Enrichment Programs and Professional Development in the Geosciences: Best Practices and Models (OEDG Research Report, Stony Brook University)
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May30, 2017

Abstract

This report is based on several evaluations of NSF-funded geoscience projects at Stony Brook University on Long Island, NY. The report reviews the status of K-12 geoscience education, identifying challenges posed by the Next Generation Science Standards (NGSS), the experiences of university faculty engaged in teacher preparation, state requirements, and the current high school science curriculum. The study then describes and analyzes enrichment, active learning strategies employed in summer programs at Stony Brook. The study also describes professional development for schoolteachers, also at Stony Brook. Next, we review the attitudes of undergraduates toward the geosciences. Finally, the report identifies best practices in the geosciences, based on an analysis of the data previously discussed.

Key Words: Geosciences, NGSS, earth science, fieldwork, enrichment, science education, teamwork, projects, best practices

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1. Geosciences: Opportunities and Challenges

The challenges and opportunities that the geosciences face in school-level education are evident in the Next Generation Science Standards (NGSS). These standards strive to base science teaching and learning on exploration, problem solving, and projects. Students are encouraged to look at the world around them with fresh eyes, asking what if questions, constructing hypotheses, collecting their own data, using appropriate methods to solve problems and to create models. These are major changes in the kinds of teaching and learning that teachers and students are accustomed to, and so professional development and new approaches to curriculum are required. A look at the science education journals and conference agendas confirms that a flurry of activity is in fact taking place regarding pedagogy in the geosciences. We have further evidence in the evaluations of exploratory and enrichment programs at Stony Brook University. Activities at Stony Brook form the foundation on which this report is constructed. But first we want to review the status of education in the geosciences in the United States.

The abstract for a recent presentation stated that, "The changes recommended by the NGSS include establishing ESS (Earth and Space Sciences) on an even footing with both life sciences and physical sciences at the full K-12 level. This represents a departure from the traditional high school curriculum in most states." (Wysession, M. 2014) The paper goes on to note, "However, in middle school, ESS has traditionally been taught at a low conceptual level, focusing on categorization instead of system processes." This suggested change seems similar to the shift that took place some years ago in biology, as teaching and learning moved from taxonomies to an explanatory and evolutionary basis that has further evolved with work on the human genome and explorations of DNA, with its reliance on computer models.

Those engaged in the geosciences therefore have extra work to do—not only to create more engaging, project-oriented activities, but also to raise the level and make their curriculum more interdisciplinary, quantitative, conceptual and applied. In addition there are political/educational issues related to the sequencing of courses and the interdependencies of concepts and skills on one another.

Some geoscience professors believe that the current order in which science courses are taught is not appropriate. In their view, the order at the school level should be: physics, chemistry, biology, and earth science (Hanson, 2015). This sequence is based on the ways in which the content, concepts, and experimental work build on one another, and this proceeds from the ways in which scientists at each level explain their work. Chemists use the findings of physics; biology in many ways builds on chemistry; and earth scientists see themselves as bringing together all of the other sciences, using whatever they need to solve problems and explain phenomena. The actual sequence in most schools is: earth science, biology, chemistry, and physics. The order is based on the amount of mathematics generally required for each class. (Physics is often identified as with or without calculus.) One solution would be to adopt something like a European model in which the sciences are more interconnected and all are taught every year at the secondary level. But in the real world of American education such changes are unlikely. Some have suggested that American high schools should at least offer advanced electives in the geosciences to juniors and seniors, leading to more advanced understandings and better decisions regarding college studies.

The scale of the problem can be seen from another perspective, considering state requirements and expectations. "Only one of the nation's 50 states requires a year-long Earth/Environmental Science course for high school graduation, whereas 32 states require a Life Science course, and 27 require a Physical Science course. Only six states require that students are taught Earth Science concepts as part of their graduation requirements." (American Geosciences Institute, 2013) The report goes on to recommend:

- The presence of Earth Science topics in state and national standards;
- Consideration of Earth Science as a graduation requirement;
- Evaluation of Earth Science concepts on high-stakes assessments; and
- Acceptance of Earth Science courses for college admission.

The issues are also related to the perceived quality of geoscience high school classes. Dane L. Schaffer (2012) recounts spending a great deal of time gathering evidence and communicating with an engineering department to convince decision makers that the Earth Science class at his high school was on a par with the other science classes. He points out that the lack of respect for Earth Science classes is connected to the fact that large numbers of Earth Science teachers are not certified in the area, or are certified, "merely because they took a test." Some of the state certification tests for secondary school science teachers are structured so that an individual can become certified in a number of areas while scoring quite poorly in one. Based on experience with high school teachers, Brian Colle (2015) of Stony Brook says by way of example, "They may be most comfortable with geology; but the atmospheric and ocean areas are where they struggle." To insure competence, school districts try to hire teachers who have majored in the discipline they will teach; but this does not always work. Many secondary school Earth Science teachers have not majored in the geosciences, but have completed the general science distribution requirements for their state. In interviews, college faculty members and K-12 teachers said that the shortage of teachers who had majored in the geosciences was a serious problem.

There are other issues rooted in the history of science teaching in the United States. Keith Sheppard (2006) of Stony Brook University points to a cyclic process in American education: Declare a crisis/commission a study/issue a report/issue a call to action/make little substantive change; and after a few years, repeat the process. The crises have been real; the studies generally accurate; the reports drafted with useful recommendations. But the actions taken have generally been insufficient to effect real change. In addition, there is no authoritative structure for American education. The federal and state governments, local school districts, associations in the disciplines, schools of education, researchers, and textbook publishers all play their roles. It is therefore difficult not only to move forward, but even to agree on a direction; and so there has been a recurring reversion to the status quo.

The nature of the geosciences presents a mix of incentives and disincentives with regard to project-based and exploratory teaching/learning efforts. Gil Hanson of Stony Brook points out that unlike biology, chemistry, and physics which offer experiments that engage students and show activity in the present moment, geoscience processes take place at a very slow, even glacial, pace, and so changes are inferred, for example, in the fossil record. But he also points out that the geosciences provide opportunities for fieldwork that engage students and combine learning with outdoor activities. In addition, lab constructions can model certain geological and atmospheric activities such as the effects of water flow and erosion as presented with stream-tables, and "tornadoes in a bottle." And students can develop their own data with, for example, weather and water-related measurements.

These issues may not indicate a crisis. But taken together they point to a situation that needs attention. The following are among the more significant issues.

1. A shortage of qualified teachers who are knowledgeable and enthusiastic about their work is holding back the geosciences. We are finding more and more that the key ingredient in improved education is not raising standards and improved testing. Progress will be made only when we develop a nation of high quality teachers. Based on real results and available evidence, it seems we should pay more attention to the selection of students for teachers colleges, the education of future teachers, and the professional development of teachers. In 2009, Finland surprised the world and itself by scoring highest in one of the better-developed international tests (Ripley, 2013). The results should not have been a surprise. During the 1970s and 80s Finland closed its standalone teacher preparation colleges and opened new ones on the campuses of its leading universities. Standards for entry into these teacher preparation colleges were raised so that admission is now as academically demanding as is admission to medical school. This is educational reform that goes to the heart of what is needed to effect change. Success in international tests surprised Finland's educators because they had not focused on testing: they focused their efforts on improved teaching and learning.

How the United States might best use this information about Finland is problematic. We do not have a national curriculum. Schools of education are both private and state run. States have required standards regarding course work and graduation requirements. Lankford et. al point out that although teachers are often well-respected individually (Bushaw & Loplez, 2011) teaching has lower status than other professions. But their study finds that while the caliber of students majoring in education, and desiring to become teachers was low and declining during the second half of the 20th century, recent years have seen a shift, based on rankings and SAT scores so that the prospects for better teachers have improved.

2. The Earth Science curriculum and pedagogy need to be revitalized. The classroom situation is related to the shortage of qualified teachers and also to the shifting priorities described above. Students in the Stony Brook summer programs frequently contrasted their fieldwork and projects with the classroom learning and unenthusiastic teachers they had experienced in their schools. Summer programs are generally more exciting than regular school, for a number of well-known reasons. But those in the Stony Brook program also offered useful insights into the current state of teaching and learning in the geosciences.

In an interview, an Earth Science teacher pointed to a situation that needs further discussion—behavior. She said people don't want to talk about. The issue cuts across American education. Because teachers in some classes are afraid that students will misbehave, they are afraid to introduce projects and quiet individual or small group learning. In practice this generally means a fast-paced class, with short answers allowing less time for students to talk or act out. But the learning in such situations is superficial, without time for thinking, interaction, and problem solving.

3. Connections between the school and college level education need to be improved. Venezia et al. (2013) describe the many ways in which weak connections between the K-12 educational system and college education in the United States "betray the college dream." They point to a significant lack of agreement between high schools and colleges in approaches to teaching/learning and assessment. The issues are particularly troubling in areas related to minority students; and the statistics pose challenges.

