

INTRODUCING STUDENTS IN GRADES K-12 TO SCIENCE AND ENGINEERING THROUGH EXPERIMENTAL LABORATORY MEASUREMENTS

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Abstract--- Historically minorities have been woefully underrepresented in the fields of science and engineering. To interest underrepresented groups, introductory programs in science and engineering have been developed for K-12 students. Among the earliest programs was NJIT's **Urban Engineering Program for High School Students**, which is still in existence. New Jersey Institute of Technology is ideally located in the heart of Newark, New Jersey, a city that typifies the urban crisis. Dr. Dana Levine began to focus on attracting young women into science and engineering with the **Females in Engineering, Methods, Motivation, and Experience (FEMME) Programs**. Dr. R. P. T. Tomkins developed the **Chemical Industry for Minorities in Engineering (CHIME) program**. In addition, the **NJIT Upward Bound, Mathematics and Science programs** for grades 9th-12th grade Newark, New Jersey high school students has developed with a strong emphasis on Chemical Engineering. All of these programs had an exposure to the chemistry/chemical engineering laboratory experiments to insure an experiential /experimental interaction coupled with communication skills.

Index Terms--- Chemical Engineering, diverse outreach efforts, experiential learning, K through 12th Grade, minorities, Pre-College, Science and Engineering Programs, Underrepresented Groups

INTRODUCTION

With the Twenty-first Century upon us, globalization has become a fact of life. Allied with the phenomena is the technological expansion that requires a more educated population and a dire need to expand the engineering manpower pool. Historically, in the United States, minorities have been woefully underrepresented in the fields of science and engineering. In an attempt to interest individuals from underrepresented groups to choose a career in these fields, introductory programs in science and engineering have been developed and aimed at K-12 students. New Jersey Institute of Technology (NJIT) has a long history of diverse outreach efforts to underrepresented K-12 students with an aim of

increasing the number of individuals from underrepresented groups entering science and engineering programs.

The Office of Pre-College Programs at NJIT has the responsibility for developing, operating and soliciting funding support from private, industrial, state and federal sources for these programs. This office and some early K-12 efforts had its beginnings about thirty years ago in the Department of Chemical Engineering and Chemistry with a strong science emphasis. With this beginning, it is not surprising that the current programs, which encompasses students from sixth to twelfth grades, have a strong basis in chemistry and chemical engineering laboratory measurements, related data analysis, and a strong emphasis on communication skills. Depending on the educational level of the student, the experiential laboratory/lecture exposure is to either bench scale or chemical pilot plant scale laboratory equipment or a combination of both.

At NJIT as elsewhere, the K-12 programs have their origins about 25-30 years ago. Most of these programs had the goal of increasing the pool of minorities entering engineering and science programs at institutions of higher learning. Among the earliest was NJIT's Urban Engineering Program for High School Students [1], which is still in existence. 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 abating an inner city High School, programs began to develop at NJIT. At the same time, Dr. Dana Levine[2], Professor of Chemistry, 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. Allied with these efforts, other programs[3] including the Chemical Industry for Minorities in Engineering (CHIME) program was developed by Dr. R. P. T. Tomkins, a member of the Chemistry Division of the Department. In addition, the NJIT Upward Bound, Mathematics and Science programs for grades 9th-12th grade Newark, New Jersey high school students has developed with a strong emphasis on Chemical Engineering. All of these programs had built into the

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curriculum an exposure to chemistry/chemical engineering laboratory experiments to insure an experiential/experimental interaction coupled with communication skills.

In other institutions in the United States, these programs began to proliferate. Anderson-Rowland [4] reported on the "Women in the Applied Sciences and Engineering Program (WISE) at Arizona State University, which was added in 1993. Genelo, Winsdom, Jooly, and Semple [5] reported in the Program for Women in Science and Engineering (PWSE) initiated in 1987 at Iowa State University. Johnson, Diamond, and Stonich [6] reported on the Carnegie Mellon 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 "Brining 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 Zubarth [14] discussed the outreach programs with super computer applications. Mengel [15] discussed the K-12 students and the worldwide web. Thiede, 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 about 30 years ago, the ASEE through the proceedings of the Annual Conferences, Section Conferences, and Frontiers in Education has been a leader in reporting on a large number of K-12 Programs throughout the United States and a few overseas programs. Seldom is there an ASEE meeting,

which doesn't publish manuscripts, related to this timely topic.

New Jersey Institute of Technology (NJIT) is an inner city urban institution located in Newark, New Jersey with a social, economic, and academically diverse student body consisting of approximately 5800 undergraduate and 3000 graduate students. The undergraduate population is approximately composed of one-third (women, Hispanic, and Afro-American) minority. The institution has, traditionally 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 minorities outreach programs. Some of those programs in which the authors have served are:

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

The authors have presented the results of their experiences and the structural details of these programs [17, 18, 19, and 20]. This paper will, therefore, only discuss the experimental details of the experiments that the K-12 students perform in the Chemistry and Senior, Unit Operations, Pilot Plant Scale, Chemical Engineering laboratory.

