New Jersey Institute of Technology's K-16 Programs to Enhance Diversity in the Technical Work Force

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INTRODUCTION

With globalization as a given fact of life in the 21st century, there is a need to expand the engineering manpower pool and its diversity in order for the United States to compete. To increase diversity in science, technology and engineering, we must reach children at an early age and educate and excite them about careers associated with these fields. Programs must be developed that interest individuals from underrepresented groups (ethnic and racial minorities, women, and the physically challenged) in science, technology and engineering, where they have long been underrepresented. K-12 Programs at NJIT and elsewhere have their origins over 30 years ago with most of these programs aimed at increasing the pool of minorities entering engineering and science and, in the past decade, research programs for undergraduates have been added to further increase this pool. Undergraduate research at NJIT has been an integral part of the curriculum, as an elective course, in each of the two senior year semesters since the 1960's but on occasion juniors have been allowed into these courses for credit. The URE Program (1990) and the McNair Program (1999) were added and in some cases, students earn curriculum credit for their research work. Therefore, these two programs, coupled with the existing K-12 programs, result in a K-16 program continuum at NJIT, and elsewhere, to increase diversity in engineering and science.

THE K-12 PROGRAMS

Among the earliest of the K-12 minority programs was NJIT's Urban Engineering Program developed over 30 years ago [1]. NJIT is ideally located in the heart of Newark, New Jersey, a city with a large minority population. In cooperation with the Educational Opportunity Program (EOP) at NJIT and bordering on an inner city high school these programs began to evolve. Simultaneously, NJIT [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. K-12 programs were developed throughout the United States under National Science Foundation (NSF) initiatives.

NJIT programs serve more than 4500 elementary and secondary school students and teachers annually through an array of pre-college programs. The Center for Pre-College Programs, which originated in the Department of Chemical Engineering and Chemistry over 30 years ago, developed these K-12 programs. Programs the authors have taught:

- Females in Engineering: Methods, Motivation and Experience (FEMME)
  - Introductory FEMME (for 4th and 5th grade students, 9 and 10 years old)
  - FEMME Continuum (6th and 7th grade students, 11 and 12 years old, who have completed Introductory FEMME)
  - Senior FEMME (8th and 9th grade students, 13 and 14 years old, who have completed FEMME Continuum)
- Chemical Industry For Minorities in Engineering (CHIME, 7th and 8th grade students, 12 and 13 years old)
- Upward Bound, Mathematics and Science Program (9th-12th grade Newark, NJ minority High school students, 14-17 years old)

These K-12 programs have a strong emphasis on laboratory safety and "hands-on" learning with Bench Scale, Freshman Engineering Laboratory and Senior Chemical Engineering Pilot Plant scale experiments. The programs have been very successful over the years with approximately 80 percent of the K-12 students enrolling as undergraduates at NJIT and other schools. For the authors, who have been involved in these programs for many years, it is extremely satisfying to have an undergraduate student approach them and remind them that we were their teachers in a K-12 program.

THE PROGRAMS

For all programs, K-12, URE or McNair, undergraduate chemical engineering students worked with the faculty members as teachers. For the K-12 programs, each summer about eight undergraduate students were trained to become teachers to the younger K-12 students. Each undergraduate student teaches a group of three or four K-12 students. In many cases, these undergraduates must first learn the chemical engineering principles and then operate all of the experiments in teams of two. The data collected are correlated according to the principles that they learned and they perform the same calculations that the younger students will perform. In most cases, these undergraduate students have not had the theory courses associated with the experiments. Many of them were sophomores and after exposure to this experience were better prepared to enter the fluid flow and heat transfer courses in the junior year. Some of these undergraduates completed the Freshman Chemical Engineering Measurements module, which was the basis for almost all of the experiments used in the program. Without the assistance of these undergraduate students, it would be impossible to have one teacher work with

twenty-five K-12 students in a laboratory with experiments that extend over three stories. In the experimental K-12 courses in chemical engineering, students are taught data measurement, collection, recording, analysis, reduction, correlation and presentation of their results in a written report and make an oral presentation. The student teachers received compensation for their efforts.