In New York State only 61% of high school graduates and 40% of African American graduates receive the State Regents certificate. The Regents curricula, upon which the exams are based, provide only basic preparation for college. Beyond these statistics, the study points to a variety of ways in which there is a mismatch between high schools and colleges. But the authors also point to avenues for solutions that include: exposing high school students to college experiences; incorporating more technology into the learning process; prioritizing teacher training; redesigning the high school experience; initiating targeted interventions; and adopting national standards. These are ambitious but important recommendations; they will be further discussed in the following pages.

For many, the mention of geosciences means the study of rocks. While geology is of course included, there is much more. It is worth taking a moment to describe the basics in traditional content terms. The geosciences include studies in:

1. Earth Sciences: The structure and evolution of the solid earth.
2. Atmospheric Sciences. The layer of gases surrounding the earth.
3. Marine Sciences: The physical, chemical, and biological properties of the ocean.
4. Space Sciences: The solar system and beyond.

The Core Curriculum for The Earth Sciences developed by New York State describes processes to be studied and skills to be learned rather than more traditional subject matter based on content. There are seven standards; they are ambitious and challenging. The first part of Standard 1 Analysis, Inquiry, and Design, is Mathematical Analysis. Key Idea 2 is on deductive and inductive reasoning and contains the example: determine the relationship among velocity, slope, sediment size, channel shape, and volume of a stream. In other words, the proposed standards and activities are quite demanding. But we know from common sense, experience, and recent history that raising standards does not in itself lead to better learning. We will return to these issues later in this report.

2. The Goals of Education and the Geosciences

In the geosciences and in education generally, people often talk at cross-purposes because they are thinking of different goals. Discussions could be simplified and made more productive if those involved agreed on which goal they were considering. The following four general goal areas can at least provide a framework in which to discuss, plan, and assess progress.

- *Maintaining the Tradition.* In the process of education, each generation shares and hands on its culture, skills, values, wisdom, and much more, to the next generation. Advocates and practitioners of the classical education believed that the study of ancient languages, mathematics, rhetoric, and certain other prescribed areas trained the mind and put one in contact with the great ideas that have formed the foundation of our culture. While these goals and practices have shifted, we still have the responsibility to pass along who we are and how we have gotten to this point. Science, history, literature, and art are all works in progress. We are both the recipients and transmitters of learning. Ideas and skills can be lost, as history shows us. Education, in all its dimensions, is the most important instrument for carrying on the traditions of the human enterprise.
- *Individual Growth and Development.* Education helps individuals find and cultivate their potential so that each of us can gain the satisfaction that comes with growth and achievement, directed toward personal and social ends. The rise of modern science and the focus on individual freedom has made this goal more prominent. Teachers while engaging students in the great ideas and practices of our tradition (goal one) should always be alert to students' individual talents and interests. These bring learning to life and often give the learner a sense of direction.
- *Career Preparation* Students must be prepared to enter the workforce in a changing world. Effective career preparation should be integral to education, and become clearer as students move through their schooling. It is now understood that those entering the workforce need both general analytical and problem solving skills along with an array of technical, communications, quantitative, and literacy skills proper to their field of interest.
- *Participating in a Democratic Society* Education should provide students with an understanding and appreciation of community and government, at all

levels. A nation is in danger if its citizens take for granted what earlier generations have achieved with great effort. Education must therefore equip the individual to participate in social and political processes and organizations.

Each of these goal areas requires the development of plans to accommodate all students, bringing them to basic levels of literacy, numeracy, and cultural awareness so that they can then find and develop their inner talents, be well prepared for careers, and be able to play constructive roles in our democracy. Science and science education are also embedded in each area.

The twentieth century witnessed a shift in educational priorities at all levels. The traditional goals and methods of science and mathematics came under attack. "Training the mind" and "improving memory" were valued less while exploration, problem solving, teamwork, and practical usefulness were valued more. In any case, we believe that identifying the four broad areas of educational goals can clarify discussions about what we are trying to accomplish in schools and colleges.

We can consider the four goals as related to the geosciences.

- Tradition. The ideas surrounding planetary motion, the formation of mountains and rivers, and the mysteries of weather have captivated the imaginations of peoples throughout the ages and have also contributed to the mathematics that gave rise to modern science.
- Individual Interest. Just as some young people are captivated by music or literature, others want to spend their time learning and creating knowledge about the world around them. And some of these students will in turn be drawn toward the geosciences.
- Careers. Beyond education, there are a growing number of careers related to water, land, ecology, and the environment. Global warming and pollution threaten the existence of the planet. There is much to be done by those who want to devote their time and energy to the geosciences.

- Public Life. The geosciences are indeed likely to be in the forefront as decisions are made about our human habitat and the world around us. A well-informed electorate and knowledgeable public officials will be needed if issues are to be addressed and problems solved.

The Bureau of Labor statistics predicted that between 2010-2020 geoscience–related occupations would increase by 21%, a growth rate 7% faster than the average of all other U. S. occupations. In reviewing the literature and in interviews, we find a great deal of confidence about career opportunities in the geosciences; and the following areas in particular.

- Education that includes teaching and research at all levels;
- Ecology and Environment, including conservation, land and water management, environmental engineering, weather analysis and reporting;
- Research, engineering, policy, and management regarding land, water, space, and other geoscience areas.

Employers for those competent in the geosciences include public and private organizations concerned with environmental issues, wildlife, natural resources, museums, and natural preservation. A recent presentation described geologists as: travelers of the world, lovers of the outdoors, caretakers of the Earth's resources, and dedicated to improving the quality of human life.

An Earth Science Summit in 2010 sponsored by the American Geological Institute listed the following as the most prominent issues facing the geoscience education community. The first three items have been discussed above. The last three may point to serious concerns depending on location, type of school, and other priorities.

- Perception of high school ESS (Earth and Space Sciences) as a non-rigorous, non-laboratory course;
- Status of the preparation and continuing education of ESS teachers;
- Inclusion of ESS alongside other sciences in the new national science education standards;
- Lack of an ESS advanced placement course;

- Challenges to ESS in schools by the creationist and Intelligent Design movements; and
- Role of the International Earth Science Olympiad in raising the profile of ESS.

The review of issues and challenges in geoscience education provides a context for the discussion of particular enrichment programs, professional development, internships, and related activities that have been implemented at Stony Brook University. These programs have emphasized diversity and the inclusion of minority students.

One of the priorities that educators at all levels seem to agree on is that too much attention is paid to the amount of material covered. The following is from an online document, Benchmarks (2016), and it is particularly relevant to the activities we will discuss in the next portion of this report.

> If we want students to learn science, mathematics, and technology well, we must radically reduce the sheer amount of material now being covered. The overstuffed curriculum places a premium on the ability to commit terms, algorithms, and generalizations to short-term memory and impedes the acquisition of understanding.

3. Opportunities for Enhancing Diversity in the Geosciences (OEDG)

The National Science Foundation (NSF) and others have documented the fact that African American, Hispanic, and Native American students are underrepresented in the STEM (Science, Technology, Engineering, and Mathematics) disciplines—with regard to numbers of students in the majors, degrees earned, and entrance into graduate school. The discrepancies become greater, moving up the academic ladder. An NSF report (2012) indicates that Black, Hispanic, and Pacific Islanders account for only seven percent of science and engineering doctoral degrees; even though these groups comprise about 31 percent of the total population. There is general agreement in the academic community and beyond that efforts should be made to remedy the situation. Several reasons can be given for making this effort (Miller, 1995). First, the productivity of the entire nation depends on the achievements of everyone. Second, civil rights benefits that have been gained will be furthered only if minority students gain the educational background required for their next steps. Finally, the maintenance of a just society requires that minority students achieve at a rate comparable to the population at large. The numbers of students majoring in and receiving undergraduate degrees in the geosciences has been particularly low—in general and particularly for minority students. In 2000, 4047 bachelor's degrees were awarded in the geosciences (Huntoon & Lane, 2007). This represents about 1% of the total number awarded in that year.

Geoscience faculty members at Stony Brook University have been awarded several grants with linking goals: to provide enrichment geoscience activities for high school students, to offer professional development for high school teachers, to increase enrollments of geoscience majors at the university, and to further develop a masters in teaching program in the geosciences.

Stony Brook University is located on Long Island, which has a history of quality public education, significant numbers of minority students, scientific industry, and rich geological formations. Stony Brook is a Research 1 institution and the proposals for the NSF geoscience grants have emphasized the importance of research at all levels, as a method of engaging students so that they might "do" and not just study the geosciences.

