Testimony of Eleanor Miele, Ph.D. February 3, 2010

Summary: Over the past twenty years the Brooklyn College School of Education has received funding from the National Science Foundation to "reform" the preparation of science teachers at all levels. Course evaluations show that students of inquiry-based science courses report gaining more ability to analyze and solve problems and to find and use information than students in traditional college science courses. Financial support for teacher preparation, professional development and access to materials of science instruction and for rigorous quantitative evaluation of the efficacy of inquiry-based science instruction is necessary to make inquiry science instruction systemic and a right for all students.

My name is Eleanor Miele and I am the Program Head of Science Education at the School of Education at Brooklyn College of the City University of New York. I am responsible for the undergraduate and graduate programs in elementary, early childhood and middle childhood science education. Brooklyn College is a publicly funded institution of higher education that serves a diverse urban community. I am trained as a traditional scientist with a doctoral degree and post doctoral research experience in molecular biology and genetics. I have 16 years of experience as a teacher of inquiry-based science to urban high school students and 17 years of experience preparing teachers of science to work in New York City schools. My testimony will address several issues in inquiry-based STEM education:

- K-12 Inquiry Science Curriculum
- K-6 Teacher Preparation
- 5-12 Science Teacher Preparation
- Need for Systemic Change

In the early 1900s John Dewey had already challenged the educational community to allow children to construct their own understanding though concrete interactions with materials and defined the essential features of inquiry learning.

> "*Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject-matter.*"[1]

Beginning in the 1960's, with funding from the NSF, science education was "reformed" to incorporate an emphasis on "doing science" in collaborative groups rather than memorizing science as passive receivers of knowledge. Over twenty years ago the Lawrence Hall of Science of the University of California at Berkeley developed the Science Curriculum Improvement Study(SCIS) followed by the Full Option Science System (FOSS) in a collaboration between scientists and educators to create curricula for elementary school students to gain scientific understanding through active inquiry. Extensive research demonstrated the power of these curricula to increase science content knowledge in students from varied socioeconomic groups and in English language learners, but large scale studies often failed to demonstrate significant improvements in science learning.

When I assumed responsibility for science education at Brooklyn College in 1998, the college had recently received funding from NSF to purchase the SCIS and FOSS kits for use in courses in methods of teaching science as part of the *Brooklyn Plan* to reform science instruction for early childhood and elementary teachers. At that time I conducted my own informal investigations into the impact of these curricula on student learning. I reviewed the aggregate scores of students from a selection of public elementary schools in Brooklyn, NY on the NYS Elementary Science Program Evaluation Test (ESPET). This test was one of the first to include evaluation of students' abilities to *do*

[1]Dewey, J. 1910. Science as subject matter and method. Science. 28, 121-127.

science inquiry. I found that schools that reported that they had adopted the NSF-funded SCIS or FOSS curricula had higher scores on the ESPET than similar schools that did not use the inquiry-based curricula. They often also had higher scores on the state mathematics and reading tests despite having high percentages of minority and Title 1 students. Unfortunately, the limited data available at that time precluded a systematic evaluation of the efficacy of the NSF-funded curricula in New York City Schools.

One anecdote illustrates the power of inquiry-based instruction in empowering elementary school students to learn. I asked teachers in a graduate class in science education to pair up and teach the same inquiry-based lesson to their own students and compare the student products. In one pairing, one teacher was teaching a sixth grade class in a parochial school and the other was teaching a second grade class in a public school that had fully implemented the SCIS curriculum. The teachers were shocked at the results. The sixth grade teacher had difficulty just preparing her students to "become scientists" for the day. The work produced by the second grade class was more sophisticated and gave evidence of deeper understanding than that of the sixth grade class. These younger children had already gained the basic skills of inquiry as kindergarten and first graders and thought of themselves as "scientists." The scientific skills and attitudes of objective observation and analysis take time and practice to develop, just like the basic skills of reading and mathematics.

One of my former students recently sent this news from the "front," a Brooklyn Middle School committed to inquiry-based instruction;

> "...our kids are totally unprepared to do inquiry-based science because they do not have the background knowledge, the non-fiction reading ability nor the higher-order thinking skills required to make the connections that we are asking them to make. We are doing inquiry in our school, but it is a long and painful process. BUT, when the kids do come through the process, they are much more engaged and excited by the process of science as something that they can do - not something that has already been done (by old white men)."

The take-home message; teaching inquiry-based science is difficult--but worth the effort and it should begin before middle school.

The FOSS curriculum has recently been adopted by the New York City Department of Education as the approved hands-on science curriculum for elementary schools city-wide. Nevertheless most schools still opt for the traditional text-based approach with "supplemental activities" because of the lower cost and because of teachers' fear of doing science in the classroom. This is however, a time of historic opportunity to systematically examine the effectiveness of the FOSS curriculum, as school systems enter a new age of data transparency.

