INTRODUCING HIGH SCHOOL STUDENTS AND SCIENCE TEACHERS TO CHEMICAL ENGINEERING[1]

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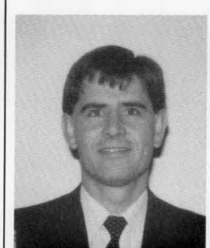

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Engineers and scientists will be key professionals in the future development and implementation of new technology programs that will serve to keep our country in its leadership role. Recent enrollment trends in engineering programs[1] show a decrease in the number of high school students who are interested in technical careers, and many who *are* interested do not have an adequate background for completion of an engineering program because they do not take advanced science and math courses while in high school.

Following the national trend, the Mackay School of Mines and the Chemical and Metallurgical Engineering Department at the University of Nevada, Reno, have also experienced significant enrollment reductions for the past few years. Figure 1 depicts the number of freshmen and total enrollment for the last ten years. After reaching a low of one freshman in 1986 and a total of twenty-four in 1987, we began an active recruiting program which involved visiting high schools and telling students about careers in chemical engineering. We visited high schools in Reno, Las Vegas, northern Nevada, and neighboring counties in California. These visits proved to be very useful, with the result that students are now more aware of careers in engineering and that teachers are now better informed and prepared to advise students who have technical interests.

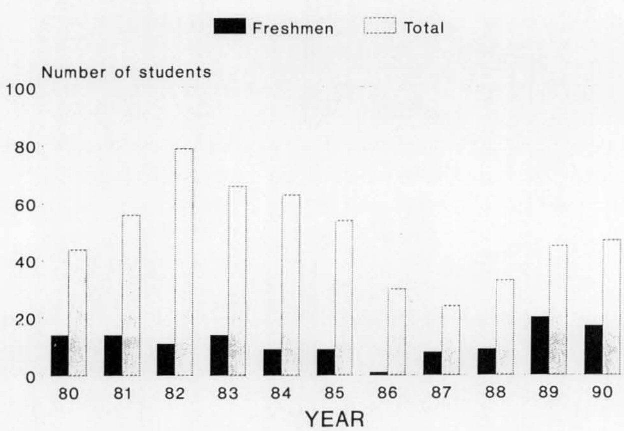

FIGURE 1. *ChE enrollment at the University of Nevada, Reno*

As a complement to the active recruiting program, a "Summer Institute" was developed. Again, the primary purpose was to introduce high school students and teachers to chemical engineering. The approach here, however, was through hands-on experimentation and exercises which were conducted with the help of university students, a more involved step than the recruiting seminars.

Active participation was the vehicle through which students could discover the challenges, the usefulness, and even the fun that is associated with this scientific discipline. The students also acquired a better feel for what types of preparatory math and

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science courses they would need to pursue an education in chemical engineering.

The program which was developed for this summer instituted included an introduction to chemical engineering, a description of typical chemical engineering jobs, and general instruction in material balances, fluid mechanics, heat transfer, mass transfer, and process control. Of course, these topics could only be covered superficially in such a short time, but it was enough to provide some insight into the problems that chemical engineers solve and the corresponding scientific background and preparation that is required.

The main goal of the program was to increase enrollment in engineering and to encourage women and minority groups to increase their representation in the engineering workforce.

STUDENT SELECTION

The science teachers in several local high schools (within a 75-mile radius of Reno) were invited to attend the summer institute, and each of the teachers was asked to select three or four of their better students who had an interest in math and science to also attend the institute. They were also asked to encourage females and minorities to participate.

Five high schools responded to the invitation, with a total of five teachers and nineteen students participating. The student group consisted of nine women and ten men, with four of them classified as minorities. Eleven of the students had just completed the freshman year, seven had just completed the sophomore year, and one had completed the junior year. Therefore, most of the students had two remaining years of high school in which to prepare themselves in math and science in the event they wished to pursue an engineering degree.

PROGRAM ORGANIZATION AND SCHEDULE

The Summer Institute in Chemical Engineering was one week in duration, with sessions lasting from 9:00 a.m. until 4:00 p.m. each day. The overall schedule of activities for the week is presented in Table 1. The program began on Monday morning with a general introduction and slide presentation about chemical engineering, attended by all students. For the remainder of the Monday session, the group of twenty-four students was divided into three groups of eight students each.

For the remaining days (Tuesday through Friday) the students were divided into two groups, "A" and "B," each of which was divided into two subgroups of five to seven students each. Dividing the students into smaller groups provided for a more personal level of participation and understanding by all students involved, which fulfilled the course criteria of active participation in experiments rather than simply listening to a lecture or watching a demonstration.

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TABLE 1
General Schedule for Summer Institute

DAY	TOPIC
Monday	• Introduction • Careers in chemical engineering (videotapes and personal experiences) • Material balances (lecture, problems, and computer exercises)
Tuesday	• Fluid mechanics session: Group A • Mass transfer session: Group B
Wednesday	• Mass transfer session: Group A • Fluid mechanics session: Group B
Thursday	• Heat transfer session: Group A • Process control session: Group B
Friday	• Process control session: Group A • Heat transfer session: Group B

Each group of approximately twelve students (groups A and B) had a common one-hour lecture in their first morning session. This was necessary in order to provide background information and to introduce the students to the subject. Some of the activities and experiments scheduled for the day were also discussed in this session, and explanations about the phenomena they would be observing or measuring were provided.

