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MATERIALS SCIENCE AND ENGINEERING OUTREACH PROGRAM

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ABSTRACT

We report on a school science outreach program that we have carried out since 1999 under the National Science Foundation funded Materials Research Science and Engineering Center (MRSEC) at Columbia University. Under this program, we have made 34 visits to twenty New York City public high schools and middle schools and have reached over three thousand students. The demographic of the schools are around 81% historically underrepresented minorities (37% African Americans and 44% Hispanic Americans) and around 55% female. This report shows how a similar program can be set up in an urban area, which can directly address the vital shortage of youths going into science, engineering and mathematics (SEM) careers. Logistics and experiences of running the program are described. Lessons learned and certain important issues of the program are addressed for an easy adaptation in a new city.

Keywords: *Public school outreach, K-12 visitation, materials science outreach*

INTRODUCTION

Swift technological advancements in the modern world increasingly require citizens to be well equipped to apply and contribute to science, engineering and mathematics (SEM) knowledge. Recent studies suggest that the United States' native work force is not able to meet such a demand[1]. A major factor contributing to this situation is the low participation of females and under-represented minorities (Hispanics, Blacks and American Indians) in SEM fields[1,2]. Late awareness of opportunities, inadequate preparation, the lack of role models and the sometimes less-than-friendly SEM culture are among many factors as barriers to recruit these individuals into SEM fields [3-5].

We report a city school science outreach program that aims to make students aware of the fun in SEM fields, the opportunities in SEM careers and the importance of their early SEM preparation in high schools. We have carried out this program since 1999 under the National Science Foundation funded Materials Research

Science and Engineering Center (MRSEC) at Columbia University. The program is also known as the MRSEC New York City School Visitation Program and is part of a multi-faceted education and outreach effort of MRSEC. This program borrows its script from the University of Washington and has inputs from of a number of other universities and technical societies. We want to provide the details of our implementation and to encourage other university materials departments and programs to start their own high school outreach programs as we did in 1999.

Among all science and engineering disciplines, we choose materials science and engineering (MSE) as the basis of our demonstrations for the following reasons. Usually in MSE solid materials are involved. Students can easily develop a physical feel for solid materials. In addition, they are safer for transport and handling as parts of demo kits. Solid materials have been the basis for electronic and information device integration and emerging consumer technologies. A Bachelor's degree in MSE is a working degree which enables a student to work in industry as an engineer and also prepares a student for graduate study. We choose MSE for outreach because the MSE BS degree gives students options as well as a definite job certainty after graduation. Besides, MSE is a relatively lesser known discipline than chemistry and physics in K-12 schools and merits some visibility.

VISITS

Beginning

The first author began this program in 1999 under the MRSEC outreach program. The program's goal is to bring the excitement of materials science and engineering to high school students in New York City. Public New York City high schools in Manhattan and the Bronx were targeted. During each visit, a team of Columbia University students introduces the high school students to the world of materials through live demonstrations. To date, the Columbia University MRSEC Education Outreach Program has made 34 visits to twenty New York City public high schools and middle schools. Fifteen of the twenty schools visited were schools which had teachers involved earlier in the Columbia University Medical School Summer Research Program (SRP) [6] and MRSEC Research Experience for Teachers (RET). Getting to know these teachers personally has proved to be very important in getting access to these high schools. Early difficulties were encountered in approaching high schools for our visits in 1999. Letters were written to school principals and superintendents and calls were made with few responses. Our big break came from talking to the high school teachers who were in our own SRP and RET programs. Our outreach has continued to be benefited by getting to know new teachers and new schools through these summer research programs. This synergy among different outreach programs was unexpected but very much welcome. Later our program has gained acceptance by the word of mouth among teachers.

Objectives of Visits

During each visit, the field of materials science is explained through exciting, hands-on demonstrations incorporating "every day" objects. One goal of these visits is to foster the interest of K-12 students in science and technology by showing them the marvels of materials science and engineering and describing the relevance of science to quality of life. Another goal is to motivate them to pursue studies in science, and to inform them of career opportunities in science and technology. A final objective is to improve the retention of a diverse student body on track for careers in science and technology. We aim to present to them an informative and entertaining show. We want to plant the seeds in them to be interested in, and pursue studies in, science and to inform them of the importance of choosing advanced level courses of science and mathematics in high schools in order to be on track for careers in science and technology. In order to grab students' attention to achieve our objectives,

theatrical elements such as fire, fog, smoke and loud bangs (see outline of demonstrations) have been strategically included.

