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Development of an Ecological Engineering Curriculum at the University of Maryland

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INTRODUCTION

Ecological engineering is a relatively new discipline that utilizes ecosystems and ecological principles to solve problems that traditionally have been addressed with conventional technological options and thinking. The new designs from ecological engineering are generally less expensive or have lower energy intensity than traditional approaches and they often result in more environmentally sound systems or decisions. These qualities of ecological engineering designs (less economic cost and greater environmental value) are bringing more attention to the discipline from decision makers, who seek to implement the designs, and from educators, who must decide how to incorporate the information into university curricula. In this paper the efforts at the University of Maryland towards developing an ecological engineering curriculum are described. There are two purposes of the paper: 1) we hope the experiences derived from our efforts may be useful to others thinking about university programs in ecological engineering and 2) we hope to stimulate discussion and ideas from others that will improve our efforts and help us overcome problems with curricula development.

Formal use of the term "ecological engineering" began in the 1960s with H. T. Odum. He used engineering principles and techniques to build model ecosystems[1,2] and later he combined engineering and ecology to create "interface ecosystems" for treating wastewater in North Carolina[3] and in Florida 4 In addition to these design efforts, Odum's symbolic modeling language, which also was initiated in the 1960s5 , has strong ties to engineering diagraming[6,7] which suggests another possible source for the origin of the term "ecological engineering". More detailed discussions of Odum's development of ecological engineering are given elsewhere[8,9].

Use of the term ecological engineering has expanded from H. T. Odum, first through his students and now through a journal published by Elsevier and an international society of the same name. Furthermore, others outside of H. T. Odum's direct influence are now taking up the term as a formal discipline[10,11] and recommending it as an important research direction[12]. Other allied approaches have grown up that also deal with ecological engineering but under different names. Ecological design[13,14,15] is one important example that has recently resulted in an

international society. This discipline may have less formal emphasis on engineering but it is definitely related. One of the founders of the new society is John Todd whose work on living machines and other contributions qualifies him as an important figure in ecological engineering. Other terms, such as bioengineering [16], soft engineering [17], and appropriate technology [18], also have been applied to various related applications. It remains to be seen whether or not a single term will come to cover all of these activities, but our approach at Maryland is to use ecological engineering as the title for our efforts.

OPPORTUNITIES AT THE UNIVERSITY OF MARYLAND

Efforts at development of an ecological engineering curriculum at the University of Maryland started in the early 1990s (Table 1). A critical step occurred when the Natural Resources Management (NRM) Program was added to the Agricultural Engineering Department. The NRM Program is a set of undergraduate environmental majors in the College of Agriculture while the Agricultural Engineering Department contains both undergraduate and graduate engineering programs which are jointly managed through the College of Agriculture and the College of Engineering . The move of the NRM Program to an engineering department brought ecologists and engineers together which created the opportunity for easier collaboration. Our strategy has been to develop an interdisciplinary curriculum slowly with continual up-dates to the dean's office in the College of Agriculture. The engineers have been cautious but supportive of the efforts and, eventually, we hope to seek formal support from the College of Engineering.

We have experimented with two courses in ecological engineering, both of which were successful in terms of enrollment and course evaluation. One course, ENAG 489C in Spring 1993, was composed of undergraduates from the NRM Program and graduate students from the Agricultural Engineering Department and it was taught by an ecologist. The other course, NRMT 489B in Fall 1995, was composed of NRM undergraduates and students in the university's environmental graduate program (the Marine-Estuarine-and Environmental Sciences Program) and it was taught by an engineer. These successful experiments in interdisciplinary courses have given us confidence to continue development of a full curriculum in ecological engineering.

The opportunity for development of the curriculum at the University of Maryland also is enhanced by access to many nearby state-of-the-art facilities. We have focused on three ecological engineering operations in our existing educational programs (Table 2) and we hope to continue our collaboration with these facilities and others as our new formal curriculum develops. The Everglades mesocosm has been most heavily used in our environmental programs and, because of this heavy use, we have been allocated a graduate teaching assistantship line from the dean's office to help with the activities. The mesocosm is a living model of the Florida Everglades[19] that was built as a prototype for part of Biosphere 2 in Arizona. This facility is an example of Walter Adey's approach to ecological engineering[20] and his contributions to our thinking on curriculum development have been invaluable. The use of algal turf scrubbers for managing water quality in the mesocosm is a special feature highlighted in our field trips to the

facility. The Mayo Water Reclamation facility is a regional treatment plant operated by the county utilities department that treats wastewater from more than 2000 homes. Our work at Mayo has resulted in one masters thesis[21] and another will be completed in 1996. This facility is especially important because it is a commercially viable example of an ecological engineering design. Finally, the living machine in Frederick, Maryland[22] is an example of John Todd's approach to wastewater treatment[23,24]. This is a unique approach that utilizes a high diversity of biological species and technical processes in the treatment design. The educational usage level of each system described above is proportional to the system's distance from the University of Maryland campus but we consider them all of critical importance to our ecological engineering curriculum because of the variety of philosophies they represent.