After the morning lecture the groups separated and participated in activities such as laboratory experiments, calculations to analyze experimental data, and computer exercises. Each of the laboratory sessions was directed by a teaching assistant, who provided guidance to the students. A rotation procedure was developed so that each of the smaller groups had an opportunity to participate in all laboratory sessions. A list of activities for each daily session (fluid mechanics, heat transfer, mass transfer, and process control) is presented in Table 2.

Lunch and refreshments were provided for all participants. These periods provided a more informal atmosphere in which the students could interact with the instructors and the teaching assistants, as well as make friends with each other.

A comprehensive notebook was prepared and distributed to each of the student participants. It contained all of the lecture notes, a description and explanation of all the experiments and demonstrations, and worksheets for performing calculations and other exercises. This material enabled the students to follow along more easily, and hopefully it will serve as a reference for them in the future. It should also be a useful guide for science teachers who might later integrate some of the material into their teaching.

The Summer Institute was taught by two professors of chemical engineering (the authors) with the help of four teaching assistants who were seniors or graduate students in the Chemical and Metallurgical Engineering department.

TABLE 2
List of Activities

Fluid Mechanics	• Introductory lecture • Reynolds number experiment • Reynolds number calculations • Pressure drop experiment • Pressure drop calculations • Computer design of slurry pipelines
Heat Transfer	• Introductory lecture • Temperature profiles in solid rods (experiment) • Temperature profiles in solid rods (calculations) • Double-pipe heat exchanger experiment • Double-pipe heat exchanger calculations • NASA space shuttle tile demonstration
Mass Transfer	• Introductory lecture • Diffusion experiment • Diffusion calculations • Distillation column experiment • Distillation column calculations • Flotation demonstration
Process Control	• Introductory lecture • Valve characterization experiment • Valve characterization calculations • Liquid level control experiment • Liquid level control calculations • Computer simulation of level control

DESCRIPTION OF TOPICS

A list of the topics covered in the Summer Institute, with a brief description of their content, follows.

Introductory Topics

Material Balances This topic introduced the students to chemical engineering. They learned how to formulate and solve material balance problems which are the basis in the design of process plants. The topic was covered in three different sessions: introductory lecture, solution of problems, and demonstration of applications using a microcomputer. In this last session the students used the CAAPS (Computer Aided Analysis for Process Systems) software[2] which is a linked system of menu-driven, compiled BASIC programs for the elementary steady-state analysis of chemical processes. The software was demonstrated for balancing chemical reactions, converting units, and performing some simple steady-state material balances.

Biotechnology A ten-minute videotape which explores the variety of careers open to chemical engineers in the field of biotechnology was shown.

Advanced Materials A fifteen-minute videotape which explores the variety of careers open to chemical engineers in the field of advanced materials was shown.

Environmental Protection A twenty-five minute videotape exploring the variety of careers open to chemical engineers in this field was shown. It described many of the current environmental problems and the role chemical engineers have in their solution.

Chemical Engineering Job Experience A description of typical job assignments given to chemical engineers was presented. The two instructors have had prior work experience in the petroleum refining and steel industries, and therefore a presentation of each of those industries was made, including a description of the petroleum refining process and the steelmaking and cokemaking processes. In addition, each instructor presented examples of his/her own job assignments while employed in those industries.

Fluid Mechanics Topics

Reynold's Number Experiment Visual observations of various types of flow (laminar, turbulent, and transition) were made by allowing water to flow through various sized and shaped conduits, and injecting a small stream of dye. These visual observations were compared to predicted values via calculation of the Reynold's number.

Pressure Drop in Pipes and Fittings Laboratory experiments were performed to measure the frictional losses of water flowing through various sized pipes, valves, and fitting. These frictional losses were compared to theoretically-predicted pressure drops.

Computer Design of Slurry Pipelines Personal computers were used to demonstrate a program that is used for designing slurry pipelines.[3] Use of the computer enabled students to investigate problems associated with slurry pipeline design through some specific design problems.

Heat Transfer Topics

Double-Pipe Heat Exchanger Three steam-jacketed, copper, circular tubes of different diameters were used to demonstrate the operation of double-pipe heat exchangers. Water was passed through the inner tube, and steam was passed through the annular space. The heat transfer coefficients, both as a function of flow rate and tube diameter, were determined for comparison with literature values.

Temperature Profiles in Solid Rods Three cylindrical rods of varying diameters and construction materials were heated at one end. The temperatures along the rods were measured to determine the temperature distribution of each rod. These results were then compared to theoretical predictions. The use of a thermocouple as a temperature-measuring device was also demonstrated.