The focus of this report is the NSF-funded OEDG program at Stony Brook that started in 2011. The program's objectives and activities were:

1. To provide summer exploratory learning experiences in the geosciences for high school students entering the twelfth grade, with particular emphasis on underrepresented minority students;
2. To expand the geosciences teaching laboratory and use it with visiting high school students during the academic year and summer;
3. To provide financial aid to selected minority undergraduate geoscience majors;
4. To strengthen connections with laboratories and industries on Long Island;

5. To provide internships for selected undergraduates:
6. To provide summer in-service training for school teachers in the geosciences;
7. To continue to study the experiences and attitudes of undergraduates regarding the geosciences.

In this part of the report we will summarize the findings from the five years of implementation. We will then suggest the program's best practices in the light of geoscience education. In these best practices, we will consider how the program fits with the broad themes of renewal in the geosciences, described above.

Summer Program for High School Students The program recruited students from Long Island and nearby areas, enrolling 15 to 20 students for five weeks each summer. The students lived in college dormitories at Stony Brook. The grade levels of students varied during the years of the project. The most successful arrangement seems to have been to have all of the students spend the program summer before entering senior year of high school. There were several benefits in this arrangement: being at an upper level they were more mature living away from home and working on team projects; they had a somewhat stronger and more predictable academic background; being closer to college entrance, they were more likely to carry the enthusiasm for the geosciences into their plans regarding future studies.

<u>Evaluation</u> The evaluation of the OEDG project used a logic model, as described by Chen (2005) focusing on: resources, activities, outputs, and outcomes. Evaluation methods included:

- Review of program documents and related literature;
- Surveys of the students and teachers participating in the summer programs;
- Site visits with observations and focus groups;
- Interviews with program instructors;
- Data analysis and report preparation.

The following pages contain material from five years of evaluations, analyses, and reports. In general, experiences of the students, head teacher, and assistants were similar from year to year are presented as relevant for purposes of evaluation and description of the program's progress. It is therefore not always necessary to indicate the year for particular comments or conclusions.

Resources for the program included:

1. An experienced head teacher who had a command of the material, the ability to develop activities, and sensitivity to the students. He provided leadership and continuity, building on the program's successes, expanding students' horizons, and guiding the staff.
2. Teaching assistants who were majoring in and planning to teach the geosciences, and were also knowledgeable in teaching /learning strategies and friendly with the students.
3. The university setting with excellent teaching space, a geoscience lab room, an atmosphere of learning on campus, and residence facilities.
4. Appropriate sites for geoscience fieldwork on campus and at other nearby areas of Long Island.
5. A carefully developed curriculum with an overview and learning objectives developed for each topic and fieldtrip.

Activities included:

1. Classroom instruction by the lead teacher, with individual and small group guidance by the teaching assistants, who were preparing for careers as secondary school teachers.
2. Fieldwork that included data from weather stations on campus and also observations and data collecting from geological and water-related sites on Long Island.
3. Student projects that included field trips, data analysis, posters, and oral presentations.

Outputs for a project of this size included the numbers of students engaged; the length of the program; and other quantitative program features described above.

Outcomes included the ways in which the summer experiences changed students' understanding, perceptions, motivation, and plans in relationship to the geosciences and their own futures. Based on the five years of evaluation, we can say that the OEDG activities at Stony Brook were carefully implemented. The evaluation found positive outcomes indicating success in the following areas.

1. The discussion and surveys provided data indicating that the high school students demonstrated a high degree of interest, motivation, and basic understanding of the geosciences.
2. The high school students who engaged in a special extended research program revealed the energy, patience, and kinds of skills needed for deeper study and further research.
3. The high school teachers in professional development workshops reported that they learned a number of new and useful teaching strategies, project areas, and exploratory methods that they planned to use with their students.
4. The college-student teaching assistants working with the program reported that interacting with the students one-to-one and in small groups gave them new insights into the teaching/learning processes and these experiences were an important supplement to their teacher training. They expected to use the experiences, particularly with science clubs and enrichment activities.

Although the program is exploratory with an emphasis on field trips and projects, it has been very carefully planned and implemented with an impressive binder of materials introducing and explaining each area of fieldwork and related learning. Each unit starts with a list of the presentations providing an overview and setting up the general topics that will be covered. For example, the lesson on, 'Invasive Species in Green's Creek,' is accompanied by photos, illustrations, tables, and graphs to explain the activities and to help students begin projects. The materials worked very well, connecting theory and practice at the appropriate level for the students.

<u>Activities and Outcomes: Focus Group Discussions With Students</u> The program is student centered and exploratory. The curriculum covers many of the topics included in the New York State Regents syllabus, such as: weather and measurements; collecting and analyzing water, soil, and mineral samples; and

experimenting with geological simulations. But the approach is field-based, with classes used to support real-world investigations, analyze data, and prepare presentations. Focus groups were conducted each year: students explained what they did and how they learned.

In discussion, students commented on activities that distinguished the program from learning in school and the benefits that they gained. In general it became evident that the explorations and trips were always accompanied by real learning in the measurements, analyses, and projects that accompanied them. The following are some of the significant activities and learning experiences.

Measurements, Data and the Processes of Science Starting on the program's first day, the students set up weather stations at several sites on campus. They took readings from the instruments every day. Working with data showed the students: that the geosciences require care; that measurements produce patterns; and that these patterns are related to larger theories. Student comments below relate to data gathered both on campus and on fieldtrips.

- *We spent a lot of time outside; the hands-on activities were good; but going for four hours when it's 95 degrees was too much.*
- *We took weather measurements: temperature, humidity. We did it at different sites, comparing the results, such as differences between sun and shade.*
- *We measured boulders, and we learned how far they had travelled; we used smoothness and roundness scales.*
- *We learned how to test water quality.*
- *We learned about the breeding of horseshoe crabs.*

Fieldwork In discussions about what they liked and how the program differed from school, the participants always talked first about the fieldtrips and related activities. They learned that it is important to do science, not just read about or study it. It is commonly understood that the information contained on a textbook page may have taken years of scientific work to discover, digest, prove, and present. Textbooks are of course needed, because we cannot take the time to rediscover all that has been done in the history of science. But it is only in making real discoveries and working with real data that students are able to experience what scientists do and how scientific knowledge progresses.

In discussions, students demonstrated that they understood the basics of the science studied in field trips. These trips were not simply about observing and collecting but were devoted to measurements, followed by analysis and inferences about, for example, the aging, weathering, and changing formations of geology on Long Island. Students talked about the rate of weathering being 2.8 mm per 100 years, and how they used this information to gain an understanding of geological formations thousands of years ago. They also talked about the geological profile of "how sediment moves on the beach and the breakdown of rocks."

When asked why we study science in general and geology in particular, the students were articulate describing the breadth and depth, and many facets of scientific inquiry. The following quotes from students point out how the fieldwork engaged their attention and aroused their curiosity. They learned: to question; to develop their own data; to use new terminology; and gain familiarity with the geological structures and history of the area.

- *We collected sediment from different beaches; we learned that there are different sizes and kinds of sediments on Long Island.*
- *Doing it on your own raises a lot of questions.*
- *When you see different outcomes you learn more.*
- *I'm more of a textbook learner, but a textbook explains experiments just one way … when you do it you see variations.*
- *The projects we do at school are usually based on someone else's data. … here we collect our own data.*
- *We learned how Long Island was pushed down during the ice age. They told us about the two moraines on Long Island.*
- *Science is meant to be a hands-on thing; you can experience the different environments that the world has to offer.*
- *It is important to understand your surroundings.*

Personal Learning Each summer the students commented positively on the small size of their group, the number of teachers, and the resulting individual attention that they experienced. The attention from the teachers helped them feel more relaxed. The fact that the group was self-selected helped the students feel at ease. They enjoyed learning, and exploring the world around them.

- *At school you might feel nervous speaking, but here we know each other and it's a small group, so we are more comfortable.*
- *Not having grades takes a lot of the pressure off.*
- *If we don't understand something, he (the head teacher) tries to make us laugh to feel better about ourselves.*
- *Your evaluation is not based on a number. At school the teachers seem to say "here is your number (grade), deal with it."*
- *In school the teacher makes you nervous, but here he listens to all of us, and since he has a lot of experience, he has pointers to improve.*
- *Textbooks are informational and if you have a good memory, you will remember. But this (the summer) is experiential.*

Projects and Teamwork Activities springing from the field trips or other research were generally team-based. The participants took measurements, collected samples, and gained background knowledge from the instructors and from the learning materials provided. Then they worked on assigned projects that were intended to consolidate their knowledge and fit into a framework for presentation. They learned about and experienced the value of working together. Because they were there by choice and had been selected in view of their interest and motivation regarding earth science, group work did not suffer from one of the more common problems in schools, namely that some do all the work and others do almost nothing. The following student comments describe some of the benefits of teamwork that they experienced.