To teach inquiry science, teachers must be comfortable with their own ability to engage in inquiry. The National Science Education Standards, published by the National Academies Press in 1996 stated that "effective teachers of science create an environment in which they and students *work together as active learners*." According to the *Standards*, "Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry." Science learning experiences for teachers must

- Involve teachers in actively investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings consistent with currently accepted scientific understanding...
- Introduce teachers to scientific literature, media, and technological resources that expand their science knowledge and their ability to access further knowledge..."[2]

As part of the NSF funded *Brooklyn Plan*, faculty in science and science education developed a new series of required inter-disciplinary inquiry-based science courses. Two of these courses are still required of all early childhood and elementary education majors in addition to the general education

[2] 1996. National Academies Press. *National Science Education Standards,* http://www.nsta.org/publications/nses.aspx

science courses required of all Brooklyn College students.

In 2005 Brooklyn College began a new online course evaluation program designed to look closely at student outcomes. The evaluation uses a standard five level Likert scale of responses and allows for student comments. For this hearing I reviewed the course evaluations with a focus on student responses to questions that are indicators of inquiry-skill development. The two questions are

- How much ability to analyze and solve problems have you gained?
- How much ability to find and use information on your own have you gained?

Possible responses are “a lot,” “a fair amount,” “some,” “a little,” and “hardly anything.” Starting with the assumption that all science courses place a high priority on the ability to analyze and solve problems, I compared the total aggregate student responses for the departments of Biology, Chemistry, Geology and Physics to those for General Science for the Spring 2009 semester.

I found that 51% of students in inquiry-based General Science courses respond that they had gained “a lot” of ability to analyze and solve problems, compared to between 16% and 29% of students in traditional science courses (20% biology, 29% chemistry, 16% geology, 28% physics). When the two “positive” responses are summed for each department the results are equally clear; 69% of physics students, 59% of biology students, 71% of chemistry students, 50% of geology students and 88% of General Science students reported that they gained either “a lot” or “a fair amount” of ability to analyze and solve problems. These data indicate that students perceive that inquiry-based courses are more successful than traditional science instruction in helping them develop analytical skills.

When asked “How much ability to find and use information on your own have you gained?” 53% of General Science students said “a lot,” compared to between 21% and 26% of students in other science courses. Skills in independent literature research are essential to scientific research, and once again students in the inquiry-based courses reported gaining more of these inquiry skills.

The ability to effectively communicate is also a fundamental skill for scientists and educators alike. In response to the question “How much ability to express your ideas verbally have you gained from this class?” 50% of General Science students responded “a lot”, compared to 18% of Biology, Geology and Physics students and 23% of Chemistry students.

One student recently summed up the value of inquiry-based instruction with this posting, *“This course is interactive, so you don't fall asleep listening to a lecture for 3 hrs. Also, you learn better when you are doing science rather than learning about science.”*

Graduates of our childhood education program enter the profession of teaching prepared to think of themselves as problem-solvers and empowered to teach inquiry-based science to children. Graduates of our program are sought out by principals who are committed to inquiry-based science instruction. Over twenty years later, the benefits of the NSF funding for the Brooklyn Plan continue to bear fruit for elementary school teachers and their students.

Over ten years ago I began to reach out to informal science institutions in the City of New York to enter into partnership with Brooklyn College to increase access to high quality materials for science instruction for all New York City schoolchildren. Working with the American Museum of Natural History (AMNH) I developed a new course: Science Beyond the Classroom. Educators at the Bronx Zoo also reached out as a result of my partnership with AMNH and we have developed two courses in collaboration that are offered to graduate and undergraduate students of education. The Wildlife Conservation Society later received funding from NSF CCLI to expand on the undergraduate courses. (In the Fall 2008 course evaluation survey 40% of graduate students taking the WCS course report gaining “a lot” of ability to analyze and solve problems. 60% gained “a lot” of ability to find and use information on their own. 100% gained “a lot” or “a fair amount” of both skills.)

Evaluation of outcomes from the first collaboration with AMNH revealed a fundamental barrier to place-based inquiry instruction in public education. Our evaluation revealed that school principals did not see field trips as “instructional time.” They would not allow the teachers we had trained to teach at

science-rich sites such as the American Museum of Natural History (AMNH) to use these rich resources to teach their students. They viewed field trips as rewards, not as educational opportunities.

Synergistically this coincided with the New York City Department of Education implementing a required inquiry-based Exit Project for graduation from middle school. The American Museum of Natural History was able to organize nine science-rich institutions in the city to demonstrate that they could support the Exit Project effort, and with funding from the City Council in 2005 the Urban Advantage project was born. Urban Advantage is a standards-based partnership program designed to improve students' understanding of scientific inquiry through collaborations between urban public school systems and science cultural institutions that has allowed place-based science investigation to flourish in New York City middle schools.

While our partners at the American Museum of Natural History worked successfully to change the system to support inquiry learning at science cultural institutions, my colleagues in the Geology department at Brooklyn College and I worked to change the college to support inquiry learning for science teachers. Bringing inquiry approaches to secondary school teachers is problematic, since their science instruction is typically conducted in science departments which have not embraced inquiry approaches to instruction. Teachers teach as they have been taught. Another problem in effective inquiry instruction is access to materials to observe and manipulate. During successive budget crises, access to materials of science instruction has often been limited in New York City schools. By designing new courses for our graduate programs in middle childhood and secondary science education in partnership with informal science partners, we were able address these two critical problems at the same time.