FEMME CONTINUUM

FEMME Continuum students 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-day effort, only involves data taking, data analysis and graphical representation of the experimental results. The program is designed so that the students develop confidence, self- esteem and a sense of accomplishment.

SENIOR FEMME

Senior FEMME participants have completed the two previous FEMME courses. 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 the theoretical background.

CHIME

The program is designed to give seventh and eighth grade urban, minority youngsters an opportunity to increase their awareness, understanding and participation in science and engineering. Students are assigned to work, in teams of two for the simple bench scale experiments and groups of three for pilot plant scale experiments. The first experiments are the bench scale neutralization of acid and temperature measurements by different thermometers. The pilot plant scale experiments in the Unit Operations Laboratory follow these bench scale experiments.

UPWARD BOUND/MATH AND SCIENCE PROGRAM

The Upward Bound Math and Science Center program 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. 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. One aspect of the program involves the assignment of students to an intensive independent research project in addition to their regular assignment. Students mentored by the authors undertook intensive, six-week experimental studies in the area of fluid dynamics and heat transfer with a written report and an oral presentation required.

EXPERIMENTAL OBJECTIVES

Each of the previously mentioned K-12 programs has a specific curriculum appropriate to the level of education of the participants. Students in all of the above programs are exposed to experimental, “hands on” projects and, as the capstone portion of the experience, a written report and an oral presentation. 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, critical thinking and allowing the individuals or teams to experience what a project is like, and to give the students a “hands-on” experience.

LABORATORY EXPERIMENTS

As one would expect, the individual programs are a function of the student’s level of educational background. Simple bench scale experiments consist of the neutralization of an acid with a base and temperature measurements as a function of time during the batch heating of water. Freshman Engineering Measurement Laboratory experiments are intermediate between the bench scale and the senior Chemical Engineering laboratory Pilot Plant scale experiments. The senior Chemical Engineering Laboratory Unit Operations equipment is chemical industry pilot plant scale equipment, some of which extends over three floors in height.

For students in the FEMME and CHIME programs, the bench scale experiments were used as an introduction and the senior chemical engineering laboratory experiments are used in a simplified manner. For the older students in the Upward Bound/ Math and Science Programs, the senior chemical engineering laboratory experiments were performed in greater detail. The students were divided into teams of two for the neutralization and temperature measurement experiments and teams of three for the pilot plant scale experiments.

BENCH SCALE EXPERIMENTS

The acid neutralization unit consists of a burette and flasks 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 of two students is given four flasks filled with 25 ml of HCl solution, each of different normality (0.05, 0.10, 0.15, 0.20) and told to measure the amount of 0.10 N NAOH required to neutralize the acid solution. Methyl Red is used as the indicator. The students graphically correlate the volume of sodium hydroxide needed to neutralize the acid solution versus the normality of the acid and develop the linear correlation. Students are told that this experiment simulates the action of antacids on an acid stomach.

In the temperature measurement experiment, students fill a 600-ml beaker with 300 ml of water and place it on a hot plate. They use 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 and record temperature readings each minute until boiling is reached. The students are asked to correlate the temperature versus time for each thermometer and also observe the differences in the reading from the two different thermometers. In addition, they also observe how the increase in temperature per unit time decreases as the temperature rises during the batch heating and remains constant at the boiling point. For both of these studies, students write a short technical report individually and make an oral presentation as a team to their classmates. The students then enter the Senior Chemical Engineering Laboratory and perform an experiment on the large-scale equipment in teams of three.

FRESHMAN ENGINEERING MEASUREMENTS LABORATORY EXPERIMENTS

Five smaller scale experiments developed for the FED Program were 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, mixing tank, a small temperature measurement bench, and two small columns 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.

SENIOR CHEMICAL ENGINEERING UNIT OPERATION LABORATORY EXPERIMENTS

The chemical engineering laboratory portion of the course involves a “hands-on” experience with both smaller, bench scale and larger, pilot plant scale equipment. The students are divided into groups of three or four and there are eight groups for each class of about 25 students. The students work on eight different experiments and are given the instructional manual [3], which was developed for this equipment and was used in the FED course. The manual is given to all students and enables them to learn about instruments, terminology and definitions used for measurements. In addition, the manual exposes the

students to Standards, Units, Dimensions, Conversion of Units, Concepts of Correlation and introduces them to Dimensionless Numbers.

