teamwork, and provided a shared learning experience.

One key lesson learned from the program's implementation is that relevancy is critical. To contemporary, sophisticated, technology-savvy, young, urban students in New York City, the geosciences and the environment may not have seemed relevant. However, after experiencing a quick succession of geophysical phenomena—an earthquake in 2011, Hurricane Irene in 2011, and Superstorm Sandy in 2012—interest in the geosciences among many students in New York City is now extremely high, and many of them have now been made aware of the critical nature of the geosciences. Through their recent experiences, they can now contextualize and relate to the dynamism and the relevance of the geosciences.

Conferences and symposia can function as essential stimuli for raising awareness of and interest in the geosciences among young students. Paid summer geoscience research internships rouse and excite teachers, and provoke a passion for the geosciences. Furthermore, minority students are especially motivated to become geoscientists when they are exposed to geoscientists who come from backgrounds similar to theirs. Parents can be involved to encourage their children to pursue the geosciences through the prospect of lucrative geoscience careers. Geoscience initiatives like this project must be treated as institutional priorities via "buy-in" from champions at all levels of school administration.

In these early stages of this young century, innovative initiatives must be devised and implemented to address the urgent need to replenish the nation's dwindling geoscience workforce. To ensure a robust, world-leading, diverse, 21st-century geoscience workforce, this nation must be intentional in its efforts to teach, recruit, train, and develop a new generation of geoscience learners. A geoscience model that engages young students similar to the one outlined above would be a critical catalyst for this necessary endeavor.

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