Logistics of Visits

Typically a team of two students led by Prof. Chan, another faculty member or Ms. Alison Biuso, our outreach co-coordinator, visits a school. There are usually between six to ten Columbia undergraduate and graduate students trained to make these visits during the academic year. Over the years we have extended to recruit interested post-doctoral fellows. The trained "students" make the actual presentations. We have all team members trained at the beginning of a semester. For each visit, the team members will practice for 2-3 hours the day before. This is helpful to determine if certain pieces of the kits are missing and to make quick replacements. This rehearsal rule is strictly adhered to no matter how many times the members have made these visits. We believe the rehearsal rule takes our performance to a professional level. We bring our kits of demo materials in a red toolbox and our own liquid nitrogen in a dewar. See photograph 1 showing team members carrying the toolbox and the dewar.

Our demonstration is tailored to the class time of either 45 or 90 minutes to be easily incorporated to the corresponding school's schedule. We also ask for the same classroom for the 4-6 presentations to avoid time loss during packing and unpacking. Our demonstration/lesson is tailored to a class size of 20-32 students. Since the coordination with schools still requires a lot of efforts, we make most out of each visit by staying there the whole day and address typically 4-6 science classes, with a possible total of 80-140 students. During the course of these visits, we have also found out that it is only necessary for the senior team member to be present at arrival and the first presentation. We also give teachers a two-page summary of the demonstration units and corresponding follow-up questions and discussion topics. Such information helps teachers to incorporate the demonstrations with their on-going lesson plans.

We will continue to visit new schools this coming year, at a rate of approximately one per a month. For the spring 2004, we are considering visits to (1) Far Rockaway High School, Brooklyn, NY, (2) Bard High School Early College, New York, NY, (3) Frederick Douglass Academy, and (4) Norman Thomas High School, New York, NY.

FEEDBACKS AND IMPACT

The high school students have been interested in these presentations and have asked many questions. Many of these questions reflect their original thinking and inquiring minds. Teachers have been excited about our visits and have requested us to return to their schools, sometimes even during the same academic year to meet with other classes. We have also been asked by the same teacher to visit her many different schools because of her advancement in career with the concomitant change of schools.

Our very first visit resulted in instant offers of teacher positions to our visiting team members by the Science Dept. Chairperson. During many visits, we have seen high school students being skeptical, staying far away and as the lesson progresses slowly come closer to the demonstration table for a closer look. It is very hard to assess our impact in terms of how many students go into careers of science and technology. In the future, we may have students fill in an online survey form for better insight about their career paths. However, one way to gauge our success is from the many requests for repeated visits to the same schools through our 5 years of running the programs. On the objective of improving the retention of a diverse student body on track for careers in science and technology, we have reached 3,130 students since the beginning of our program in 1999 to April of 2004. The demographic of the schools are around 81% historically underrepresented minorities (37% African Americans and 44% Hispanic Americans) and around 55% female.

A recent visit (10/03) to East Side Community H.S. in Manhattan elicited an enthusiastic response from Mr. Jim Wallace (teacher hosting the visit) [only italics added]:

"As always, the visit from the MRSEC folks was a "highlight" of not only the Fall, but of the year! Our student population is mostly from working and "poor" families. Our school's mission is to provide "non-high-academic-achieving" students with the opportunity of going on to some sort of post-hs schooling. (90% do this.) So the exposure to not only the concepts, but also the demos and especially the grad-student role models is a unique and BIG deal. At the end of every quarter, I ask students for "feedback." The visit was mentioned by many under 'List three things you liked about the class this quarter.' I want to also thank Director Dr. Irving P. Herman and Mentor Dr. Louis Brus for their support of this program. I realize that there are hundreds of demands on professors, students, resources and especially TIME. But this program is really worth all that it takes to make it go. "Science" jumps from the "textbook" and becomes something live, fun, and challenging…your program is certainly one of the best that I've heard of or seen. Please keep it up! You're a joy to collaborate with!"