- *We used a lot of teamwork. Some people are better at data questions, so we specialized; you have different perspectives; so we got a greater breadth of understanding.*

- *There were two or three in a group; we shared; my partner did the picture part and I did the typing, so it worked out.*
- [Was teamwork useful in data collecting?] *Yes, people have different ways of thinking, so it was good.*
- [How was the teamwork different from group work in school?] *In school, some people don't do any work, but here everyone wants to learn; we talked about how to improve; it's like a big family.*
- *At school everyone goes home, but here we do everything together. … We have a common interest because we all like science.*

The students were articulate describing their projects, including their hypotheses and how they tested them. One group studied the sediment on Fire Island. They made certain hypotheses based on location and the consistency of the sediment. They said, "We were wrong," meaning that they could not verify their hypothesis about different kinds of sediment. But one student added, "If we had read the experiment in a textbook I don't think I would have absorbed as much." This comment was particularly apt in view of the current emphasis on process and problem solving as opposed to acquiring information.

Another group discussed their project, which considered how water quality—pH, temperature, oxygen levels, etc.—affected fauna and flora. The goal and connections are in some ways obvious but a great deal of careful measurements and recordkeeping were involved in the process. The students began to learn and were able to explain how the answers to scientific questions are generally not "yes" or "no." But seeking the answer leads to an understanding of the complex relationships among variables.

Time was a factor in several of the experiments. Students were surprised at how fast bamboo grows and how slow the growth is for algae. They learned not only to condct experiments based on hypotheses but also to project into the future, describing what certain habitats were likely to become if invasive species were not controlled.

Presentations, More Thorough Learning, and Confidence Each year, as part of the evaluation, students were asked about their experiences preparing and giving presentations, whether they had similar experiences in their schools, and if so how the summer was different. These questions led to more general discussions of the differences in learning, and in the teachers. The participating students generally found that the more relaxed atmosphere of the summer program made them less nervous, more comfortable and better able to learn. They also commented on how differences in the teachers made them more confident in their learning.

> *In earth science we covered the same information (as in school) but in more depth; they give you more about everything; in school there is a certain list they have to cover for the Regents; here it is more fun.*
>
> *In school, you can only ask questions about the things that are going to be on the test; here they are not worried about tests.*
>
> *Instead of having the rocks and plants, here you had to go out and look for them…. Here is mica I found today.*

The students discussed how the summer program was different from school where, "you sit in a classroom with 30 people." The major benefits of the summer program, they said, were the hands-on activities and the small group work in which they analyzed what they had done and worked on presentations.

- *You learn more when you have to prepare a presentation; you want to tell other people in ways so that they can learn.*
- *It helps you put it in order and make it clear;*
- *You have to pick what is more and less important.*
- *It is more challenging and interesting because it is your work; you don't just Google or get it from a book.*
- *You learn to not just use the Internet; we try to draw our own conclusions.*

<u>Discussion with Teaching Assistants</u> As was noted above, the summer students commented positively about the teaching assistants who assisted them—with fieldwork, in their research projects, and as they prepared presentations. Each

summer the program engaged several Stony Brook Geoscience majors, who plan to teach the discipline at the school level. The evaluation included discussions with these students.

When asked about the general atmosphere and impact of the program, the teaching assistants said that they noticed changes in the students during the course of the program. And they reflected on certain indirect benefits.

> *Some did not have a geology background; a few had an interest in science; some wanted to study acting or something else … It was interesting to see changes in their outlook and perception of things; there was a big change and that was a success; … even if you don't produce large numbers of geoscientists, at least to change some minds about science and have them go back and spread the word to others, that makes the program a success.*

They also said that a number of the students were in fact considering further study in the geosciences. They noted misconceptions about the geosciences, common not only to high school students but also in college and beyond.

> *A lot are considering something in the geosciences… but they are looking more at environmental issues regarding health; they got engaged with climate changes.*

> *Most of the undergraduate geology majors that I was in class with did not start out as geology majors; they started in physics or chemistry and took a geology course, and switched in. When you tell them you are a major in geology, people think, 'O you do rocks.'*

> *When I first took a geology course, I didn't know too much about it; it took awhile for me to want to do it; Sandy, the hurricane, made me want to do it.*

The TA's, who have been connected to high schools doing observations or practice teaching, were asked more generally about the high school curriculum and how students responded, or what were the challenges.

Earth science is vast and incorporates biology, physics, chemistry, and math, so it should be taken later. (How can this be remedied?) *There are things a teacher can do; but some are lazy*.

They described an energetic high school teacher who was herself doing geoscience research and through projects was able to motivate and engage students. But they also noted some of the challenges facing the geosciences, compared with the other sciences.

With biology, it is kind of a natural thing, you see plants and animals; with chemistry you have an experiment in the lab that is happening right before your eyes. With a lot of earth science you have to imagine it; you can't take students to a volcano or an earthquake; and some of the processes take place over thousands of years. So you have to take them out of the classroom.

Student Research Group Several students who had participated in the 2013 summer program returned for the 2014 summer to participate in guided research. They were enthusiastic about their projects, describing what they had undertaken. The site visit took place after about a third of the summer program had been completed. The student researchers talked about their projects including the hypotheses they had made and what they had determined up to that point.

- *We have been testing the acidity of different soils on campus, finding that the acidity decreases as you go deeper. We have done it in different areas, like the grassy areas near the parking lot. We thought it was because they put salt on the parking lot in the winter. Dr. Hanson said it might be from the calcium in the concrete; we might test the concrete; but won't have enough time to do everything.*
- *We went to Avalon last week to get more samples. It is important to label them carefully, so we know where it came from.*

When asked about the qualities of a good researcher, the students talked about: patience; being able to teach yourself; organization; the ability to interpret in order to know what the numbers mean. When asked about their goals for the remaining weeks, they said that they had to finish their projects, write reports, and prepare presentations.

A survey of the students who had returned for research revealed substantial differences from those in the general summer group in self-reported knowledge, interest, and motivation toward the geosciences. The numbers are small, but they indicate a trend, particularly in trying to attract students to the geosciences as they begin their college work. The next section of this report shows tables with data for the general students and then for the returning students on the pre-program survey.

Surveys of Summer Students The following tabulations show the responses on student surveys for a typical year. Survey items covered: interest in geoscience areas; self-reporting of general skills related to academic work; reporting about career knowledge; and reporting of general knowledge about the geosciences. The most significant pre/post increases were in response to items 15 – 22. These asked about knowledge of areas in geoscience, careers, and skills required for success in college. It is not surprising in view of the program but it is useful to document the fact that students reported higher levels of knowledge about areas of the geosciences and related careers. Responses to open ended items were more specific and more focused on the geosciences for the post-survey.

GeoPrep High School Summer Program Pre/Post-Program Surveys
Pre: N=13, Post: N = 13 (*Numbers 1-22 were rated on a 4-3-2-1 scale and numbers 23-26 were rated on a 5-4-2-1-x scale.)*

Numbers 1-9: Very Strong Interest, Strong Interest, Some Interest, Little Interest

Geoscience includes atmospheric science, earth science, geology, and marine science. Please check your level of interest in each area.

	Mean Rating		Percent 3 or 4	
	Pre	Post	Pre	Post
1. Earth Science	3.62	3.62	92	92
2. Research	3.15	3.23	85	69
3. Reading about science	3.46	3.38	92	85
4. Marine Science	3.08	3.15	69	77
5. Atmospheric science	2.77	3.31	62	85
6. Careers in geoscience	3.46	3.62	85	92
7. Studying geoscience in college	3.54	3.46	85	92
8. Studying science in college	3.92	3.69	100	92
9. Knowing what it takes to do well in college	3.69	3.92	92	100

Numbers 10-14: Very Good, Good, Fair, Poor - respectively

How good are you in each of the following?

10. Writing about science	3.31	3.08	92	85
11. Presenting in front of a group	3.54	3.62	100	100
12. Being a 'team player' in school activities	3.92	3.92	100	100
13. Being a 'team player' outside of school	3.92	3.77	100	92
14. Using PowerPoint	3.77	3.54	100	100

Numbers 15-22:4, I know a great deal; 3, I know a moderate amount; 2, I know a little; 1, I know nothing.

How much do you know about each of the following?

	Pre	Post	Pre	Post
15. Geology/Earth science	3.62	3.77	100	100
16. Ocean science	2.85	3.15	62	85
17. Atmospheric science	2.92	3.15	69	85
18. Careers in the Geosciences	3.31	3.23	85	85
19. Careers in engineering	2.23	2.46	31	54
20. Careers in biology	2.92	2.83	77	58
21. The study skills to do well in college	3.38	3.58	85	100
22. The social skills to do well in college	3.23	3.54	77	92

Numbers 23-26: Strongly Agree, Agree, Disagree, Strongly Disagree, I don't know - respectively

Please check one box on each line to indicate how much you agree with each of the following statements:

	Mean Rating		Percent 4 or 5	
	Pre	Post	Pre	Post
23. The geosciences are interesting	4.77	4.92	100	100
24. I like studying science	5.0	4.62	100	92
25. Geoscientists are well paid	3.15	4.08	62	92
26. Geoscience is a respectable career	4.46	4.77	92	100

Written Responses Pre-Program Survey

27. What are you most looking forward to in the summer program?

The respondents wrote about learning, increasing their knowledge, and engaging in research and field trips. Some mentioned particular areas of the geosciences. Some talked about meeting other young people with similar interests. In all, the comments revealed knowledge and enthusiasm for the summer's activities.

