we purposely submit research proposals in which part of the work is designed for undergraduate research and necessary funds for the undergraduate work are requested as an integral part of the proposal. Space is always a question, but it has always been available.

The tangible results of the work of these 30 students is impressive. In 80% of the cases, the objective was accomplished and the project was thus rated a "success." Approximately 50% of the students involved entered graduate school. Approximately 50% of the research results were publishable as an independent paper or as part of another research paper; 30% led to development of equipment for the department; and about 30% served to improve relations with industry due to the competence of the work. About 15% (4 to 5) led to research proposals that were granted. Finally, these projects led to substantial improvement in student/faculty relations. These results lead us to consider our program of undergraduate research to be a successful and worthwhile part of undergraduate education at the University of Maine.

TABLE 5
Spruce Pulping

4 Students @ 6 cr. hrs. each	=	1240 st. hrs.
Faculty Time	=	90 hrs.
Technician Time	=	185 hrs.

COSTS

Capital	=	$ 600
Materials	=	1,800
Total Cost	=	$2,400

RESULTS:

1. Reviewed Publication
2. Digester Performance Reviewed
3. Industrial Relation Established
4. Research Grant Obtained

TABLE 6
Experience Summary (30 Students)

PROJECT COST AND STAFFING

Students: 1 to 4 = 155 to 1240 hrs.
Faculty: 5 to 100 hrs.
Grad. Student: 0 to 50 hrs.
Technician: 0 to 300 hrs.
Materials: 0 to 7000
Capital: 0 to 27,000
Space: "?"

RESULTS

80% of Projects Successful
50% Students—Grad. School
50% — Publishable Results
30% — Dept. Development
30% — Industrial Relations Improvement
15% — Research Grants

IMPROVED STUDENT/FACULTY RELATIONS

Undergraduate research should be an option available to at least the more gifted students in all chemical engineering programs, but is often not available because of the limited resources available and because of the view of faculty that directing undergraduate research is personally unrewarding. *This need not be.* Resources can be expanded from outside sources by the department administration and the faculty to permit this option to be offered to a significant number of students. By properly managing their time and other supervisory time, faculty can direct undergraduate research so that it results in publications, improved experimental methods, and research proposals, all of which lead to personal rewards to the faculty. What *is* required is a consensus that undergraduate research is a desirable option and the willingness of faculty to participate in designing projects, collecting resources, and providing supervision. □

STATE UNIVERSITY OF NEW YORK AT BUFFALO

ChE UNDERGRADUATE RESEARCH PROJECTS IN BIOMEDICAL ENGINEERING

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THE UNDERGRADUATE PROGRAM IN chemical engineering at the State University of New York at Buffalo is highly structured. At present, the chemical engineering program is organized on the basis of four courses per semester with each course carrying four units of credit. Contact time is at least one hour per week per unit of credit. In the program most of the technical courses are specified through the junior year. Although the program is undergoing changes, technical electives are still chosen by the students in the senior year.

The Department of Chemical Engineering conducts an active undergraduate research pro-

With enrollments in the senior class now at about 120 . . . such an intellectual environment is a "must to humanize chemical engineering education.

gram for the senior student. Research projects are available both in the Fall and Spring semesters and the projects count as a technical elective in chemical engineering. Roughly one half of the seniors participate in the undergraduate research program. With drastically increasing enrollments over the past five years, an undergraduate research project is a desirable option to bring about a good intellectual environment where professors and students can work together in small groups. With enrollments in the senior class now at about 120 (compared to 35 students five years ago) such an intellectual environment is a "must" to humanize chemical engineering education.

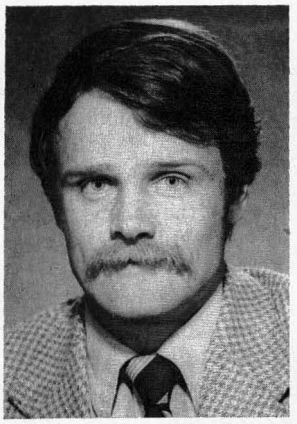
Biomedical engineering is one of the specialized areas of chemical engineering in which seniors can choose a research project. Usually one or two faculty members in the department offer biomedical engineering projects, and four to six undergraduates complete projects each year. Many students have an interest in medicine and the application of chemical engineering principles to biological problems is fascinating to them. For a definition of biomedical engineering, the reader is referred to the recent article by Peppas and Mallinson [1].