Many undergraduate students, graduate students, and postdoctoral scientists from many different departments including Chemistry, Applied Physics, Chemical Engineering and other MRSEC groups regularly participate in our high visitation program. In the academic year of 2003-2004, we have Jing Tang, Gordana Dukovik, Oksana Cherniavskaya, Liwei Chen and Matt Sfeir (Brus group), Jenna Pike and Joan Raitano (Chan group) and Mike Holman (Adams group). As some of these students graduate, we often have new blood in the system from our start of the academic year recruiting efforts and promotion to students by our MRSEC faculty members. During the 5 year period, we have also found the participation of undergraduates becoming limited because of their class schedules. Rarely can they spare a whole weekday for such activities without class conflicts. Because of this we have been gradually relying on graduate students and post-doctoral fellows (postdocs) more. We often have new graduate students and postdocs signed up to be trained. In conducting this program we have become ever more aware of the impact of the program on the Columbia students and postdocs who make the actual presentations. They get very engaged in these activities and get excited about their interactions with the students at the targeted schools. They also have developed confidence in their public speaking skills. The team members often list the outreach experience in their resumes and get good response from future employers and graduate schools. They have also gradually become effective MSE spokespersons. Our earliest team members, Ms Oratai Jongprateep and Mr. Alex Papandrew who were MSE undergraduates doing research in Prof. Chan's laboratory, have since gone to graduate schools.

SHARING PROGRAM

We are sharing our experience with interested faculty everywhere. Details of our outreach program and photographs of our visits are posted in our MRSEC website: *http://www.cise.columbia.edu/mrsec/education_mrsec.htm.*
One of our presentations has been videotaped. It has been converted to a Quick-Time movie, and is also on our MRSEC website. Its URL is *http://www.cise.columbia.edu/mrsec/stream2.html.*

Our basic demonstration modules have been adapted from a script written originally by Brian D. Flinn, Gordon Graff, Katie Gunnison, and James Webb of the Department of Materials Science and Engineering in the University of Washington in 1998. We intend to continue our collaboration with the University of Washington and to update their original script together with better safety and new lessons [7]. We will also post the updated script on our websites for others to download.

Outline of Basic Demonstration units:

1. Properties of Materials Being Sensitive to Temperature:(fog and loud bangs) Racquetballs are shown to bounce at 22^{o}C (295 K) and to be brittle at 77 K (-196^{o}C).
2. Solid State Phase Transformation Concepts of Crystal Structures: The change of crystal structure due to a change in temperature is demonstrated by shaping a memory alloy wire and heating it to regain its original shape.
3. Work Hardening of Metals:
4. The concept of dislocations and the origin of ductility in metals are demonstrated.
5. Thermal Conductivity of Metals and Ceramics: (fire and smoke) The concept of fire (oxidation) resistance is illustrated using a Mg wire and its burnt ash: MgO, while the concept of heat conduction is illustrated with metal rod, glass rod, and a space shuttle tile.
6. Strength vs. Toughness: (loud bangs) These are compared by using embroidery hoops with stretched Al foil and plastic wrap, silly putty, Corelle plates, Kevlar fiber compared to a cotton string, and balloons with and without tape reinforcement.
7. Stress Analysis Using Birefringence: Polarized sheets reveal stress contours in rainbow color and stress concentrated areas in transparent plastics.
8. Superconductivity – Meissner Effect: (fog) The Meissner effect is illustrated by the levitation of a magnet above a ceramic superconductor immersed in liquid nitrogen.

There are other inputs from various societies and workshops such as ASM, TMS, the American Ceramic Society, the Materials Research Society and the National Educators' Workshop [8] as well as from other university outreach such as University of Wisconsin, Prof. Ellis [9] and University of California Irvine, Prof. James Nowick. We are also working on further curriculum development for this program. In some cases this will involve adapting material developed at other MRSECs and elsewhere. Kits on materials and nanomaterials have been purchased from the University of Wisconsin MRSEC web site, which will be adapted into a presentation. We also are planning a demonstration of the structure of grapheme sheets, graphite, and carbon nanotubes.

LESSONS LEARNED

Over the years we have learned that the following are essential factors for the smooth running of the program:

1. Access to high schools through personal contacts,
2. Dedicated faculty to oversee the program,
3. Dedicated staff to coordinate with schools for team's visit, arrival and entry,
4. Dedicated person (not students) to keep track of all components of the demonstration kits,
5. Continuing recruiting and paying visiting team members and
6. Steady and adequate funding support.