- *I look forward to expanding my knowledge of geology and other sciences.*
- *Meeting new people and having the chance to do something that interests me all summer*
- *Working with people my age, exploring sciences I enjoy and sciences I do not know much about*
- *Looking forward to activities related to what I will study in college*
- *Increase my knowledge of Geosciences and see what careers are available and how I can prepare*

- *Research, field Trips, collaboration with students of the same interests*
- *To have hands on experiences, gain new science knowledge and to work with professionals*

28. What do you think will be most interesting in the summer program?

More students mentioned field trips than any other activity. But they also listed a number of the other exploratory activities in the program.

- *I think being with people that all share the same interests in geology will be the most interesting part of the summer program*
- *The field trips (5)*
- *Learning fields of science I do not know much about, ocean and atmospheric science*
- *Everything listed on this program equally interests me*
- *Seeing the difference between classroom science and field science, the feeling of living at a university, and being a part of the culture of science*
- *The varieties of activities. Being able to participate in college level classes. Meeting new friends and exploring new surroundings*
- *Weather forecasting*

29. What do you think will be your major in college?

The students identified a number of science areas

- Environmental science or geology (2)
- Geology (2)
- Uncertain, but some field of science (2)
- Earth sciences, not English
- Geology, chemistry, biology (2)
- Major in science, minor in Spanish
- Planetary science or Astronomy
- Geology or pre-med (2)

30. What kind of career would you like to pursue after college?

Most of the careers that students mentioned were related to geology.

- A career with Environmental Protection Agency (EPA)
- Geology or remote sensing
- Paleontology or astronomy
- Something in education
- Uncertain
- Geology, for the USGS (2)
- Meteorologist or environmentalist
- Something that would make me excited to go to work in the morning
- NASA
- Medicine or geosciences (2)
- Marine biologist

Written Responses Post-Program Survey.

Question 27: What was most enjoyable in the summer program?

The students listed the trips, experiments, and hands-on activities as most interesting (9). Several said, "everything," and a one each said: meeting other students and meeting professors.

- *Wildwood park*
- *Meeting the professors, getting to use our own research and working hands on*
- *The hands on work*
- *The trips, especially the boating/fishing, analyzing data 4*
- *Kayaking 2*
- *Everything*
- *Brookhaven Lab, Fire Island, kayaking*
- *Working together with people of similar interests*
- *Everything. It sparked my interest in the geosciences*

Question 28: What was the most interesting academic component of the summer program?

Students mentioned a wide range of activities which taken together cover the entire program—the exploratory learning activities, trips, or particular learning activities, the planetarium, animals, the Long Island sound.

- *Taking weather measurements and predicting weather for the day*
- *Exploring science around Long island instead of a classroom*
- *Going out on trips and expanding my knowledge*
- *Constellations in the planetarium*
- *The trip to Southampton*
- *Everything*
- *Research projects*
- *Taking and comparing samples from different areas*
- *Visiting Brookhaven Lab and learning about solar panels and turtles*
- *Talking to the man from NASA 2*
- *Learning about animals*
- *Loved the program in general*

Question 29: What do you think you would like your major to be in college?

Responses ranged across the sciences. Several students mentioned more than one major.

- *Geology (7)*
- *Astronomy (3)*
- *Marine Science (2)*
- *Chemistry*
- *Psychology*
- *Medicine*
- *Science*

Workshops for Geoscience Teachers Each summer in addition to the student geoscience workshops, the OEDG program offered a one-week workshop for earth science and geology schoolteachers. This workshop included a combination of class work, field activities and the preparation of lessons for school. In survey responses, teachers gave high ratings to all aspects of the program. They reported that the most interesting activities were those that included labs, fieldwork, and hands-on experiences. They believed that their students would respond positively to the lessons developed, and said that they would continue to develop new lessons based on the summer's activities. Regarding improvements, they recommended even more demonstrations, fieldwork, labs, and lessons tailored to individual courses and teacher needs. Results of the 2012 survey are shown below.

Teacher Participant Survey (N = 12)

Please indicate you level of agreement or disagreement (Agree strongly = 5; Agree = 4; Disagree = 2; Disagree Strongly = 1)

	Mean Rating	% 5 or 4
1. The workshop improved my skill base in geoscience.	4.3	100
2. The workshop enhanced my conceptual understanding.	4.5	100
3. The activities will be useful with classes at school.	4.6	92
4. I believe students will respond positively to lessons developed.	4.5	100
5. The activities will need to be reworked for my classes./	4.1	92
6. I will recommend the program to teacher colleagues.	4.9	100
7. Engaging with other teachers was productive..	4.8	100
8. In general, the program met my expectations.	4.4	92
9. The workshop topics fit well with the curriculum	4.3	83
For each of the following, please indicate (Very Likely, 5; Likely, 4, Possibly, 2, Not at all likely, 1)		
10. I will develop a lesson based on the demonstration.	4.9	100
11. Others at my school will be interested in the activities.	4.6	83

12. What was most beneficial about the workshop?

- *Boat trip (2); lab activities*
- *Everything*
- *Activities can be used for demos (3)*
- *Teaching aids; experiments (2)*
- *Talking to other educators*
- *Collecting data*
- *Oceanography*
- *Mix of lecture and hands-on*
- *I will have to modify, most of the information is way beyond my students*
- *Enhanced my knowledge base*

15. Which laboratory experiences were most engaging and why?

- *Hands-on more than computer-related*
- *On the boat, estuary (4)*
- *Convection cells with oil (2)*
- *Density tank (2), great visuals for difficult concepts*
- *Hands-on visual demos (2)*
- *Tank showing the fronts*
- *Salinity and egg experiment (2)*

- *Using computers to analyze data; students need visual aids*
- *Weather balloon launch*

16. How would you improve the program?

- *More time with labs, Boat, experiment time, hands-on (3)*
- *Exchange of lab activities*
- *Lecture followed by demo*
- *Time for feedback about adapting to student needs*
- *Instructors need more on how to use the technology; can't always see what is going on*
- *More prep for teachers; more attention to our specific concerns*
- *Would be helpful if information related to NYS Regents*
- *More than met my expectations.*

Phone Interviews One of the professors teaching the workshop said that the 2015 teacher participants came "with a lot of background." This made it possible to move into more complex and challenging ideas and activities. The demonstrations and experiments were immediately transferable to the classroom. A teacher described how, on the day of the phone interview, she had used some of the techniques from the summer. She said that the AP class in question was much like a college class in which the students worked on their projects and measurements for long periods, with guidance from the teacher only as needed.

In interviews, the professors teaching the workshop discussed issues confronting the geosciences at the school level.

> *There is a spectrum of teacher knowledge; a lot don't have earth science-related degrees. They may be more comfortable with geology; but the atmosphere and ocean is where they struggle.*

The professors discussed geoscience-related problems confronting students in the schools. Their comments echoed issues discussed earlier in this report.

> *Some (of the difficulties) are related to teacher background. And the subject is taught early; so the students are not as mature. They may get excited and then never see it again. It could help a lot if they had a senior elective. By the time they are seniors it is in the distant past. It's not an easy thing to fix. For example, atmospheric science is usually only a few weeks. On the Regents they struggle with items related to the weather.*

The importance of fieldwork came up repeatedly in the interviews.

There is a huge advantage in being able to go out into the field. In physics and chemistry you are in the lab. But out there, nature has all these twists and that is what makes the field exciting; I could go out there two days in a row and see things very different.

Toyota-Sponsored Workshops on Geosciences for Teachers In addition to the OEDG summer workshops for students and teachers described above, the Institute for STEM Education has over the years offered a wide range of educational programs. One of these, sponsored by the Toyota Foundation, was offered in the Geosciences, introducing schoolteachers to a variety of hands-on, exploratory activities related to issues and priorities in the New York State curriculum, the certification processes, and particular teacher interests. Promotional literature for the program said that earth science was selected for several reasons:

- More students take the earth science Regents exam than take the chemistry and biology combined.
- There is a shortage of teachers certified in earth science.
- Earth science has been under-valued in both high school and college programs, and there are efforts underway to redress this shortcoming.

The program was four days in length, with 24 teachers participating. The evaluation included a visit to the campus with interviews and observations of classes and related activities.

<u>Program Activities and Outcomes</u> The participants were both middle school and high school teachers. In brief conversations, during class and at lunch, they were highly positive about the program and about teaching with more active, exploratory, and "real" activities.