LABORATORY EXPERIMENTS

As one would expect, the individual programs are a function of the student's level of educational background. The experiments consist of simple bench scale systems to our senior chemical engineering laboratory unit operations equipment.

The 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. 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 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 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 is 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. 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 °F and °C. They then 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. For both of these studies, the younger students write a short technical report individually and make an oral presentation as a team to their classmates. The younger students then enter the Senior Chemical Engineering Laboratory and perform an experiment on the large-scale equipment in a group of three.

SENIOR CHEMICAL ENGINEERING UNIT OPERATION LABORATORY EXPERIMENTS

The experimental 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 manual [21], which was developed for this equipment and is used in our Fundamentals of Engineering Design course for our entering Freshmen. 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. The students are taught how to collect and record experimental data, use the computer to graphically correlate their data and finally to write an individual report and make a group oral presentation to their classmates. This summer the students will also prepare a poster session for their parents on the last day of class.

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 experiments consist of the smaller scale equipment that contains the same equipment but on a smaller scale and, in addition, a Pitot Tube for flow measurement. For these two experiments, the students calibrate the Rotameter, the Orifice Meter, the Venturi Meter, determine the characteristics of the pump (pressure head developed versus the flow rate) and correlate the pipe friction factor versus the Reynolds Number.

There are also two units 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-long cylindrical plastic pellets and airflow is used as the fluidizing medium. In the smaller unit, there are two, two-inch diameter columns. The 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. In both studies, the students measure the pressure drop across the column with manometers and the height of the bed as a function of the fluid superficial velocity through the bed. The fluid velocity is increased slowly and the students observe the characteristics of a Fixed Bed and a Fluidized Bed. The students are then asked to determine the point of minimum fluidization, which is an important design parameter in the design of fluidized beds.

There are two large-scale units available for the study of

Pressure Drop in Packed Towers. These 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. The water rates are set at 1000 and 2000 pounds per square foot per hour. The students correlate the Pressure Drop per Foot of Packing in inches of water per foot versus the Air Mass Velocity in pounds per square foot per hour on logarithmic coordinates and identify the loading point and the flooding point, which are two important parameters in the design of packed towers.

In the **Efflux Time from a Tank**, four tanks about 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 32 inches. Three of the tanks are equipped with quick close valves and one tank has no valve. The students fill the tanks to a height of four feet and begin draining the water, recording the time it takes the water level to change four inches. They then correlate the height of the liquid in the tank versus the cumulative time and observe that the height decreases with diminishing slope. The run is repeated for each of the different pipe lengths for each diameter pipe and a correlation is developed of the total efflux time needed to reduce the level to four inches versus the pipe length.

In the **Concentric Tube Heat Exchanger**, the students study the transfer of heat from hot water flowing through the inner tube to cold water flowing in the annular space. The equipment can be operated in either parallel or countercurrent flow. At a constant cold water flow rate of 2.0 Liters per minute (range, 0.2-3.0 Liters/minute) the students vary the hot water flow rate from 1.0 to 4.0 Liters per minute in one Liter per minute increments in parallel flow. The experiment is repeated in countercurrent flow. The calculations involve a comparison of the heat lost by the hot water to the heat gained by the cold water and the per cent closure of the heat balance. Based on the heat transferred, they calculate the overall heat transfer coefficient and correlate it with flow rate of the hot water and compare the curves of parallel and countercurrent flow. In addition, the students correlate the temperature of each stream with heat exchanger length for both parallel and countercurrent flow.

A small cylindrical, agitated, baffled mixing tank is used to study the power requirements as a function of agitator revolutions per minute (RPM) for various sizes and shapes of agitator 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 students multiply the force times the lever arm to obtain the torque and then multiply the torque times the RPM to obtain the power, which they convert into Watts. The power required in Watts and in Horsepower/Gallon is correlated

with the Agitator Speed in RPM. The students can also correlate the Power Number versus the number of revolutions per second of the impeller (RPS), or the Power Number versus the modified Reynolds Number.

A small temperature measurement bench as equipped with many different types of temperature measurement instruments is also available for comparative studies. Mercury in glass, thermocouples, platinum resistance thermometers, etc are compared.

THE PROGRAMS

For all programs, undergraduate chemical engineering students eligible for work-study funding or enrolled in the Undergraduate Research Experience (URE) program, work with the two Faculty members directing to the course. Each summer about five to eight undergraduate students are involved. These undergraduates first run all 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. Some of these undergraduates had actually completed our freshman Chemical Engineering Measurements module, which was the basis for almost of the experiments used in this program. Many of them, however, are sophomores and after exposure to this experience are better prepared to enter the fluid flow and heat transfer courses in the junior year. They also have a good start on the experiments that they will perform in their senior year in the Chemical Engineering Unit Operations course.

CONCLUSIONS

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 work 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.

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