We began in partnership with the AMNH and our sister college Lehman College to create TRUST, Teacher Renewal for Urban Science Teachers. Together we developed a program including new inquiry-based geoscience courses at the two partner colleges and a summer institute at the AMNH that would count as graduate credit toward teacher certification. Our external evaluator found that 87% of TRUST participants reported that they had taken their students outside the classroom for instruction.

The new course developed at Brooklyn College, Geology 613: Earth Science in the NYC Urban Environment, requires four field trips and is described as follows:

Investigation of five guiding questions regarding the connections between geology and New York City: On what is the city built? Of what is the city built? How has the New York City environment changed? Why did the metropolis develop here? What environmental hazards does New York City face? Mandatory weekend field trips within Manhattan and Brooklyn.

In the Spring 2009 offering of this course, 60% of participants responded that they had gained “a lot” of general knowledge about the subject. 45% responded that they had gained “a lot” of ability to analyze and solve problems. And 55% said they had gained “a lot” of ability to find and use information on your own. Compare these results to the results for the Geology department as a whole, which had the lowest average scores for these questions of all science departments.

Based upon the success of the TRUST project we received funding from the NSF Geosciences division for *Science and the City*, a plan to develop a new 30-credit program of inquiry and field based courses in geoscience for teachers of Earth Science. Our goal was to create an entirely new approach to science teacher preparation using a City-as-Lab approach to produce graduates who are able to integrate the resources of the city into their teaching.

This program includes twenty-four credits in geology that model active learning pedagogies. The courses are thematic in nature and focus on core knowledge from the New York State Core Curriculum in science with an emphasis on inquiry-based learning. The courses were designed by a team consisting of members of the Division of Science of the New York City Department of Education,

experienced middle and high-school earth science teachers, informal science educators and college faculty in geology and education.

All course assignments are based on goals that are student–centered, concrete, measurable, and develop higher-order thinking skills by providing practice in key content and process skills through activities and assignments in real world applications. Course assignments in all courses require teachers to create age-appropriate learning activities for students utilizing NYC and NYS cultural and/or natural resources.

During the summers of 2007 and 2008 the New York State Education Department funded a summer science institute, New York City Earth Science & Technology which allowed us to pilot two new courses each summer without cost to the teachers. To evaluate the effectiveness of this summer institute we conducted a program evaluation..

In summer 2007 the content knowledge gain of the participating teachers was assessed by a program evaluator (not the course instructor) using a pre-test/post-test comparison based upon the New York State Regents examination in Earth Science. We found this approach to provide limited data on knowledge acquired. For 2008 we used an open-ended assessment embedded in the first and last course sessions. Students completed a concept map of their current understanding of the main theme of the course on day one and the final session. Concept Mapping, developed initially by Joseph Novak at Cornell University in the course of research to follow and understand changes in children's knowledge of science, is now widely used to organize and represent knowledge. Post course concept maps showed gains in the number of concepts and connections. There were also fewer misconceptions on post-test concept maps.

For all courses, the pedagogic skills of course participants were also assessed by an external review of unit and lesson plans prepared as major course assignments. All lessons prepared by course participants were found by external reviewers (New York City Earth Science Teachers) to be standards-based and inquiry-based. Privacy and union regulations have precluded meaningful assessment of impacts on student learning in New York City classrooms, but new agreements for data sharing indicate that it may soon be possible to obtain data on the impact of inquiry-based teaching in classrooms.

New York City schools face a critical lack of earth science teachers and a high attrition rate of new teachers. At the outset of this project only 7% of the certified science teachers in the city were certified to teach Earth Science. Based on the recommendations of our colleagues in the NYC DOE who assisted us in design of this new inquiry-based masters program, for the past three years, the New York City Department of Education has funded a cohort of NYC Earth Science Immersion Teaching Fellows at Brooklyn College. Over 90% of these Fellows are successfully teaching Earth Science in New York City public schools.

Needs:

In order to systematically institutionalize inquiry-based science instruction, it is essential to support changes system-wide that will support higher order learning and discourage mere memorization and recall. Most current methods of assessment discourage inquiry-based instruction. Development of a digital assessment system based on concept maps would be a benefit to inquiry-based instruction since software for concept mapping is widely available and used. We need to continue to support inquiry-based teacher preparation and professional development and provide ongoing funding for materials of instruction. True systemic change requires additional support for pure research in science education and cognition in science learning. Funding to support the professional education of researchers in science education is also needed to properly document the efficacy of inquiry-based instruction. Properly trained evaluators who understand both science and pedagogy are rare. It is 100 years after John Dewey first introduced the idea of "progressive" inquiry-based instruction. It is time that it was the norm and not the exception, a right and not a privilege.