THE DEVELOPMENT OF COMMUNICATIONS SKILLS THROUGH A LABORATORY COURSE*

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FEW WOULD DISPUTE THE obligation of departments of chemical engineering to provide students with a sound technical education in the fundamentals of thermodynamics, heat, mass and momentum transfer, separations processes and chemical reaction engineering. That schools in this country have been successful in doing so is indicated by the high level of industrial competition for new graduates. However, despite the facility with which a young working engineer performs design calculations or process analyses, such efforts will prove fruitful only if they are communicated effectively to others. In fact, in a recent survey of prominent engineers, 95% of the respondents indicated that writing ability played either a very important or a critically important role in their work. [1] Unfortunately, training in communications skills for engineers in most colleges and universities is relegated to the two or three courses in Freshman English required of all students to graduate. Even if courses in technical communication were available, the typical chemical engineering curriculum is highly structured and such an option, regardless of its merits, faces stiff competition from other free electives. A natural alternative to requiring an additional writing course is the incorporation of an emphasis on communication skills into the laboratory course. Such an approach has been followed in the Department of Chemical Engineering at Stanford since 1978.

The present configuration of our undergraduate laboratory has evolved as a result of concerted efforts to teach good communication. It was neces-

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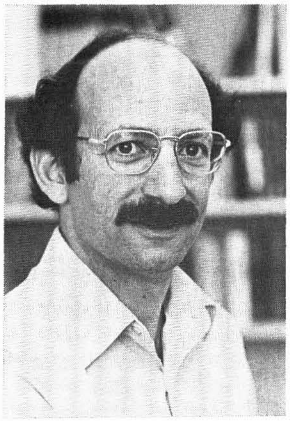

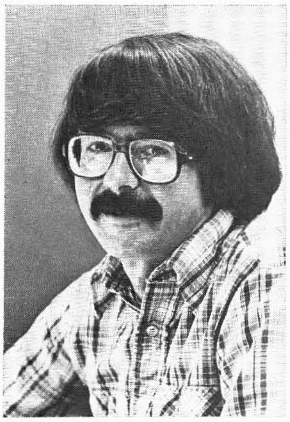

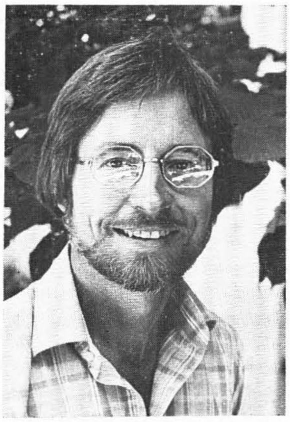

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sary, however, to first ensure that the experiments were of uniformly high quality. In 1978 the department received an Instructional Scientific Equipment grant from the National Science Foundation. This grant, with additional funds from the Stanford School of Engineering, the Department of Chemical Engineering and a Special Program Grant from the Dreyfus Foundationtion, allowed new instrumentation to be purchased so that new experiments in chemical reaction engineering and polymer materials science could be developed and existing ones upgraded. Second, in a major commitment of department resources, a new position was created for a technician whose primary responsibility would be the undergraduate laboratory, his duties to include routine maintenance, renovation of existing apparatus and design and fabrication of new instrumentation. Third, three existing laboratory courses were formally dropped from the curriculum, their best experiments added to those developed under NSF support in a new six unit two quarter sequence. These actions allowed strong emphasis on the development of oral and written communication skills.

A key element in the new laboratory course has been the assistance provided by the Communications Project of the School of Engineering at Stanford University. [2] This is an innovative program, initiated in September 1976, and designed to assist engineering students in improving their writing and speaking abilities. Among other things, the Communications Project involves person-to-person tutorials and the rewriting of graded reports, features which have been made integral parts of our laboratory course. The unique aspect of the Communications Project is that the communications tutors are not professional staff members; they are undergraduate engineering students who have been specially selected on the basis of their writing and speaking talents and then given instruction to hone their abilities further. The underlying philosophy is that the tutors act as role models with whom the students may closely identify.