CURRICULUM IDEAS AND PROBLEMS

Our discussions are leading us to develop an ecological engineering curriculum at the graduate level within the department. This is appropriate because of the large number of courses required to integrate ecology and engineering. Also, a recent increase in undergraduate enrollment has occurred in the department's engineering programs due to the change in name and focus from agricultural engineering to biological resources engineering. We feel some of these undergraduate engineers will elect to enter the graduate ecological engineering program, so that the new program can have some recruitment from within. Of course, we also feel we can attract undergraduates from other universities, especially because of our access to the state-of-the-art ecological engineering facilities mentioned earlier.

The challenge now is to develop some new courses to complete the curriculum. Some of these courses should prepare ecologists to be qualified in engineering and others should prepare engineers in ecology. In terms of ecology the special intellectual challenge is to teach use of the self organization or self design process, which is characteristic of ecosystems[25,26,27]. This may be addressed with new courses in microcosms and ecological modeling. The biggest challenge is to design courses which will prepare ecologists in engineering. The engineers in the department will be most helpful in this regard and our efforts may utilize some of the recent new syntheses in engineering[28,29]. The question of accreditation and relationships with the discipline of environmental engineering are further problems we face, but recent joint editorials in the Journal of Environmental Engineering and in Ecological Engineering[30] on these subjects give us hope that problems can be dealt with.

The ultimate test of our efforts at curriculum development will be if our graduates can find jobs and if they are successful. Indications are that jobs exist for graduates with training in ecology and engineering in new fields of wetland creation, bioremediation, restoration ecology, sustainable development, ecosystem management and many other fields. Our goal is to train people who will work in these fields and who will develop new approaches to environmental problems that were not possible with past disciplinary training that focused on either ecology or engineering separately.

Table 1. Activities in Ecological Engineering at the University of Maryland.

ecological engineering is mentioned as a future direction in the Natural Resources Management Program Review Report submitted to college dean (November 1990)
the Natural Resources Management Program is moved administratively to the Agricultural Engineering Department creating an opportunity for development of a program in ecological engineering (September 1991)
Dr. William Mitsch from Ohio State University is brought in for a seminar and meetings with Agricultural Engineering faculty and the college dean about ecological engineering (February 1992)
ecological engineering is included in discussions of the college's strengthening committee and is mentioned in the final report of the committee to the dean (July 1992)
the college dean, associate dean and Agricultural Engineering Department head visit with Dr. Walter Adey at the Everglades Mesocosm of the Smithsonian Institution to discuss educational plans (November 1992)
ENAG 489C, Introduction to Ecological Engineering, is offered which includes both ecology (NRMT) and engineering (ENAG) students and is taught by an ecologist (Spring Semester 1993)
proposals for an ecological engineering program, including a preliminary undergraduate curriculum, are included in plans submitted to the college reorganization committee (February 1993)
a graduate assistant position is allocated from the dean's office to support educational ties between University of Maryland ecology programs and the Everglades Mesocosm of the Smithsonian Institution (September 1993)
the Agricultural Engineering Department moves into a new building which allows a mixing of ecology and engineering graduate students in the same office (January 1994)
NRMT 489B, Constructed Wetlands, is offered which is composed of ecology (NRMT and MEES) students and is taught by an engineer (Fall Semester 1995)

Table 2. List of state-of-the-art facilities in ecological engineering that are utilized in environmental programs at the University of Maryland.

FACILITY	DESCRIPTION	EDUCATIONAL USE
Everglades mesocosm of the Smithsonian Institution (Washington, D. C.)	Greenhouse scale living model of an Everglades transect with algal turf scrubbers for water quality control	Field trips, graduate student research, undergraduate research and internships
Mayo Peninsula Water Reclamation facility (Annapolis, Maryland)	Two kinds of constructed wetlands for domestic wastewater treatment	Field trips, graduate student research
Living Machine of Ocean Arks, Inc. (Frederick, Maryland)	Greenhouse scale domestic wastewater treatment facility using a sequential system of specialized ecosystems	Field trips

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