NASA Space Shuttle Tile Demonstration An actual NASA space-shuttle tile was used to demonstrate the thermal insulating power of modern ceramic materials. The tile was heated to 900°C in a furnace, and then, due to the thermal conductivity of the material, the students found they were able to hold it without burning their hand.

Mass Transfer Topics

Diffusion Experiment The diffusion coefficient of acetone in air was determined at various temperatures. Acetone was placed in a graduated cylinder and maintained at a constant temperature while air was blown through the top. The rate of diffusion was determined by measuring the change in acetone liquid level as a function of time. The experimental results were compared to theoretical predictions.

Distillation Column Operation A pilot-plant size distillation column was operated to demonstrate the principles underlying separation of two liquid components in solution. Liquid samples and temperature measurements were taken during steady-state operation while separating an acetone-water solution. The students were taught how to plot equilibrium data and to calculate the number of stages required for a given separation by using the McCabe-Thiele method. They used this information to compare with their experimental measurements and to calculate the overall efficiency of the distillation column.

Flotation Demonstration A Denver laboratory cell was used to demonstrate the underlying principles of flotation. This process uses differences in the surface properties of particles in an aqueous pulp to affect a separation. Hydrophobic particles are floated to the surface by finely dispersed air bubbles and are collected as froth concentrate. Hydrophilic particles do not adhere to the air bubbles, but remain in suspension in the pulp and are carried off as underflow.

Process Control Topics

Valve Characterization The valve-sizing coefficient of a miniature control valve was determined as a function of valve-diaphragm pressure. The students also determined whether the control valve had linear or equal percentage inherent characteristics. The procedures used for specifying control valves in practical applications were also discussed.

Automatic Control of Liquid Level An analog controller was used to maintain the liquid level in a tank at a desired value. The principles of automatic process control were described, and the student was exposed to the actual instrumentation used in the field. Performance of the level controller was evaluated for various operating conditions. The problems which can arise by improper design or through selection of the wrong settings was also demonstrated.

Computer Simulation of Level Control A computer program that simulates the operation of three non-interacting tanks in series was used to demonstrate some of the principles of process control. The program runs on a microcomputer and graphically displays the level of one of the tanks.

This level can be monitored on-line as the user changes various controller parameters. The program runs interactively and the student can become the plant operator who has the capability of making changes to the process. The student can open or close the control valve, select manual or automatic operation, change the setpoint, or change controller settings. As a result, he or she can observe the results of any given change immediately on the screen.

COURSE EVALUATION

At the end of the week the students were asked to complete a course evaluation to help us improve the course in future years. The questions included in the form are shown in Table 3.

The response to the Summer Institute was very favorable; many of the students and teachers indicated that they would be interested in attending the next session also. The students selected the computer sesions and the laboratory experiments (which involved more participation) as their favorites. The videotapes and some of the calculation sessions seemed to be less attractive. However, in response to the question about the session they liked the least, the answer that students repeated the most was "none." Several students indicated that they would include "all" sessions as those they liked the most, and one student wrote, "I liked almost all of them the same. They put into perspective the thoughts installed into our brains in the morning." The difficulty level of the material covered was considered appropriate by 74% of the students, while the remaining 26% thought it was somewhat high. One student commented, "A few early-morning sessions were hard to understand at first but were cleared up by the afternoon. Having daily periods build on each other was very effective."

The majority of the students (62%) indicated that the time spent on lectures should remain the same, and 33% of them would like this time reduced. The opposite occurred for the time spent in the laboratory doing experiments or computer work: 62% suggested an increase and 33% no change. More mixed results were obtained for the time spent doing calculations: 52% suggested no change, 38% indicated that the time should be decreased, and 10% suggested an increase. The notebook that was prepared received very favorable comments, as did the instructors and teaching assistants. One student said about the notebook, "It was nice to have notes completed so we could look back and read what we missed. It will be nice to keep and look back at." Another student wrote, "I plan to study this book and use it for future reference."

TABLE 3
Questions on the Course-Evaluation Form

1. **Has this course been of help in understanding something about chemical engineering?**
2. **What session(s) did you like the most? Comments.**
3. **What session(s) did you like the least? Comments.**
4. **Was the overall material covered and discussed**
   - **too difficult?**
   - **too easy?**
   - **about right?**

   Circle your answer and provide any comments. If any specific session was too difficult or too easy, please indicate below.
5. **How do you feel about the time spent on each activity? Mark your suggestions and provide any comments.**

	Increase	Decrease	No Change
Time spent on lectures			
Time spent in laboratory			
Time spent doing calculations			

6. **Did you find the notes useful and clear? Comments.**
7. **What would you suggest changing to make the course better?**

The students made several suggestions on how to improve the course. Their suggestions ranged from making the course and/or days shorter to making it a four-week course. Even though the course emphasized hands-on laboratory experimentation by the students, they would like to see more experiments in a variety of areas. One general suggestion was that students should have had a course in chemistry before attending the institute since some of those who had not been exposed to chemistry had trouble understanding the material.

In summary, the Summer Institute in Chemical Engineering proved to be a very enjoyable and useful experience for everyone involved.

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