Classes that were observed in the Geosciences teaching lab demonstrated the variety of resources available in terms of equipment, supplies, and experienced teachers. These resources and activities included:

Stream table. Two activities were introduced: (1) To demonstrate and teach various concepts related to erosion, pollution, flooding, and sedimentation. Different kinds of measurements were taken, such as slope; geological features were discussed including kettle holes and the meandering nature of streams. The teacher/participants conducted measurements, calculating and describing the impact of the stream on its surroundings.

The teacher explaining the use of the stream table was competent and experienced. He adeptly drew participants into discussions about the Geoscience professions, "Here is another example of what geologists do." And "How do they do that?" He also talked about contour farming, showing how it works, with the use of the stream table. These comments offered a context for the discussion, namely, the profession of studying the earth, its shape, formation, impact on human life, and more. If transferred to the classroom, this kind of discussion might also motivate students to learn more in this area, and perhaps take courses or even major in geology in college.

The stream table used was an expensive model, but the teachers commented they could do a lot of the activities with less expensive or homemade materials.

Flow of Water Through Different Substances The participants observed in the lab were divided into two groups, each spending time on a particular activity, and then exchanging places. The water flow was the second activity. It was familiar to most of the teachers—one they had done with students—but, as the instructor pointed out, the commercially available materials used for the experiment were marbles and it was usually necessary to adjust or fudge the data to make the experiment work out.

The teachers divided themselves into teams of four, allotted themselves tasks—measuring, recording data, etc. The instructor on occasion said things like, 'We don't want kids to …' keeping the teaching/learning aspect in mind.

In addition to these and other resources, the Geosciences teaching lab contains samples and specimens, teaching/learning aids, as well as computer and audio/visual apparatus.

<u>Developing a Research/Exploration Mentality</u> One of the faculty for the summer program was asked in a phone interview whether the activities that the teachers

were working with could be translated intact back to the schools. She said that the more important benefit was that the activities would encourage a way of thinking, working with materials, collecting data, and problem solving. In other words the teachers were not so much gathering a collection of completed lessons and experiments as working on strategies, ways of thinking and teaching that they would then try to share with their students. While it is true that this larger goal is of great importance, it appeared that the teachers were also introduced to activities and projects that would be directly transferable to the classroom—with adjustments for the class level and other circumstances.

Preparing for New Challenges in the Classroom. Earth Science in New York State is taught at the eighth or ninth grade and more students take the course than any of the other sciences. The subject has therefore become something of a gatekeeper course through which students decide whether or not they like science. Teachers view the course as an opportunity to engage students in hands-on, exploratory approaches. But because of the large numbers of students taking the class and their ages, behavior and classroom management problems often arise. In addition, strategies are changing with regard to special education students, and several of the teachers expressed concern that their classes in the coming school year would involve inclusion for the first time.

The program offered the teachers substantial binders of materials about the lessons, methods, and experiments. In addition, the procedures that were covered in classes were made available online. The teacher participants brought lessons and shared them during one evening session. In addition to these practices, there was a very healthy level of collegiality, with teachers informally sharing ideas and strategies.

Survey Data The teacher participants were asked to complete surveys rating the different activities, field trips, and processes. Ratings on a five-point scale were consistently over 4, and in a few areas such as the permeability activity and stream table were at or close to 5. Comments were consistently positive about all aspects of the program. The only qualifications that teachers made were that some activities did not fit the curriculum they were following or that because of their location they would be less likely to use certain activities, such as those in marine science.

Undergraduate and Pre-College Attitudes Toward the Geosciences In addition to the assessment activities described above, the evaluation also conducted an ongoing investigation of under-represented minority high school students, and also looked at Stony Brook undergraduates' attitudes and experiences with the geosciences.

We have found that large numbers of students who might be good candidates for the geosciences select other STEM areas as their majors. There are several reasons (some mentioned above) why students are likely to turn their attention to other areas of science. First, areas such as biology and environmental studies are frequently discussed in the popular media. Second, medicine, nursing, and allied health are popular careers. Third, geology is generally studied in the eighth or ninth grade, receiving less attention in high school than the other majors, and many students do not consider it as a college major. Fourth, college students are not made aware of the wide-ranging careers in the geosciences. Finally, as we have noted, much of what happens in geology is in a very long-term timeframe and not as engaging for students as the other sciences. There are nevertheless a number of ways in which the geosciences can be made appealing to high school and college students. The evaluation has collected data from cohorts of under-represented minority students engaged in academic support programs sponsored by New York State, particularly STEP and CSTEP.

Science and Technology Entry Program (STEP). For more than 15 years, Stony Brook has sponsored a three-credit college course, Environmental Geology, for high school students on Long Island. The program is under the overall-umbrella of STEP, a statewide program aimed at increasing interest and motivation toward the sciences. The course is funded in part by BOCES (Bureau of Cooperative Educational Services) and also by the participating school districts. The course is not funded by the OEDG grant but since the goals are aligned with the grant, we are considering the attitudes and interests of students as a data source—in the investigation of attitudes of undergraduates (and potential undergraduates) toward the geosciences. The course begins with three weeks on campus during the summer and then meets on designated Saturdays during the academic year.

The 23 students in this program (2013) completed a survey assessing general interest and motivation in the geosciences. Tabulations, shown in Appendix 2, reveal high levels of interest in science generally, and an expectation of majoring in a STEM field in college, for most of the students.

The STEP students are selected primarily for their interest in science and desire to engage in enrichment activities. The numbers were small and so the statistics are of limited use. The survey results do however confirm the fact that high school students who are interested in science see themselves as much less likely to major in an area of the geosciences than in some other field of science.

CSTEP (College Technology and Science Entry Program) The CSTEP program provides academic and social support for students majoring in areas of science and technology. These students completed a summer bridge program emphasizing academic preparation for college, and process skills such as time management. Each year about twenty of the incoming students completed a survey. In response to the first set of questions between 15 and 38 percent, depending on the year, said they were likely to take courses in the geosciences. Only 5 to 13 percent said they were likely to major in the geosciences. Results of three years of surveys of the CSTEP students are found in Appendix 3.

Elements of a Model for Best Practices The review of Geoscience literature and curricula as well as the evaluation of enrichment programs at Stony Brook make it possible for us to identify best practices that taken together can form the basis for a model for enrichment in the geosciences.

1. Identifying Applicants. The Stony Brook program's overall goal was to attract more Geoscience majors at the college, with particular attention to under-represented minority students. With this in mind, representatives visited schools and distributed program literature to area schools, a number of

which already were already in contact with the university through other programs. Students applied for the program and were interviewed and screened primarily based on interest and motivation toward the sciences. Over the years the program enrolled students at different levels of high school and finally determined that those going into senior year were best able to benefit from the program and were more likely to pursue the sciences when entering and continuing in college.

2. Fieldwork. All science derives from the "real world." But students generally learn in classrooms from textbooks and teachers. Some teachers create excitement but science is often seen as not connected to the outside world. The OEDG summer enrichment workshops took students outside, guiding them as they began to see the world as scientists see it. This outside learning included several key elements.
   - Students engaged in guided observation and in gathering materials, and these activities were accompanied by measurements. The students did not wander about, as children might, collecting shells or identifying plants. Rather they were taught to measure geological phenomena. Some measuring can be done on the spot. In other situations, samples were brought back to be further examined. Examples: Students set up and gathered data from weather stations; they measured distances between boulders; collected water samples.
   - After measuring, students constructed hypotheses and looked for ways to verify or reject these hypotheses. As was described in several places in this report, the summer instructors guided students to begin thinking more generally about patterns that might exist in space and time. Examples: Students considered the differences among weather data at different locations, times, and days; they discussed why certain formations or rocks were widely separated and calculated the time it must have taken for the separation; they learned to do pH and other tests on water.

- The findings were followed by study to backup and expand understandings, interacting with existing knowledge and theory. In this way study and learning about geology occurred naturally as students wanted to verify and expand their investigations. Examples: Students engaged in projects about the development of geological features on Long Island; they considered global warming and its meaning.

3. Building Confidence and Motivation. In fieldwork and in the classroom, efforts were made to help students develop positive self- images, confidence in themselves as young scientists, and the motivation to further develop their scientific skills and concepts. A number of teaching/learning strategies were helpful in this regard. (Studies have reported the effects of stereotyping and negative expectations.) Teachers and mentors in the OEDG program do not use grades or negative assessments in working with students. They did not give unmerited praise, but guided students, suggesting areas of inquiry, ways to work with data, and additional information that might be useful. There was a mood of affirmation and the expectation that students would be successful. "If we don't understand something, the teacher makes us laugh to feel better about ourselves." In brief, the approach to teaching and learning was positive but realistic. Students gained confidence while remaining realistic about their level of knowledge add skills.

