Outreach K-16 Programs to Enhance Diversity in the Science and Engineering Fields

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***Abstract*:---** *Minorities are an underrepresented group in science and engineering fields. Factors that impact on this include lack of role models, home environment, economics and educational opportunities. The changing technological global economy requires an increase in the diversity of our scientists and engineers in both industry and academia. To accomplish this goal, K-16 programs funded by industrial, governmental and philanthropic organizations have been developed all over the world. To increase diversity in science and engineering, we must reach children at an early age and to educate and excite them about the various careers associated with these fields.*

At New Jersey Institute of Technology (NJIT) initiatives were taken to achieve diversity goals about thirty years ago. The current K-12 hands-on programs have a strong basis in Chemical Engineering and Chemistry. The experimental exposure can be on bench scale or pilot plant scale sized laboratory equipment.

These K-12 programs may or may not be student linked to our NJIT research programs and the, which are for undergraduate students. Whereas the goal of our K-12 program is to increase the underrepresented, undergraduate student education pool, the aim of the Undergraduate Research Experience (URE) and Ronald E. McNair Post-baccalaureate Achievement Programs is to increase the number of underrepresented advance degree recipients. The URE Program, which is open to all levels was initiated in 1990, has graduated 140 students, of whom, approximately 90 percent have gone on for advanced degrees. The NJIT Ronald E. McNair Post baccalaureate Achievement Program fosters a desire in underrepresented students to obtain a Ph.D. degree and enter the field of higher education in Science, Engineering and Mathematics (SEM). Since its inception, 44 students have been enrolled in the program with 22 of the 44 graduating and enrolling in Graduate School.

Index Terms --- K-12 programs, undergraduate research, underrepresented students, diversity, post-baccalaureate achievement

INTRODUCTION

As we enter the 21st Century with globalization is a given fact of life and there is a need to expand the engineering manpower pool and to increase its diversity. Programs must be developed that interest individuals from underrepresented groups in science and engineering. The K-12 Programs at NJIT and elsewhere have their origins about 30 years ago and were aimed at increasing the pool of minorities entering engineering and science programs. At NJIT, in the past decade, research programs for undergraduates have been added to further increase this pool. These programs, are the Undergraduate Research Experience (URE) Program and the Ronald E. McNair Post-baccalaureate Achievement Program.

Undergraduate research at New Jersey Institute of Technology has been an integral part of the curriculum, as a three credit hour elective course in each of the two senior year semesters, since the 1960's. The courses are senior level but on occasion juniors have been allowed into these courses for credit. The Undergraduate Research Experience (URE) Program and the Ronald E. McNair Post-baccalaureate Achievement Program were added in the past decade but the objectives of these programs differ from the undergraduate research elective courses and in some cases grant curriculum credit. Thus, the need to expand the engineering manpower pool and to increase its diversity has led to a K-16 program at NJIT.

THE K-12 PROGRAMS

Among the earliest of the K-12 programs was NJIT's Urban Engineering Program for High School Students [1]. New Jersey Institute of Technology is ideally located in the heart of Newark, New Jersey, a city that typifies the urban crisis felt throughout the nation. In cooperation with the Educational Opportunity Program (EOP) at NJIT and bordering on an inner city High School the programs began to evolve. Also at NJIT, Levine [2] began to focus on attracting young women into science and engineering. This was the start of the Females in Engineering, Methods, Motivation, and Experience (FEMME) Programs. These programs were developed throughout the United States under National Science Foundation initiatives. Other programs at NJIT were developed [3]. Anderson-Rolland [4] reported on the "Women in the Applied Sciences and Engineering Program (WISE) at Arizona State University, which was added in 1993. Gennelo, Windom, Kimberly, Jolly, and Semple [5] reported in the Program for Women in Science and Engineering (PWSE) initiated in 1987 at Iowa State University. Johnson, Diamond, and Stowich [6] reported on the Carnegie Melon University program to teach the City of Pittsburgh high school girls about engineering and science using female faculty. National Science Foundation commitments led to workshops dealing with this topic [7]. In 1996, the NSF issued its eighth report to

