An Ecological Engineering Curriculum

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Introduction

This paper further describes efforts to develop an ecological engineering curriculum at the University of Washington. We define ecological engineering as the design of sustainable systems consistent with ecological principles that integrate human society with its natural environment for the benefit of both. In a previous paper we discussed in detail our concept of ecological engineering, its potential scope of application, and a broad outline of an undergraduate curriculum (Bergen et al., 1997a). In this paper we present a specific curriculum designed as a track in a proposed natural resources engineering degree program.

We believe ecological engineering is a distinct discipline with ecology as its fundamental science base. Students will learn to practice design with an appreciation for the relationship of organisms (including humans) with their environment and the constraints on design imposed by the complexity, variability and uncertainty inherent to natural systems. This approach represents a new paradigm for engineering design. In another paper, we identified principles to guide those practicing ecological engineering that reflect our own thinking as well as ideas from others who have written on engineering and ecological design (Bergen et al., 1997b). The five basic design principles we propose are:

1. Design consistent with ecological principles
2. Design for site-specific context
3. Maintain the independence of design functional requirements
4. Design for efficiency in energy and information
5. Acknowledge the values and purposes that motivate design

We define ecological engineering broadly and advocate its application to a number of problem areas. Potential applications include:

1. The design of ecological systems (ecotechnology) as an alternative to man-made/energy intensive systems to meet various human needs (for example, constructed wetlands for wastewater treatment).
2. The restoration of damaged ecosystems and the mitigation of development activities.
3. The management, utilization, and conservation of natural resources.
4. The integration of society and ecosystems in built environments (for example, in landscape architecture, urban planning, and urban horticulture applications).

Disciplines and practices exist that deal with all the applications listed above. We feel, however, that ecological engineering can offer a unique approach to each (see Bergen et al., 1997a for more detail).

Proposed Curriculum

Our vision for an ecological engineering degree program is not to teach engineers a little ecology, nor ecologists some engineering design skills. Rather we believe a curriculum that has strong ecology, engineering fundamentals and design components is required. The objectives of the curriculum are to:

1. Provide a broad education, including a strong liberal arts background emphasizing critical thinking and life-long learning, which will enable students to be informed, responsible, and effective professionals in society.
2. Develop students' written and oral communications skills so that they can organize and express information and ideas logically and convincingly.
3. Develop students' understanding of fundamental scientific principles, with a strong emphasis on ecological science, which serve as a sound basis for the synthesis of knowledge leading to rational solving of problems involving ecological systems.
4. Develop students' knowledge and ability to employ engineering methods including analysis, computation, modeling, experimental techniques, and design to solve engineering problems involving ecological systems.
5. Develop students' understanding of their legal, ethical and professional relationships with society to prepare them for the professional practice of ecological engineering.

Figure 1 illustrates the potential knowledge areas and skills relevant to an ecological engineering curriculum. The figure shows two paths of knowledge feeding into a capstone design experience. On the left side of Fig. 1 are curriculum components associated with ecological science, and on the right are the more traditional components of an engineering program. The right side forms an area of study we call sustainable design. As noted previously, we believe ecological engineering design differs from traditional practices, and must be guided by the five principles stated above.

To move from the general to the specific, we are proposing an ecological engineering curriculum for the University of Washington. The curriculum was designed under a number of important constraints. First, it is to be a track within a proposed natural resources engineering degree program, and parallel to our existing forest engineering curriculum. This is being done, in part, to facilitate and expedite introduction of the curriculum. We intend for students to have this option available as soon as it is approved by the University. Creating a new degree program is a much larger hurdle, raising non-trivial questions regarding core faculty and administration. The close tie to our existing forest engineering curriculum makes these concerns less relevant. It is important to note here that the University or Washington does not currently offer an undergraduate degree in environmental engineering, which would be another potential home for an ecological engineering curriculum. Also, due to its close relationship with forest engineering, the proposed curriculum has a number of core forest engineering courses that would probably not be required in a more general ecological engineering curriculum.