In addition, the team members need to be well rehearsed for the demonstration lessons. The first factor, gaining access to local schools from personal contacts, is important because it can easily be the show stopper. At UW, the local schools were contacted through undergraduate students who came from these local schools. The last factor is probably the most important because its presence makes the other factors more easily realized. The funding we need is mainly for the support of a fraction of time of the dedicated staff, Ms Alison Biuso. The day pay per visiting member is $110 including expenses. The payment to the visiting team members and refurbishing of the demonstration kits cost only around three thousand dollars not including overhead or fringe benefit cost per year. Most of the faculty involvement is volunteered and not compensated. Our funding support has been coming from the NSF-MRSEC program.

The initial program at the University of Washington (UW) was funded through NSF-

Engineering Coalition Schools for Excellence in Education and Leadership (ECSEL) program, which ended in 2000. From 1995 till 2000, the outreach program at UW reached over 4000 K-12 students. The outreach had specially targeted schools with a high population of Native American, Hispanic and African American. Since 2001 the MSE outreach program at UW has since evolved from visiting schools to an open-house program, which requires less funding but also has proven to be very effective.

The MSE Department Chair of UW has interviewed all its graduating students for the last three years and one of the questions he asks is: "What made you choose MS&E as a major?" In the past three years, on average, 10% of the students have indicated that the visit to the Open House was their first meaningful introduction to MSE. The demos at the Open House led them to further research and explore the MSE Department. Also UW MS&E is one of the largest UG department in the country, awarding approximately 35 BS degrees every year. Clearly, this is also a proven program for recruiting undergraduate MSE students.

SUMMARY

We have reported our experience over the last five years of starting and running the school visitation program in New York City originating from a well-run program at UW. The program can be implemented in a straightforward way in a new urban area with proper funding and support. The RET program within MRSEC has been extremely synergistic for the present visiting outreach program to gain access to local K-12 schools through the RET teachers. Alternative ways of getting to know schoolteachers and access to schools can work as demonstrated by UW in Seattle. We encourage other MSE departments/programs in other cities to develop a similar outreach program to encourage youths to go into SEM careers and target to improve our future national work force for a new era of technology. Further development for longitudinal tracking of students is underway. Suggestions are welcome to this effect. A map of the school locations in the New York (Figure 1), a picture of a typical team (Photo. 1) and pictures taken during the demonstration lessons (Photo. 2a-e) are shown.

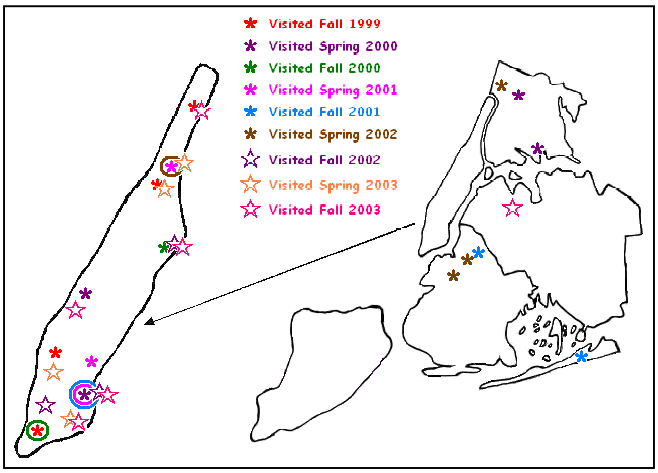

Figure 1. A map of five boroughs of New York City showing the locations of high schools already visited and to be visited. (The expanded borough is Manhattan. The other four, clockwise starting from the north, are the Bronx, Queens, Brooklyn, and Staten Island.)

Of the approximately (overall) 3,130 students visited since the start of our program to April of 2004, ~81% were historically underrepresented minorities (37% African Americans and 44% Hispanic Americans) and ~55% were female, based on the demographics of the schools. Besides the above graphic presentation of schools we visit, a list of the schools is included in the appendix.

Photo 1

Photo 2 c

Photo 2 a

Photo 2 d

Photo 2 b

Photo 2 e

APPENDIX

LIST OF HIGH SCHOOLS VISITED FROM 1999 THROUGH JANUARY 2004.