Congress and the Government entitled "Women Minorities and Persons with Disabilities in Science and Engineering". An entire chapter in the report was devoted to pre-college education [8]. McCartney, Reyes, and Anderson-Rowland [9] reported on the Arizona State University program for underrepresented minority students and their teachers from eight high schools. Kelly and Heywood [10] discussed a K-12 program in the British Isles. Moore [11] chaired a conference session on " Issues in K-12 Internet Usage". Papers were presented by Rude on "The Role of Universities in K-12 Internet Access", Moore on "Internet Access Resources: Searching, Newsgroups Presentation Software, K-12 Resources, Blocking Software" and by Trilling on "Approaches to Dissemination of Experimental Programs". Similarly, Agogino [12] chaired a session on "Bringing Engineering to K-12 through Interactive Multimedia and Internet (Panel)". Hirtzel [13] discussed the declining interest in science and engineering coupled with declining high school enrollments and the subsequent importance of outreach programs. In 1997, Walker and Ziebarth [14] discussed the outreach programs with super computer applications. Mengel [15] discussed the K-12 students and the worldwide web. Thiele, Razvan, and Lesko (16) discussed the "Development of Engineering Measurements Laboratories"; a concept used by the authors in the NJIT K-12 programs.

At the 1997 Fall Regional Conference, Mid Atlantic Section, ASEE, an entire session with six papers was devoted to K-12 education. At the Annual ASEE meeting in St. Louis, June 18-21, 2000, a number of sessions were devoted to K-12 programs. Barbara Christe developed a session on K-12 Diversity in Engineering Technology (Session 1648). Barbara Bogue developed a session on K-12 Programs that Work (Session 1692) and Chalmers F. Sechrist developed a session on K-12 to ECE Education (Session 2332). Since the start of K-12 programs, the ASEE has been a leader in reporting on a large number of K-12 Programs throughout the United States and a few overseas programs.

New Jersey Institute of Technology has a social, economic, and academically diverse student body of about 5800 undergraduate and 3000 graduate students with the undergraduate population composed approximately of one-third women, Hispanic, and Afro-American) minority. The institution has, for the most part, consisted of students who were the first in their families to seek a college education. Over the last 30-40 years, however, the ethnic background of the children of immigrants has changed.

NJIT has a long history of outreach programs for elementary through college level students. The outreach programs developed by the Office of Pre-College Programs serves more than 4500 elementary and secondary school students and teachers annually through an array of pre-college programs. The Office of Pre-College Programs, which originated in the Department of Chemical Engineering and Chemistry about 30 years ago, developed these K-12 programs. It is, therefore, not unusual to find departmental faculty being involved in the development and teaching of various minority outreach programs. Some of those programs in which the authors have taught are:

- The Summer Academy (11^{th} grade students)
- Females in Engineering: Methods, Motivation and Experience (FEMME)
    - Introductory FEMME for 4^{th} and 5^{th} grade students)
    - FEMME Continuum (6^{th} and 7^{th} grade students who have completed)
    - Senior FEMME (8^{th} and 9^{th} grade students)
- Chemical Industry For Minorities in Engineering (CHIME, 7^{th} and 8^{th} grade students)
- Upward Bound, Mathematics and Science Program (9^{th}-12^{th} Newark, NJ High school students)

SUMMER ACADEMY

The Summer Academy is a program designed for advanced 11^{th} grade students to enable them to earn college credits during the summer. During the summer of 1994, summer academy students were taught with our newly developed Fundamentals of Engineering Design measurements laboratory course. It was the trial run prior to offering the course to our freshmen in the Fall 1994. Twelve students were enrolled and the program ran 3 hours per morning, for eight days, the equivalent of the freshman course.

FEMME CONTINUUM

FEMME Continuum students only undertook experiments on neutralization of acids of different strengths by titration and temperature measurements by mercury in glass and metallic dial thermometers. This program, which is a two-(2) day effort, only involves data taking, analysis and graphical representation of the experimental results. About 25, post 4^{th} and 5^{th} grade, high potential young women who have successfully completed the Introduction to FEMME program are admitted. The students are taught laboratory safety, data taking, data analysis and graphical presentation of their results. The program is designed such that the students working in groups of two with the student teachers continue to develop confidence, self- esteem and a sense of accomplishment.

SENIOR FEMME

Senior FEMME participants have completed the two previous FEMME courses. The Chemical Engineering and Chemistry part of the program lasts for two complete days (Four, three hour periods) and involves about 25 students working with the student teachers, in groups of three. The participants undertake the experiments in the senior Chemical Engineering Laboratory. All students are required to calibrate a Rotameter and are assigned one of the large-

scale, unit operations experiments. These experiences are predicated on simplifying the experimental data required and minimizing the required theoretical background.