COURSE ORGANIZATION

In order that the students have an appropriate technical background for the experiments, the course sequence is given in the winter and spring quarters of the senior year after all necessary lecture courses have been taken. A total of twelve experiments in five different areas have been developed to date. These include fluid mechanics (determination of flow profiles using Laser-Doppler velocimetry, drag force on spheres), heat transfer (transient and steady conduction, forced convection, radiative energy transport), mass transfer (steady diffusional mass transfer), chemical reaction engineering (isothermal batch reactor, tubular reactor, continuous flow stirred tank reactor), and polymer materials science (viscoelastic creep, dilatometric measurement of glass transition temperature, differential scanning calorimetry). Four faculty members are associated with the course, with two sharing responsibility for the experiments each quarter. In addition, there are two graduate teaching assistants each quarter, one working with each faculty member. Finally, there are one or more peer tutors from the Communications Project in both the written and oral skills areas.

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The experiments are carried out by groups composed of three students with each group performing eight experiments during the two quarter sequence. For each experiment one person acts as group leader and the other two as assistants. Although all group members should be conversant in the underlying theory, the group leader bears ultimate responsibility for the successful completion of the experiment. He must ensure that the instrumentation is operating properly, that the appropriate data are taken and that the calculations, shared among all group members, are done correctly. The team concept is an important element of the course. Efficient group operation in the planning, execution and analysis of each experiment requires effective intragroup communication and close cooperation. In its ideal form, this experience provides a model for the student in his later professional activities, e.g. as an engineer on a process design team. Finally, since organizational responsibilities and reporting requirements are rotated among group members throughout the two quarters, each student receives multiple exposure to several forms of expression, both written and oral.

COMMUNICATION SKILLS DEVELOPMENT

The philosophy behind the reporting procedures (to be described shortly) is that development of writing and speaking skills requires extensive practice, i.e. learning by doing. Moreover, the student must make an active effort to comprehend his errors and to correct the problems through rewriting his reports until the presentation is clearly organized. An essential part of the educational process is the tutorial session in which the student meets individually with a writing and/or speaking tutor from the Communications Project, as appropriate. The tutorial session can serve as a device to assist in preparation such as a preview of an oral presentation or after the fact as a means of evaluating clarity of presentation in a report which has already been graded for technical content. To assist the students in understanding the level of faculty expectations for written and oral reports, a course syllabus is provided in which guidelines are given. In addition, during the first week of the course winter quarter, before the experiments begin, some lectures are devoted to fundamentals of communications skills. The students are also advised to obtain and read *The Elements of Style*, by William Strunk and E. B. White, 3rd. ed., MacMillan Publishing, New York, 1979 before the experiments begin. This small text is concise and quite readable; in fact, it serves as a good model of the objectives for the written reports.

Perhaps the most important skill learned is the ability to present results and conclusions clearly and concisely in a short written report or oral presentation.

Since this course has only been offered a limited number of times in its present form, it is still evolving. The following description applies to the course which was offered during the 1979-80 academic year in which four distinct forms of communication were utilized. Three of these were written and one oral. The most extensive written document is the major technical report which is required of the group leader for each of the first six experiments. This report presents the theoretical background, objectives, laboratory procedure, results, conclusions and recommendations in a style typical of a journal article. Although this document is a major undertaking, the student must exercise judgment in determining the depth of coverage warranted for a particular experiment. Since there are three persons to a group, each student does two of these major reports during the first six experiments. The major report is graded twice: once for technical accuracy and once for effectiveness of communication. The first person to read the report is one of the graduate teaching assistants who prepares a critique emphasizing technical accuracy. The report is then examined by the faculty member in charge of the experiment, again mainly for technical purposes. However, if the report organization is so confusing that it is not possible to determine whether the student comprehended the intent of the experiment, the report is returned to the student for rewriting. Upon resubmission, the faculty member and teaching assistant agree on a grade on the technical content which is up to 75% of the total possible points. The report is then returned to the student who must make an appointment with the writing tutor from the Communications Project. In this second evaluation phase the tutor will go through the report individually with the student and examine it solely for clarity of communication. After this tutorial session, the student is usually required to rewrite sections, or even the entire report. After resubmission, the tutor assigns a grade, up to 25% of the total possible points, on the basis of the degree to which the student has complied with the suggestions made during the tutorial session.