A valid question can be raised about the success of an undergraduate research program in biomedical engineering conducted in a chemical engineering department. The seniors participating in the program have practically no background in the biological sciences, and yet they are requested to make a contribution in the field in the time-span of one semester. In order to succeed, the topics are narrowly defined with clearly identifiable objectives. The chemical engineering component of the project is the most important, while the biological component is of secondary importance. Projects can also be conducted in collaboration with a graduate student who is working on his or her thesis. A few projects are conducted in collaboration with a faculty member of the School of Medicine. The consequences of the above are that the projects are closely supervised with realistic objectives that can often be completed in a 16-week period. Individual lectures at the beginning of the semester are useful to orient the student in the proper direction. For experimental projects, the necessary equipment must be available and operational. Training sessions in safety and the operation of the equipment are necessary to familiarize the student with the laboratory. Table 1 shows the mechanics and different facets of research that the student is exposed to as he or she proceeds through the project. A short but succinct written report with a compilation of data and a final oral presentation culminates the research project.

TABLE 1
Aspects of the Undergraduate Research Project

Choosing a Topic
Lectures
Literature Survey
Discussion Sessions
Laboratory Training
Experiments
Computer Programming
Research Seminars
Oral Presentations
Written Report
* * * * *

The goals of an undergraduate research program have to be two-fold; first and foremost is education, and second is the generation of useful data and results. The educational aspect is for the



Photograph by E. L. Nowak

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student to learn how to initiate, perform and complete the necessary tasks. The student learns to conduct a literature survey, to organize his thoughts, to utilize the facilities of the university, to make experimental measurements, to present oral talks, and to write a report. It has been this instructor's experience that the undergraduates are also successful in the second goal, i.e. the majority of projects have yielded useful data and theoretical results. Half of the projects have led to publications.

In order to gauge the experience of other researchers with undergraduates in biomedical engineering projects, a questionnaire was sent to forty chemical engineering professors in this country and in Canada. The responses of twenty-three professors (from twenty-two universities) active in biomedical research were collected. Only three faculty members did not have any undergraduates involved in biomedical projects in the past four years. Table 2 shows the number of undergraduates and the number of projects for the remaining twenty professors. It can be seen that the number of undergraduates conducting research with these faculty members has been reasonably steady over the past three years. The faculty members were enthusiastic about offering biomedical engineering projects to undergraduates. Some of the responses are shown in Table 3.

A surprising result of the survey is that 58% of the projects in Table 2 led to either presentations at national meetings or publications in refereed journals. This is a respectable number and indicates that many undergraduates can perform quality research work. Another interesting result of the survey is that 31 percent of the students went on to chemical engineering graduate school, 22 percent went to medical school and 47 percent went into industry or other careers. These numbers indicate that biomedical engineering projects are chosen, in part, by chemical engineering undergraduates who are interested in going to medical school. This is a fairly new phenomenon and it would be interesting to find out how these students will perform in their medical studies in comparison to those students with a more traditional pre-med background. The percentage of undergraduates who went to chemical

TABLE 2
Number of Undergraduates Working with Twenty Faculty Members in Biomedical Engineering Projects*

	ACADEMIC YEAR			
	1976-77	1977-78	1978-79	1979-80
Number of Chemical Engineering Undergraduates Participating	37	46	50	51
Number of Biomedical Engineering Projects	32	33	38	39

*From the responses of 23 ChE faculty members interested in biomedical engineering.

TABLE 3
Responses from ChE Faculty to the Question:

ARE UNDERGRADUATE RESEARCH TOPICS IN BIOMEDICAL ENGINEERING USEFUL IN A CHEMICAL ENGINEERING DEPARTMENT?