Fall 1999
High School of Leadership and Public Service
The Bayard Rustin High School for the Humanities
George Washington High School
A. Phillip Randolph High School

Spring 2000
Martin Luther King High School
DeWitt Clinton High School
Adlai E. Stevenson High School
East Side Community High School

Fall 2000
High School of Leadership and Public Service (2nd visit)
Manhattan Center for Science and Math Careers

Spring 2001
East Side Community High School (2nd visit)
Frederick Douglass Academy
Baruch College Campus High School

Fall 2001
Far Rockaway High School, Brooklyn, NY
Junior High School 126
East Side Community High School, Manhattan, NY (3rd visit)

Spring 2002
The Ethical Culture Fieldston School
Brooklyn Technical High School
Bard High School Early College
Frederick Douglass Academy (2nd visit)

Fall 2002
East Side Community High School (4th visit)
On-campus visit-Murray Bergtraum High School for Business Careers
High School of Economics and Finance
Manhattan Center for Science and Math Careers

Spring 2003
Frederick Douglass Academy (3rd visit)
City-As-School
Bard High School Early College - (2nd visit)
A. Phillip Randolph High School

Fall 2003
The Renaissance Charter School
East Side Community High School, Manhattan, NY (5th visit)
Park West High School
Manhattan Center for Science and Math Careers (3rd visit)
High School for Health Careers and Science
George Washington High School Campus

Spring 2004
Talent Unlimited High School

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REFERENCES

1. *Land of Plenty: Diversity as American Competitive Edge in Science, Engineering and Technology*, The Congressional Commission on the Advancement of Females and Minorities in Science, Engineering and Technology Development, Washington, D.C., 2000.
2. M.J. Johnson and S.D. Sheppard, "Relationships between Engineering Student and Faculty Demographics and Stakeholders Working to Affect Change," *Journal of Engineering Education*, **93**, No.2, 139-151 (2004)
3. E. Seymour and N.M. Hewitt, *Talking About Leaving: Why Undergraduates Leave the Sciences*, Westview Press, Boulder, CO, 1997.
4. *Women, Minorities, and Persons with Disability in Science and Engineering: 2000*, National Science Foundation, Arlington, VA 2000 (NSF 00-327).
5. *Entry and Persistence of Women and Minorities in College Science and Engineering Education*, G. Huang, N. Taddese and E. Walter (eds), U.S. Department of Education, National Center for Education Statistics, Washington, D.C. 2000 (NCES 2000-601).
6. Summer Research Program (SRP) for NYC Science Teachers is founded and run by Prof. Samuel C. Silverstein in the College of Physicians and Surgeons at Columbia University since 1990. The program is funded by private and public sources. The dedicated stuff at SRP is Mr. Jay Dubner who also runs our RET program. SRP has enriched our RET program with career development training for the teachers. For more details see *http://www.sciensceteacherprogram.org/*
7. B. Flinn, R. Bordia, S.-W. Chan, *et al.*, "A Guide to Developing a Materials Science Demonstration Program," to be published in Journal of Materials Education, 2005.
8. Also see the National Educators' Workshop website and the many class demonstrations at *http://mst-online.nsu.edu/mst/index.html.*
9. A.B. Ellis, University of Wisconsin-Madison MRSEC outreach presentation at Univ. of California, Santa Barbara, Nov. 1998.

AUTHORS' BIOGRAPHIES

Siu-Wai Chan is a full professor of Materials Science and Engineering in the department of applied physics and applied mathematics at Columbia University. Before coming to Columbia University, she was a permanent member of research staff at Bellcore (now Telcordia, a division of SAIC). She received her Bachelor's of Science degree in Materials Science and Metallurgical Engineering from Columbia University and her Doctoral of Science degree in Materials Science and Engineering from Massachusetts Institute of Technology with an emphasis in materials interfaces. She has been honored as a Presidential Faculty Fellow in 1993, a Guggenheim Fellow in 2003, an Advance Fellow, and a Tan Fellow in 2004. Her research interests are thin films, nanoparticles, grain boundaries and interfaces, high Tc superconductors and electronic oxides.

Brian Flinn is a research associate professor of Materials Science and Engineering in the department of materials science and engineering at the University of Washington. He received his Bachelor's of Science degree and his Master degree in Metallurgical Engineering from Colorado School of Mines, and his Doctor of Philosophy in Materials Engineering from University of California, Santa Barbara. His research interests are structural ceramics, composites and post-consumer recycled plastics and their relationship among processing, properties and microstructure. In addition, he was an active member of the ECSEL coalition team (1995-2000) and has a continuing interest in engineering education research.

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