THE RICE UNIVERSITY APPROACH TO GRADUATE STUDY AND RESEARCH IN ENVIRONMENTAL SCIENCE AND ENGINEERING

by A. W. Busch

Perhaps the most invoked, and overworked, word in academic circles today is "interdisciplinary" or its complement "multidisciplinary." A graduate program is simply not in vogue and certainly not erudite unless the work carried on is avowedly interdisciplinary. (I hasten to add that our program at Rice University is *both* inter- and multidisciplinary.) A fringe benefit of the word seems to be a feeling of sublime confidence that an interdisciplinary flavor to a program of graduate study and research automatically assures the development of sound concepts, firm new theories, and impeccable analytical and experimental data.

The nominal existence of interdisciplinary graduate programs, however, is not effective for solving problems in environmental pollution unless the competence to handle broad-based concepts is actually developed. This competence requires more than exposure to knowledge from a variety of disciplines; it requires interpretation and judgment based on fundamental understanding and flexibility of approach. This, then, is the background philosophy of our program at Rice. We try to stress the "why" rather than the "how." A broad and basic "why" competence is important in stimulating the development of new concepts and techniques for knowing "how" to accomplish an engineering objective. The only drawback (if that is the appropriate word) to our program is that our graduates are not suited for routine work in a consulting firm bound by design criteria promulgated by regulatory agencies and based on traditional concepts of limited and often questionable validity. We feel, of course, that this is actually an advantage, for the greatest hindrance to advances in technology is the acceptance, based on purportedly economic and practical expediency, of established "how to" procedures. Clearly, I think, the graduation of nonconformist, hardnosed, inquisitive young men and women is not currently commensurate with the situation in many institutions. However, we feel one of the responsibilities of universities such as Rice is to educate a relatively

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few students for the job of moving technology ahead; to anticipate and plan for problems of the future, before they become national emergencies to be solved on an expensive crash basis.

Even if you were willing to believe that these broad-gauge concepts, on which our program is based, burst full-fledged into existence at the time the activity in Environmental Science and Engineering began twelve years ago, I must in candor admit that this was not the case. The development of the program must be likened to a dynamic Phoenix, rising in a succession of flights from the ashes of a series of "ultimate" plans. Certainly an obvious tribute to the administration at Rice exists in the fact that none of these flights have been "shot down." Such is the atmosphere at Rice that even the most outlandish proposals for changes in approach or procedure receive a full measure of critical evaluation. That is, of course, essential for a university whose technological divisions are concerned largely with the future, a little with the present, and not at all with the past, except as a foundation of experience.

Before moving on to a discussion of some of the technological advances contributed by the Rice students, a brief comparison of traditional programs and the Rice activity may be of interest.

Environmental Engineering had, as did all fields of engineering, its genesis in Civil Engineering. This association has caused a quantity and structural orientation to be maintained overly long. Dams and reservoirs are still being presented as ultimate solutions to water supply problems. Plants, rather than processes, are being designed for pollution control operations. The curricula and faculty are cloistered within the department in the traditional programs; even biologists and chemists are often listed as civil engineering professors. Courses are numerous, often up to twenty-five, and stress "how to" concepts. Because of the large number of courses and the urgency of completing the M.S. degree in twelve months maximum, little "think time" is available to the student. Because the M.S. is considered the first degree offered in the field, a program of accreditation has been initiated. The result of the cloistering and the accrediting program leads one to raise the insidious question, "Does a separate discipline really exist?"

The Rice program was initiated in 1955 on a modest scale (one staff member) and for six years was part of Civil Engineering, offering the traditional course alignment initially but moving toward greater utilization of courses offered in other departments. In 1961 the program moved into the Chemical Engineering Department and abolished all but two courses in Environmental Engineering, one of which is an advanced topics seminar dealing with current literature. The curriculum has been based on the premise that a large fraction of the knowledge and concepts existing in other disciplines, particularly Chemical Engineering and Biology, can be applied directly to problems in environmental science and engineering. The approach to water and water pollution control as problems of a rate process nature has been especially fruitful. The research effort has been aimed at defining mechanisms operative in the biological and chemical processes pertinent to environmental pollution. Students develop the mathematical and scientific competence to enable their theses to be a combination of theoretical hypothesis, mathematical description, and experimental verification.

Until recently the program emphasis was restricted to aqueous system study because of the small staff and because of the belief that rigor in one area is preferable to superficial treatment of several areas. Effective as of July, 1967, the activity will be a separate interdepartmental entity serving the university as a focal point for study and research in the man-environment problem spectrum. This move was made to facilitate an obviously urgent need for a broader base for competence in the field of environmental pollution.

This broader base is typified by the next two speakers on the program. You will note that these professors hold joint appointments in Environmental Science and Engineering and in another academic department. Belief in this approach to bringing knowledge from a variety of disciplines to bear on environmental pollution problems is basic to our program philosophy. Other departments besides Biology and Electrical Engineering with which we plan to formalize faculty associations include Architecture, Chemical Engineering, Chemistry, Economics, Geology, and Psychology.

Without delving into detailed analysis of the concepts involved, I want to list a few of the past and ongoing research accomplishments of our program. As noted earlier, our efforts until quite recently were concerned solely with aqueous systems and more specifically with the problem of organic pollution and the biological processes pertinent to its measurement and alleviation.

As most of you know, the concept of pollution measurement in terms of biochemical oxygen demand is based on a five-day incubation period. This is, of course, not a practical measure for process control. The concept is also not theoretically sound. During the past eight years we have published a series of papers reporting a simple, straightforward procedure for the measurement of biologically degradable organic matter in water. This procedure may be completed in as short a time as four hours if results are desired in terms of oxygen demand. We have also pioneered in the use of carbon balances for pollution measurement. With the Beckman carbon analyzer our procedure can be completed within one hour and furthermore yields valid quantitative results compared to the indefinite five-day B.O.D. value.

In the area of biological process design we have established procedures whereby bench-scale data may be used directly for plant-scale design. Currently, one of our graduate students is working on a definition of mixed culture steady-state requirements, and another on computer-aided prediction of transient effects on process performance. These studies will enable us to complete establishment of biological oxidation process design and control as a science rather than an art.

The time-honored and mystical biological film-flow reactor known as the trickling filter has also been under study for several years. The definition of this system as diffusion limited under laminar flow conditions is complete. Current work is aimed at establishing the kinetic and bio-chemical effects of recirculation. The continued use of this device, which is not subject to process control, stretches our credulity. We hope to contribute to the demise of the trickling filter.

Perhaps the power of interdisciplinary competence in mechanistic analysis is best shown in the work done by two of our students on nitrate metabolism. These studies have disclosed two established theories as myths and provide us yet another handle for grasping the complex biological systems with which we must deal.

Estuary analysis studies are in progress under the direction of Dr. Leeds whom you will hear later.

Dr. Ward is bringing competence in ecology and algal systems to our research activity which he will describe shortly.

A brief comment on our current and future status is that in Drs. Ward and Leeds you see the type of faculty we propose to continue to attract. Our students are selected for their motivation, enthusiasm, and durability. A few are present today and I hope some of you can chat with them. Our research, which includes such concepts as optimum scale in process selection and the filled system of direct water reuse, will continue to be aimed at the future.

In closing I leave you with our slogan: TSOPAYT. These letters emblazoned on our students' pysches stand for "The Steps of Progress are Yesterday's Theories."