CHIME

The program is designed to give seventh (7^{th}) and eight (8^{th}) grade urban youngsters an opportunity to increase their awareness, understanding and participation in science and engineering. There are about 24 students in the program and the students are assigned to work, in groups of two for the simple bench scale experiments and in groups of three for pilot plant scale experiments. The chemical engineering and chemistry portion of the CHIME Program introduces students to careers in chemical and environmental engineering. Video tapes, laboratory safety lectures, lectures on theory and operation of apparatus for measuring pressure drop in packed towers, in circular conduits and fluidized beds, calibration of flow meters, draining time of water from a cylindrical tank, agitation in a tank, heat transfer in a double-pipe heat exchanger, neutralization of an acid, and temperature measurements by different type thermometers are used for instruction. The first experiments are the simple bench scale neutralization of stomach acid by "Tums", and temperature measurements by different thermometers. The pilot plant scale experiments in the Unit Operations Laboratory follow these bench scale experiments. The students record and analyze the data, are taught how to prepare a brief technical report and the audiovisual materials for an oral presentation, both of which are the culmination of the course. The Chemical Engineering and Chemistry portion of the overall twenty- (20) day program is done in six and one half days.

UPWARD BOUND/MATH AND SCIENCE PROGRAM

The Upward Bound Math and Science Center program is funded by the US Department of Education and is designed to enhance the high school students' academic ability and interest in mathematics and science. Only students who are performing well academically are admitted. The program is an intensive six (6) week summer program which meets five (5) days a week for students residing in or attending high schools in Newark, NJ. As in the other programs, chemical engineering is only a part of the program and is a lecture/ laboratory integrated experience consisting of 3.5 hours per section, (25 students) one day per week. There are two sections. In addition to the students undertaking the broad program which consists of studies in computer science, architecture, math, physics and chemical engineering they also do an independent research project. In the chemical engineering part of the program, the lecture topics cover the theory of experimentation, statistics, units, dimensions, graphics, data collection and analysis, oral presentation and report writing. The course also has a homework assignment component. The laboratory experience consists of experiments on the chemical engineering pilot plant size equipment listed previously. Students undertake experimentation, in groups of three, in greater depth than any of the other programs and are expected to undertake more than one experiment. After the data reduction and analysis, a detailed technical report is prepared. Based on their laboratory experience and their written report, an oral presentation is made to their class and the program faculty.

One aspect of the program involves the assignment of about nine of the students to perform a more intensive independent research project. These students are assigned a mentor, who works very closely with them. Students mentored by the authors and their student teachers undertook experimental studies in the area of fluid dynamics and heat transfer using the equipment in the Fundamentals of Engineering Design (Freshmen Laboratory) in addition to the regular course experiments. These mentor groups met 2 days per week for 1.5 hours and focus on one experiment for the entire six weeks. At the end of the program, a written report and an oral presentation are required of all students.

In addition to serving in those elementary and secondary school programs, the authors have also been involved in the:

- Educational Opportunity Program (EOP)
- Undergraduate Research Experience (URE)
- Alliance For Minority Participation (AMP)
- McNair Post Baccalaureate Research Program

These latter four programs involve students from underrepresented groups at NJIT and are aimed at encouraging students to develop to the full extent of their abilities and continue onto graduate school. Each of the previously mentioned K-12 programs has a specific curriculum appropriate to the level of education of the participants. The authors believe in exposing students in all of the above programs to experimental projects, which expose students to a laboratory type experiment, data collection, data reduction, a written document and, as the capstone portion of the experience, an oral report. These oral presentations may be to other students, in the case of the K-12 programs or to peer review panels in program competitions as in the case of the undergraduate research programs. The main goal of each of these programs is to give students an exposure to independent learning, allow the individuals or teams to experience what a project is like, and to give the students "hands-on" experience. The students in all programs are given lectures in background material with an emphasis on laboratory safety.

EXPERIMENTS

The simple bench scale experiments consist of the neutralization of an acid with a base and the temperature measurements as a function of time during the batch heating of water. The senior Chemical Engineering Laboratory Unit Operations equipment is chemical industry pilot plant scale,

some of which extends over three floors in height. For the younger students in the FEMME Continuum, Senior FEMME and CHIME programs, the bench scale experiments are used as an introduction and the senior chemical engineering laboratory experiments are used in a simplified manner. For the older students in the Summer Academy and Upward Bound/ Math and Science Programs, the simple bench scale experiments were not used. For these students, the senior chemical engineering laboratory experiments were performed in greater detail. The students are divided into groups of two for the neutralization and temperature measurement experiments and groups of three for the pilot plant scale experiments.