"They provide the student with the same opportunity to apply his engineering skills to topics in other chemical engineering areas. In addition, students can identify more closely with biomedical problems."
Lauri Garred, Lakehead University

"Some students are interested in the biomedical engineering field and this gives them a chance to find out whether or not they want to continue in it."
Herb Weinstein, City University of New York

"It's an exciting and fun way to learn chemical engineering. It is a completely different and challenging area from the conventional applications of chemical engineering that the students are exposed to in other courses. The proviso, of course, is that the students have engineering problems to solve and not problems that would be more relevant in a biomedical faculty."
Mike Sefton, University of Toronto

"They are a logical and interesting medium to apply chemical engineering principles and a good vehicle for learning how to do research."
Richard Seagrave, Iowa State University

"It gives the student another option to examine. Many chemical engineering students are very interested in in chemistry and biology. They find the application of reaction kinetics and transport phenomena to physiological systems fascinating."
Larry McIntire, Rice University

"If ongoing graduate research already exists in the department—yes. Otherwise, I believe that the undergraduate doesn't have access to vital facilities and moral support which are necessary for success in most cases. It wouldn't be desirable to create make-work medical projects in a vacuum, and doing so would also be a waste of the faculty's time."
Mike Williams, University of California, Berkeley

"Yes, if the faculty members involved are willing to work with the students. It gives students a broader background in engineering applications."
Robert Popovich, University of Texas

engineering graduate school is considerably higher than the national average. Surprisingly, only about 25 percent of the students who went to graduate school chose a graduate research topic in biomedical engineering. The results obtained by the survey are very similar to the experiences encountered by this instructor over the past three years [2].

There is general agreement among the professors that the job market for BS chemical engineers in biomedical engineering is non-existent. For the PhD level the opinions are varied, ranging from poor to excellent. There is general agreement that the job market is small. Most professors feel that the demand for PhD chemical engineers in biomedical engineering exceeds the supply. In Canada, however, there is practically no demand at all, although predictions for the future are good.

In summary, it appears that biomedical research projects are useful in a chemical engineering department in order to provide interesting and stimulating research topics to undergraduates. Many of the undergraduates continue their studies at an advanced level, but not necessarily in the area of biomedical engineering. The productivity of the students appears to be excellent as judged from the number of publications. It should be pointed out to those undergraduates with a strong medical interest, that the job market on the BS level is poor. □

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PRINCETON UNIVERSITY

SENIOR THESIS RESEARCH AT PRINCETON

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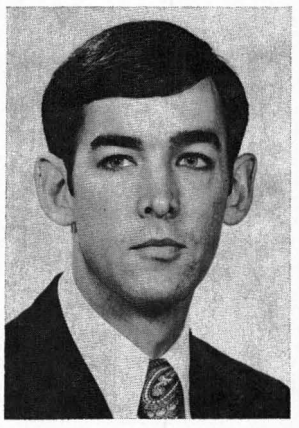
AN ACTIVITY WHICH IS as much a part of spring at Princeton as the blooming of the tulip trees at the Woodrow Wilson School fountain is the scheduling of our forty-to-fifty seniors to present the results of their senior thesis research to their thesis advisor and one other faculty member designated as the second reader. The Herculean task of finding free time slots amidst busy and conflicting schedules falls to Professor Dick Toner, the departmental coordinator for senior thesis work. At about the same time the juniors are making the rounds of the faculty discussing topics for next year. The students select topics after Dick Toner has arbitrated conflicts and sought, to some degree, to equitably match student interest and faculty availability.

The senior thesis at Princeton is not an option for a few good students, but is rather an integral part of the educational process for all our students. Between 1950 and 1956, senior independent research projects were offered as an alternative to a laboratory class associated with the senior-year chemical engineering design course. With class sizes then being in the teens, the senior thesis process was rather informal. In 1957 the senior thesis was made mandatory, and the design laboratory was discontinued. Our present policy requires that all seniors do thesis work; however, each year we grant exemptions to two or three students who plan to attend medical school or business school



Robert K. Prud'homme did his undergraduate work at Stanford University in Chemical Engineering, followed by graduate work at Harvard University in Environmental Engineering before he "saw the light," returned to Chemical Engineering, and obtained a Ph.D. at the University of Wisconsin—Madison. He joined the faculty of the Chemical Engineering Department at Princeton University in 1978. In what little spare time is available he avidly reads the fairy tales of C. S. Lewis, J. R. Tolkein, and George Mac Donald. He plays a passable game of squash, and drives a rather battered 1968 Volvo.