The second written form of communication is a brief technical summary required of each of the assistants. This is strictly limited to 300 words in length and should provide a clear and concise description of how the objectives were met and the major results. No supporting graphs or tables are permitted and the use of equations is discouraged. The grading of this report, both for technical accuracy and for effectiveness of communication, is done by the faculty member and teaching assistant. Again, the report usually has to be rewritten before a final grade is assigned. Each student will do four of these technical summaries over the first six experiments.

The third form of written report is used during the last two experiments of the second quarter. This is a short technical report or extended abstract which is prepared by each of the group assistants. The report is three to five pages long and includes a brief theoretical background, objectives, presentation of results by means of graphs and tables and discussion of the observations and conclusions. Each student does one or two of these reports.

The oral communication exercise is a ten minute talk which is required of one of the two assistants for each of the first six experiments and of the group leader for the last two. Thus, each student presents at least three and perhaps four talks over the two quarter sequence. Heaviest use of the Communications Project tutors is made in this phase of course activity, e.g. in 1979-80 there were three speaking tutors for a class of 29 students. The student presents his talk first to the speaking tutor individually and then to the entire class during one of the two weekly lecture periods. Immediately after the presentation, questions of a technical nature are posed by the general audience. Then two previously selected class members give oral critiques of the communications aspects of the talk. Finally, each faculty member, teaching assistant, speaking tutor and student evaluator fill out grading forms on the structure of the talk, use of visual aids, delivery and technical content. A summary of these written evaluations is given to each student.

Although the course is only two years old, it has become a focal point for the synthesis of other elements of the undergraduate program. It differs appreciably, however, from the orientation of the traditional engineering courses, which typically emphasizes mastery of the technical aspects of a subject. Although development of sound experimental technique is certainly one of the course objectives, the final course grade depends to a substantial degree on the ability of the student to communicate the results of his laboratory efforts. The selection of a laboratory course as the vehicle to teach communication skills is particularly appropriate for engineers. The class format is designed to present students with varied requirements which are closely analogous to what they will experience in their professional employment. Perhaps the most important skill learned is the ability to present results and conclusions clearly and concisely in a short written progress report or oral presentation. Rarely will supervisors or, especially, managers have the time for more extensive discussions during the interim status review of individual phases of an overall design project, for example. However, in the final documentation of the design for internal or external distribution, the ability to organize large amounts of data, design calculations and recommendations becomes essential. The major report format is directed toward this objective. Two pedagogical features of this course bear special note. These are the emphasis on rewriting of graded written reports, which is the rule rather than the exception, and the use of tutorial sessions for advance preparation on the oral talks and followup analyses of the written reports. Only through a clear understanding of his deficiencies and extensive practice will the student develop the desired facility in expressing his ideas and describing his achievements. □

REFERENCES

1. Davis, R. M., Engineering Education *68*, 209-11 (1977).
2. For more information contact Ms. Ellen W. Nold, Director, Communications Project, School of Engineering, Stanford University, Stanford, CA 94305.

REVIEW: AMUNDSON

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volume contains many examples of Amundson the artist and Amundson the craftsman.

Although a number of the papers in the collection appear in a condensed form in textbooks, the original papers are a preferable source. Many are important references for graduate-level courses in chemical engineering. The polymerization papers with Liu, Warden, Zeman, and Goldstein are, for example, required reading in a course on polymerization reaction engineering. (During my graduate study in 1965, I spent a summer in industry studying and applying these papers to the modeling of a polymerization reactor.) Material in the papers on the single catalyst particle and on tubular and packed bed reactors has permeated most graduate-level courses in chemical reaction engineering and is ideal supplementary reading for students.

At a price of more than $100, the volume unfortunately lies outside the budget of many who would greatly benefit by its presence in their personal libraries. No academic or industrial chemical engineering department should be without at least one copy of this book. For those engaged in or embarking on a career of research that involves the mathematical modeling of chemical engineering systems, the collected wisdom of much of Neal Amundson's incomparable career is well worth the personal investment. □

In Memoriam

LLOYD A. SPIELMAN

Lloyd A. Spielman, 42, Professor of Civil and Chemical Engineering at the University of Delaware, died on March 26 in Newark, DE.