BENCH SCALE EXPERIMENTS

The acid neutralization and temperature measurement experiments are bench scale apparatus. The acid neutralization unit simply consists of a burette and beakers while the temperature measurement experiment uses a hot plate, a 600- ml beaker filled with 300 ml of water, a standard mercury in glass thermometer and a metallic dial thermometer. In the neutralization experiments each group is given four flasks filled with 25 ml of HCL solution, each of different normality and told to measure the amount of NAOH required to neutralize the solution. Methyl Red is used as the indicator. The students correlate the volume of sodium hydroxide needed to neutralize the acid versus acid strength and develop the linear correlation. The students are told that this experiment simulates the action of antacids (TUMS, Mylanta, etc.) on an acid stomach.

In the temperature measurement experiment, the students fill a 600- ml beaker with 300 ml of water and place it on a hot plate. The students then take a mercury in glass thermometer subdivided in units of one degree Fahrenheit and a metallic dial thermometer containing unit divisions of 10 degrees in ^{o}F and ^{o}C. They then record temperature readings each minute until boiling is reached. The students are asked to correlate the temperature versus time and observe how the increase in temperature per unit time decreases as the temperature rises during the batch heating. The students also observe the differences in the reading from the two different thermometers.

SENIOR CHEMICAL ENGINEERING UNIT OPERATION LABORATORY EXPERIMENTS

The experimental chemical engineering laboratory portion of the course involves a “hands-on” experience with equipment both bench scale and pilot plant scale. The pilot plant sized equipment is located in the senior unit operations laboratory and consists of a piping arrangement for a fluid flow experiment that contains flow meters and various diameter piping and fittings. Each group is assigned a different pipe diameter. They also measure the pressure drop in an Orifice meter and a Venturi meter and calibrate each. Both water and air Rotameters are also calibrated.

The students also measure pressure drop in packed towers which are 6-inches in diameter and packed to a height of about five feet and contain ½ inch Ceramic spheres, ½ inch Ceramic Raschig Rings, ½ inch Ceramic Berl Saddles and ½ inch Ceramic Intalox Saddles. The pressure drop per foot of packing is correlated with the airflow rate at various liquid flow rates in the counter current operation.

Pressure drop is measured in an air-fluidized bed, 6-inches in diameter containing 0.110-inch diameter and 0.125-inch long cylindrical plastic pellets. The students correlate pressure drop and bed height with airflow rate and determine the point of minimum fluidization.

Efflux time from various columns equipped with a quick close valve is also measured. The students correlate the height of the liquid level versus time as a function of different diameters and lengths of outlet pipe. They correlate the total time required to empty the tank with effluent pipe length for each diameter and model the system.

FRESHMAN ENGINEERING MEASUREMENTS LABORATORY EXPERIMENTS

Five smaller scale experiments developed for our Fundamentals of Engineering Design Program for freshmen are also used. This equipment is primarily bench scale. It consists of a flow through pipes experiment, a double pipe heat exchanger equipped with both parallel and counter current flow, a small cylindrical agitated, baffled mixing tank, a small temperature measurement bench, and two small columns that are packed with No. 10 Ballotini particles to enable study of both air and water fluidization. These five experiments are used to perform the same tasks that were used in the other laboratory experiments but the nature of each experiment is specific to the related theory.

THE UNDERGRADUATE RESEARCH PROGRAMS AT NJIT (K 13-16)

In recent years, undergraduate research has been increasing at a rapid rate. This fact is very clearly presented by Zurer [17] in a feature article entitled, “High Hopes Hang on Undergrad Research”. The article begins with “There’s no doubt about it: undergraduate research is hot stuff. Witness the multiday sessions on the topic in the Division of Chemical Education at the American Chemical society meeting in Orlando earlier this month” (April 2002). The author further states that “Chemists believe undergrad research motivates a broad cross section of students to stick to science”. In another very current article, Zydney, Bennett, Shahid and Bauer [18] report on a survey of alumni from the College of Engineering at the University of Delaware assessing the impact of the undergraduate research

experience. They found that alumni with research experience were more likely to pursue graduate studies for advanced degrees among other findings. Donnely [19] reports on "Developing and implementing a successful research experience for undergraduates program; a roadmap designed by the engineering research center for particle science and technology". The paper discusses the program, project selection, recruiting, logistics and program management. Halstead [20] asks the question, "What is Undergraduate Research?". She points out that after much discussion in a session sponsored by the Council of Undergraduate Research, a consensus was reached that "Undergraduate Research is an inquiry or investigation conducted by an Undergraduate that makes an original intellectual or creative contribution to the discipline". The web site Engineering Village 2 lists at least 50 very current articles on very specific technical topics used as projects in undergraduate research. The National Science Foundation realizes the importance of undergraduate research and supports these programs through its Research Experience for Undergraduates (REU) program.