   Projects, Teamwork, and Presentations. Fieldwork and the learning that accompanied it led to team-based projects. In schools, both teachers and students are often disappointed in group-work because some students do all the work. These students feel the process is unfair; and those who do very little work, learn very little. The summer program however attracted motivated students. They all enjoyed science and in working together they discovered their own skills and learned to appreciate each other's talents. The projects also increased their understanding of the dimensions of science—gathering data, exploring meaning, looking for relevant theories, writing, learning computer skills, preparing posters, and more. "Some people are better at data questions, so we specialized; you have different perspectives; so we got a greater breadth of understanding." "At school everyone goes home, but here we do everything together. … We have a common interest because we all like science."

4. Teacher and Teaching Assistants. The team projects, discussed above, were successful in large part because of the involvement of the head teacher and teaching assistants. The numbers were such that each faculty member was responsible for only two or three team projects. They were thus able to bring appropriate resources to each project, assist individuals and work with them on the preparation of presentations and posters.

   The summer workshops were successful because the head teacher and teaching assistants brought a number of important traits to the project including: knowledge of the geosciences, the ability to make topics relevant and interesting to the students, respect for the students, and enjoyment in the teaching-learning process.

The best practices can be summarized in a somewhat different way, considering four levels of educational programming.

1. Objectives The program's objectives were clearly stated and understood by the teachers and students.
   - Using exploratory science, gave students experiences in doing rather than just learning about science.
   - The program motivated students so that they would be likely to consider learning more STEM in college and perhaps major in the geosciences.
2. Organizational Arrangements Residence on the college campus, fieldwork, data analysis, projects, and presentations were all aligned with the objectives providing well-rounded experiences and learning.
3. Teacher Activities The teachers worked with the students as young adults taking responsibility for their learning and their futures. They were knowledgeable in how to bring science explorations and learning to the

students in ways that reached them in the world, while also expanding their horizons concerning the importance of the geosciences.

4. Student Activities Student learning was active; as they asked questions, explored, took measurements, evaluated data, and built on what they learned. Their knowledge grew and expanded as they moved from one investigation to another.

Appendix 1

High School Teachers Workshop Survey The OEDG program offered a week-long workshop during August, 2013 for earth science and geology school teachers. The workshop included a combination of class work, field activities and the preparation of lessons for school. In survey responses, teachers gave high ratings to all aspects of the program. As in past years, the teachers reported that the most interesting activities were those that included labs, fieldwork, and hands-on experiences.

Teacher Participant Survey (N = 6)

Please indicate your level of agreement or disagreement (Agree strongly = 5; Agree = 4; Disagree = 2; Disagree Strongly = 1)

	Mean Rating	% 5 or 4
1. The workshop improved my skill base in geoscience.	5.0	100
2. The workshop enhanced my conceptual understanding.	5.0	100
3. The activities will be useful with classes at school.	5.0	100
4. I believe students will respond positively to lessons developed.	5.0	100
5. The activities will need to be reworked for my classes.	4.29	100
6. I will recommend the program to teacher colleagues.	4.86	100
7. Engaging with other teachers was productive.	4.71	100
8. In general, the program met my expectations.	4.86	100
9. The workshop topics fit well with the curriculum	4.57	100
For each of the following, please indicate (Very Likely, 5; Likely, 4, Possibly, 2, Not at all likely, 1)		
10. I will develop a lesson based on the demonstration.	5.0	100
11. Others at my school will be interested in the activities.	4.71	100

12. **What was most beneficial about the workshop?** The teachers covered a number of areas in their responses and were particularly pleased with what they believed they could take back to their classrooms with modest expenses for new materials.

    I was very impressed with the experiments. I hope to get some for my own classroom. I loved the ocean; perhaps a more comfortable boat would be nice. I was disappointed that we didn't do a balloon launch.

    The instructors' knowledge and topics really helped to clarify misconceptions and weather and oceans. I learned a lot; my base knowledge of the topics has improved.

    Hands-on activities that do not involve expensive equipment

    Some of the labs/demos using simple materials were useful for me, since my school has a small budget.

    The lab activities can be used for both 6th grade science and earth science

    Being taught by experts in their field who love what they do and to share it with us.

    The experiments and the boat ride.

13. **Which laboratory experiences were most engaging and why?** Respondents said they found all of the labs engaging. Favorites were: the warm and cold

fronts, green houses, microclimates, density of water for an egg to float, convection with oil/thyme

14. **How would you improve the program?** The teachers had a number of practical suggestions.
    - *Make sure lab materials are prepared.*
    - *Make the workshop longer: one week for weather; on week for ocean.*
    - *Take the higher level information out of the presentations; not used in high school.*
    - *Have more and better resources to use in the lab.*
    - *Don't go on the ocean.*
    - *Make it 3 credits.*
    - *Have more experiments.*

    Materials from the Museum of Long Island Natural Sciences at Stony Brook describe the geological formations and history on Long Island, and go on to discuss the various collaborations that exist.

Appendix 2

Survey of High School STEP Students

Item 5 was rated on a 5, 4, 3, 2, 1 scale.
Items 6, 8, and 9 were rated on a 4, 3, 2, 1 scale.
Item 7 was Y/N and the students who answered "Y" were tallied.
Items 10 and 11 were rated on a 5, 4, 2, 1 scale.
Items 12 and 13 were rated on a 5, 4, 2, 1, x scale, where "x" represents "I don't know."

1. Year of school (entering): 11^{1h} (12), 12th (11)
3. Gender: Male (12); Female (11)

4. Which of the following best describes you? African-American (4); Hispanic (13); Asian (5); White (1); Other (1) (Haitian/Brazilian)

The following show the mean for each item and the percent 4 or 5 in parentheses

	2012	**2013**
5. I enjoy outside activities such as hiking and camping?	4.40 (93)	1.83 (4)
6. How likely is it you will take the following college classes? (4, Definitely; 3, Probably; 2, Probably not; 1, Definitely not)		
a. Physics (force, motion, and magnetism)	2.93 (80)	3.09 (87)
b. Chemistry (chemical reactions and atomic structure)	3.07 (80)	3.33 (87)
c. Computer Science (designing, building, and programming)	2.93 (67)	2.59 (45)
d. Mathematics (algebra, calculus, and geometry)	3.27 (87)	3.48 (83)
e. Engineering (designing and building roads and machines)	2.60 (53)	2.61 (52)
f. Biology (plants, animals, and ecology)	3.00 (71)	3.43 (87)
g. Geosciences (geology, geography, meteorology, and/or oceanography)	2.79 (64)	2.27 (36)
h. Psychology (behavior and mental health)	2.93 (73)	3.17 (74)

7. College classes previously taken/currently taking?	Number of students
a. Physics (force, motion, and magnetism)	16
b. Chemistry (chemical reactions and atomic structure)	5
c. Computer Science (designing, building, and programming)	5
d. Mathematics (algebra, calculus, and geometry)	15
e. Engineering (designing and building roads and machines)	5
f. Biology (plants, animals, and ecology)	6
g. Geosciences (geology, geography, meteorology, and/or oceanography)	4
h. Psychology (behavior and mental health)	3

8. Likelihood you will major (or are majoring) in one of the following?

(4, Definitely; 3, Probably; 2, Probably not; 1, Definitely not)	**2012**	**2013**
a. Physics (force, motion, and magnetism)	2,53 (47)	2.14 (36)
b. Chemistry (chemical reactions and atomic structure)	2.47 (47)	2.61 (60)
c. Computer Science (designing, building, and programming)	2.6 (47)	2.1 (29)
d. Mathematics (algebra, calculus, and geometry)	2.6 (47)	2.55 (50)
e. Engineering (designing and building roads and machines)	2.47 (47)	2.05 (27)
f. Biology (plants, animals, and ecology)	2.8 (60)	3.27 (86)
g. Geosciences (geology, geography, meteorology, and/or oceanography)	2.54 (39)	1.62 (10)
h. Psychology (behavior and mental health)	2.78 (60)	2.64 (54)

9. I would really enjoy a career in…

(4, Definitely; 3, Probably; 2, Probably not; 1, Definitely not)

a. Biology	2.86 (60)	3.23 (86)
b. GeoScience	2.57 (57)	1.91 (23)
c. Medicine	2.79 (57)	3.26 (74)
d. Law	2.53 (60)	1.82 (27)

10. How much do you agree with the following statements? (5, Strongly agree; 4, Agree; 3, Neutral; 2, Disagree; 1, Strongly Disagree)

	2012	**2013**
a. I like science.	4.33 (93)	4.74 (100)
b. I am good at science.	4.40 (93)	4.3 (83)
c. Learning science is mostly memorizing.	3.53 (67)	3.35 (50)
d. Environmental research is important.	4.27 (92)	3.91 (86)
e. I like math.	3.87 (80)	3.87 (74)
f. I am good at math.	4.93 (80)	3.83 (70)
g. I want to study more science in school.	4.13 (80)	4.52 (96)
h. Everyone can do well in science if they try.	4.4 (87)	4.39 (96)
i. Science is boring.	2.07 (20)	1.91 (17)
j. I would rather work on a science project in an outdoor setting than in a research laboratory.	3.87 (74)	3.7 (65)