There are two experiments on **Pressure Drop in Pipe and Fittings**. One of these experiments is a large unit with plant scale Pipes, Fittings, Pump, Orifice Meter, Venturi Meter and a Rotameter. The second experiment consists of the smaller scale equipment that contains the same equipment and, in addition, a Pitot Tube for flow measurement.

Two units are used to study the **Pressure Drop in a Fixed and Fluidized Bed**. In the larger unit, which is 6 inches in diameter, the bed is packed with 0.110-inch diameter and 0.125-inch long cylindrical, plastic pellets and airflow is used as the fluidizing medium. In the smaller unit, there are two, two-inch diameter columns. One column is packed with coarse No. 8 Ballotini particles (440/530 microns) and is fluidized with water while the other column is packed with fine No. 10 Ballotini particles (210/325microns) and is fluidized with air. For **Pressure Drop in Packed Towers**, the units are 6-inch diameter glass columns packed to a height of five feet with ½-inch Ceramic Raschig Rings, Berl Saddles, Intalox Saddles, or Spheres. The students measure the pressure drop across the dry packing with only the upward flow of air. Following this test, the students repeat the study with the downward flow of water and the upward flow of air.

In the **Efflux Time from a Tank,** four tanks each 6 inches in diameter and about 6 feet high are equipped with fittings to enable the connection of effluent pipes of different diameter from ¼-inch to one inch and lengths of 6, 12, 18, 24, and 36 inches. Students correlate the height of the liquid in the tank versus the cumulative time.

In the **Concentric Tube Heat Exchanger**, students study the transfer of heat from hot water flowing through the inner tube to cold water flowing in the outer annular space. The experiment is performed with both parallel and countercurrent flow.

In the **Agitation in Tanks** experiment, a turbine agitator is installed and the force is measured as a function of agitator speed in revolutions per minute. The power required in both Watts and Horsepower/Gallon is correlated with the Agitator Speed in RPM.

THE UNDERGRADUATE RESEARCH PROGRAMS AT NJIT

In recent years, undergraduate research has been increasing at a rapid rate as cited by Zurer [4]. Another current article, [5] reports 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. NSF realizes the importance of undergraduate research and gives support through its Research Experience for Undergraduates (REU) program. These programs differ from the K-12 programs because the goal is to give a more mature group of students, independent research experience coupled with critical thinking, teamwork, and an extensive development of communication skills.

Undergraduate research at NJIT has been an integral part of the curriculum since the 1960's. 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 URE (1990) and the McNair (1999) programs, which are designed to recruit qualified students from underrepresented groups and introduce them to the challenges associated with research. The students are expected to perform original research under the guidance of a faculty mentor and to publish the results of their research in acceptable journals and to present the results of their effort at national and international technical conferences. Both programs require participants to present their research efforts at the annual NJIT Research Symposium. The aim of these programs is to foster an interest in the students to continue their education in Graduate School and obtain advanced degrees. The primary aim of the McNair Program, however, is to produce more faculty members from the underrepresented student body by allowing them to gain an insight into the research process, learn about Graduate Schools and learn about an academic career. The URE Program allows students to perform research and independent study under the guidance of a Faculty Advisor. The program provides academic and educational assistance to 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 McNair Program, which is funded by the Department of Education (DOE), however, has a different goal. This program seeks to recruit juniors and seniors from low income, first generation, underrepresented groups with excellent academic credentials, who are majoring in Science, Technology, Engineering and Mathematics (STEM). 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 their work. Hence, this effort would broaden the diversity in the field and provide

positive role models for groups underrepresented in the professorate. Since its inception 100 students have enrolled in the program, and forty have enrolled in Graduate School. The authors have served as advisor/mentors 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.

CONCLUSIONS

NJIT K-12 programs have dramatically increased the number of minority students entering universities. Approximately 80 percent of these students go on to undergraduate university education. Ninety percent of those students who have participated in the Undergraduate Research Experience Program go on to obtain advanced degrees. Forty-five percent of those students that are Ronald E. McNair scholars enroll in graduate programs. 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. Not only are students better prepared for graduate school but also their intellectual and educational growth makes their chances for completing the program of study greater.

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