Undergraduate research at New Jersey Institute of Technology has been an integral part of the curriculum, as a three credit hour elective course in each of the two senior year semesters, since the 1960's. The courses have senior level numbers and curriculum integration, but on occasion juniors have been allowed into these courses for credit. In recent years, two other research programs have been made available to the students and in some cases grant curriculum credit. These programs are the Undergraduate Research Experience (URE) Program and the Ronald E. McNair Post-baccalaureate Achievement Program and are designed to recruit qualified students from underrepresented groups and introduce them to the challenges associated with research. The aim of these programs is to foster an interest in the students, who will consequently, continue their education in Graduate School and obtain advanced degrees. The Undergraduate Research Experience (URE) and McNair Post-baccalaureate Research Program have as a goal to encourage undergraduates to perform research and pursue their education to the Doctoral level. The aim of the McNair Post-baccalaureate Achievement Program is to produce more faculties from the underrepresented student body. Undergraduate students who enter these programs gain an insight into the research process, learn about Graduate Schools and learn about an academic career.

The URE Program, which was initiated in 1990, allows students to perform research and independent study under the guidance of a Faculty Advisor. The program provides technical assistance to Equal Opportunity Program (EOP) and other ethnic minority students and engages them as early as the freshman year in research projects. The program provides counseling, career guidance and mentorship and gives the students the opportunity to present the results of their research. By increasing the number of individuals from underrepresented groups who obtained advanced degrees, diversity at this level of education increases. Since its inception, about 90 per cent of the approximately 140 underrepresented and/or disadvantaged graduating students have gone on for advanced degrees.

The NJIT Ronald E. McNair Post-baccalaureate Achievement Program, which is funded by the Department of Education, however, has a different goal. The McNair Program seeks to recruit juniors and seniors from low income, first generation, underrepresented groups with excellent academic credentials, who are majoring in Science, Engineering and Mathematics (SEM). Its objective is that with the aid of a faculty mentoring/research experience students develop a desire to obtain a Ph.D. degree and enter the field of higher education. The students are encouraged to present the results of their research at technical conferences and to publish in peer reviewed journals. Hence, this effort would broaden the diversity in the field and provide positive role models for groups underrepresented in the professorate. Since its inception in September 1999, forty-four students have enrolled in the program, twenty-two students have graduated and enrolled in Graduate School.

The authors have served as advisor/mentors to many undergraduates in the regular curriculum research courses and for URE students and McNair Fellows. Several of these students have received Program, Institute, and National Awards for their research effort.

THE PROGRAMS

For all programs, K-12, the Undergraduate Research Experience (URE) Program or the Ronald E. McNair Post-baccalaureate Achievement Program, undergraduate chemical engineering students who are eligible for work-study funding or the URE program work with the two faculty members. For the K-12 programs, each summer about eight undergraduate students are involved. These undergraduates first learn to operate all of the experiments in teams of two, and correlate their measurements. As each of the programs begins, these undergraduates then become the teachers and mentors for the younger students. These undergraduates have had exposure to the various modules of our Fundamentals of Engineering Design course but have had no previous exposure to the Senior Chemical Engineering Laboratory equipment. Some of these undergraduates had actually completed our freshman Chemical Engineering Measurements module, which was the basis for almost all of the experiments used in this program. For the Undergraduate Research Experience Program or the Ronald E. McNair Post- baccalaureate Achievement Program, students are encouraged to pick a faculty mentor and begin a research program.

CONCLUSIONS

For the K-12 programs, the student review of the chemical engineering portion of the programs was unanimously excellent. They were particularly excited with the "hands

on" laboratory experiments but also found the communication efforts rewarding. In addition, from students' comments and program administrators' feedback, the research experience of the students has been greatly appreciated and helped them develop both academically and in maturity. It has been a rewarding experience for the authors in seeing, not only the physical results for new laboratories for the department in operation, but also in helping students of all ages develop in their education. Some of the students from these programs enroll as freshmen and in graduate school. One very satisfying aspect of teaching these students is that they never forget you. It is very satisfying to walk on campus, be greeted by a student (grown up and not recognized by the authors) and told that they were students in our summer programs. Some of these students are now the student teachers for their younger counterparts. The authors consider themselves extremely fortunate to be able to participate in such programs as educators.

For the Undergraduate Research Program, since its inception, about 90 per cent of graduating students have gone on for advanced degrees. Since its inception in September 1999, the Ronald E. McNair Post baccalaureate Achievement Program, has had twenty-two students with ten graduating and enrolling in Graduate School.

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