11. How much do you agree with the following statements?
(5, Strongly agree; 4, Agree; 3, Neutral; 2, Disagree; 1, Strongly Disagree)

a. Geosciences are interesting.	4 (87)	2.74 (39)
b. Geosciences are very important.	4.2 (93)	3.35 (65)
c. Biology is interesting.	4.13 (87)	4.59 (95)
d. Biology is very important.	4.33 (93)	4.65 (100)
e. Math is interesting.	4 (80)	3.74 (70)
f. Math is very important.	4.47 (93)	4.43 (96)
g. Engineering is interesting.	3.93 (74)	3.7 (37)
h. Engineering is very important.	4.07 (80)	3.87 (78)

12. How much do you agree with the following statements?
(5, Strongly agree; 4 Agree; 2, Disagree; 1, Strongly Disagree)

	2012	**2013**
a. I am interested in Hydrology.	2.54 (31)	2.63 (31)
b. I am interested in Geography.	3.13 (47)	2.68 (37)
c. I am interested in Geology.	3.50 (64)	2.59 (29)
d. I am interested in Meteorology.	3.20 (53)	2.63 (32)
e. I am interested in Oceanography.	3.2 (53)	3.05 (50)
f. I am interested in Volcanology.	3.27 (53)	2.79 (42)

A13. How much do you agree with the following statements?
(5, Strongly agree; 4, Agree; 2, Disagree; 1, Strongly Disagree,
x; I don't know)

	2012	**2013**
a. I'd enjoy being a Geoscientist.	3.4 (60)	2.19 (19)
b. Geoscientists earn good incomes.	3.67 (78)	2.56 (44)
d. I like working with other students in science.	4.13 (87)	4.35 (100)
e. I am comfortable using computers.	4.2 (87)	4.26 (91)
g. I am comfortable using a geological GPS device.	4.0 (75)	3.74 (79)
h. I'd enjoy being an engineer.	3.25 (58)	3.32 (63)
i. I'd enjoy being a scientist.	4.0 (86)	4.05 (80)

(Letters *c* and *f* were missing from the original survey above. For consistency's sake, no adjustments were made here.)

14. What has been most interesting in your geoscience studies?
The areas frequently listed as most interesting included: the makeup of the earth (Mechanics of the earths core, tectonic plates, as well as the ring of fire, and natural disasters). Another popular topic was planets and stars.
Other responses included: Isotopes (2), The Oceans(1), and a general appreciation for gaining new knowledge in general (3)
Three respondents said they did not enjoy earth sciences.

15. What has been most challenging in your geology studies?
The majority listed mineral properties and memorizing rocks as most difficult
Seven respondents said that nothing was difficult; several were left blank.

Appendix 3
Survey of Stony Brook CSTEP Students

Geosciences: Student Survey: CSTEP Participants (N = 20)
Item 5 was rated on a 5-4-3-2-1 scale.
Items 6, 8, and 9 were rated on a 4-3-2-1 scale.
Item 7 was Y/N and the students who answered "Y" were tallied.
Items 10 and 11 were rated on a 5-4-2-1 scale.
Items 12 and 13 were rated on a 5-4-2-1-x scale, where "x" represents "I don't know."

Mean Rating

5. I enjoy outside activities such as hiking and camping? 4.07 (2011) 4.42 (2012)

	2011 Cohort	2012 Cohort	2013 Cohort
6. How likely is it you will take the following college classes?	Mean(%4or3)	Mean(%4or3)	Mean(%4or3)
a. Physics (force, motion, and magnetism)	3.3 82	3.8 100	3.65 95
b. Chemistry (chemical reactions and atomic structure)	3.5 88	3.25 80	3.45 95
c. Computer Science (designing, building, and programming)	2.19 25	2.74 58	2.7 50
d. Mathematics (algebra, calculus, and geometry)	3.94 100	3.95 100	3.6 90
e. Engineering (designing and building roads and machines)	2.56 44	3.4 75	2.6 45
f. Biology (plants, animals, and ecology)	3.19 82	2.9 55	3.2 70
g. Geosciences (geology, geography, meteorology, and/or oceanography)	2.94 38	1.79 16	1.9 15
h. Psychology (behavior and mental health)	2.94 82	2.32 42	2.5 50

7. College classes previously taken/currently taking?	No. of Students
a. Physics (force, motion, and magnetism)	7
b. Chemistry (chemical reactions and atomic structure)	7
c. Computer Science (designing, building, and programming)	1
d. Mathematics (algebra, calculus, and geometry)	14
e. Engineering (designing and building roads and machines)	0
f. Biology (plants, animals, and ecology)	9
g. Geosciences (geology, geography, meteorology, and/or oceanography)	1
h. Psychology (behavior and mental health)	7

Mean Rating

	2011 Cohort	2012 Cohort	2013 Cohort
8. Likelihood you will major (or are majoring) in one of the following?	Mean(%4or3)	Mean(%4or3)	Mean(%4or3)
a. Physics (force, motion, and magnetism)	1.81 13	2.53 42	1.89 28

b. Chemistry (chemical reactions and atomic structure)	2.06 13	2.0 26	2.05 26
c. Computer Science (designing, building, and programming)	1.75 13	1.89 16	1.89 21
d. Mathematics (algebra, calculus, and geometry)	1.94 19	2.11 32	1.89 28
e. Engineering (designing and building roads and machines)	2.56 56	2.95 75	2.25 44
f. Biology (plants, animals, and ecology)	3.06 63	2.58 47	2.56 67
g. Geosciences (geology, geography, meteorology, and/or oceanography)	1.94 13	1.58 11	1.32 5
h. Psychology (behavior and mental health)	2.19 38	1.74 16	1.95 37

9. I would really enjoy a career in…
(4, Definitely; 3, Probably; 2, Probably not; 1, Definitely not)

a. Biology	2.68	68
b. GeoScience	1.89	5
c. Medicine	3.21	68
d. Law	2.21	37

10. How much do you agree with the following statements? (Scale = 5-4-2-1)
(5, Strongly agree; 4, Agree; 3, Neutral; 2, Disagree; 1, Strongly Disagree)

	Mean	**%5or4**
a. I like science.	4.6	95
b. I am good at science.	4.45	100
c. Learning science is mostly memorizing.	3.1	55
d. Environmental research is important.	5.9	90
e. I like math.	3.85	85
f. I am good at math.	3.9	85
g. I want to study more science in school.	4.15	85
h. Everyone can do well in science if they try.	3.55	65
i. Science is boring.	1.75	5
j. I would rather work on a science project in an outdoor setting than in a research laboratory.	3.21	53

11. How much do you agree with the following statements?
(5, Strongly agree; 4, Agree; 3, Neutral; 2, Disagree; 1, Strongly Disagree)

a. Geosciences are interesting.	2.84	42
b. Geosciences are very important.	3.05	60
c. Biology is interesting.	4.21	89
d. Biology is very important.	4.05	79
e. Math is interesting.	3.63	74
f. Math is very important.	4.42	95

g. Engineering is interesting.	3.74	68
h. Engineering is very important.	4.37	95

Mean Rating

12. How much do you agree with the following statements? (4, Strongly agree; 3 Agree; 2, Disagree; 1, Strongly Disagree)

	Mean	**%5or4**
a. I am interested in Hydrology.	2.13	6
b. I am interested in Geography.	2.32	21
c. I am interested in Geology.	2.0	5
d. I am interested in Meteorology.	2.55	30
e. I am interested in Oceanography.	2.24	17
f. I am interested in Volcanology.	2.24	17

13. How much do you agree with the following statements?
(5, Strongly agree; 4, Agree; 2, Disagree; 1, Strongly Disagree,
x; I don't know)

a. I'd enjoy being a Geoscientist.	2.07	13
b. Geoscientists earn good incomes.	2.33	22
d. I like working with others in science class.	4.1	90
e. I am comfortable using computers.	4.2	95
g. I am comfortable using a geological GPS device.	4.06	88
h. I'd enjoy being an engineer.	3.69	69
i. I'd enjoy being a scientist.	3.94	76

(Letters *c* and *f* were missing from the original survey above. For consistency's sake, no adjustments were made here.)

14. What has been most interesting in your geoscience studies?

- Learning the history
- Volcanoes (2)
- Rocks
- Meeting other students

15. What has been most challenging in your geology studies?

- Learning about the atmosphere
- Volcanoes
- Geography
- Math class (2)
- Classifying parts of the ground

16. If you have undertaken research in geology what were the more important ideas, skills, or understandings?

- Ability to admit you are wrong (4)
- Planetary motions
- How seasons work

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