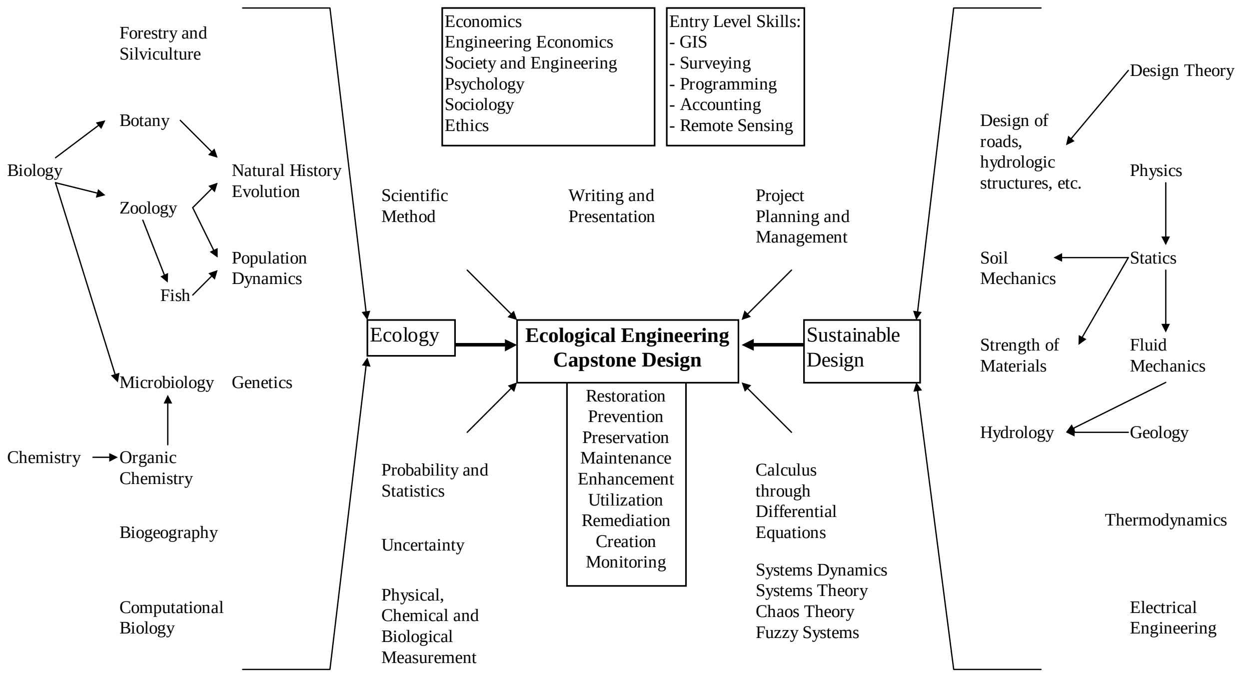

Figure 1. Potential knowledge areas and skills for an ecological engineering curriculum culminating in a capstone design course.

The second major constraint is that we want to design a curriculum that, at least initially, requires little or no new course development. Our proposal uses existing classes, drawing from as many as 10 different departments. We will, however, revise our forest engineering capstone design course (FE 450) to make it appropriate for ecological engineering students.

A third constraint is that we desire to meet the core curriculum requirements of both the College of Engineering and the College of Forest Resources. At the University of Washington there are no biology, organic chemistry, let alone ecology courses in either of these undergraduate core sequences (although they do have considerable math, science and communication requirements). We will describe below how students obtain an appropriate ecological science base. Table 1 lists the course requirements for our 180 quarter-credit ecological engineering curriculum.

Table 1. Courses for a 180 quarter-credit ecological engineering track of a natural resources engineering program.

Ecological Engineering Curriculum Requirements	**Credits (180 total)**
Math, Statistics and Basic Sciences	**49**
Math Courses: MATH 124, 125, 126: Calculus with Analytic Geometry I, II, III MATH 307: Introduction to Differential Equations MATH 308: Linear Algebra with Applications	21
Statistics Course: ENGR 315: Probability and Statistics for Engineers, OR QSCI 381: Introduction to Probability and Statistics (application to biological problems), OR	3

STAT 390: Probability and Statistics in Engineering and Science	
Chemistry Courses: CHEM 142, 152: General Chemistry I, II	10
Physics Courses: PHYS 121/(131): Mechanics (and lab) PHYS 122/(132): Electromagnetism and Oscillatory Motion (and lab)	10
Additional Physics or Biology: PHYS 123/(133): Waves (and lab), OR BIOL 201: Introductory Biology	5

Written and Oral Communication	**12**
English Composition Course	5
Technical Communications: ENGR 231: Introduction to Technical Writing ENGR 333: Advanced Technical Writing and Oral Presentation	7

Visual, Literary, & Performing Arts and Individuals & Societies	**24**
Engineering and Society Course: FE 330: Forest Engineering in Society	4
Applied Microeconomics Course: ENGR 250: Fundamentals of Engineering Economy, OR ECON 200: Introduction to Microeconomics, OR FM 461: Forest Management and Economics II	4
16 additional credits total from approved UW courses	16

Ecological Engineering	**95**
Graphics or GIS Course: ENGR 123: Introduction to Engineering Graphics, OR CFR 250: Introduction to Geographic Information Systems in Forest Resources, OR GEOG 360: Principles of Cartography, OR ESC 442: Geographic Information System Applications to Forest Resources	4
Measurements Thread: Two courses minimum: FE 340: Plane Surveying CIVE 316: Surveying Engineering FE 368: Natural Resource Measurements FE 490: Photogrammetry FISH 210: Fisheries Techniques FE xxx: New course on environmental measurements w/CIVE/FISH/GEOL/FE	8
Mechanics Thread: ENGR 210: Engineering Statics ENGR 220: Introduction to Mechanics of Materials CIVE 342: Fluid Mechanics CIVE 366: Basic Soil Mechanics	16
General Engineering: ENGR 142: Computer Programming for Engineers and Scientists I, AND ENGR 230: Kinematics and Dynamics, OR ENGR 260 Thermodynamics	8
General Forest Engineering: choose at least two courses from: FE 341: Timber Harvesting FE 425: Wildland Hydrology	6

FE 470: Properties of Biological Materials FE 480: Silvicultural Engineering Systems	
Ecological Basis for Engineering Design: FE 332: Ecological Basis of Forest Engineering, and Select courses totaling at least 20 credits for the approved list.	24
Design: FE 444: Introduction to Forest Engineering Design FE 450: Advanced Forest Engineering Design	8
Thematic Electives: Courses totaling at least 16 credits must be identified from a list that is available from the program office. Each individual student must provide a document (approximately 1 page typewritten) that describes how the courses that are selected, in combination with other courses taken by the student, contribute toward specific knowledge, skills and abilities appropriate for future work or study in the area of ecological engineering.	16
Free Elective	5

Our proposed curriculum is not unlike other, existing, engineering curricula at the University of Washington. What makes the curriculum unique, however, is that the scientific basis for design is found in ecological science, through the *ecological basis for engineering design* course sequence. In addition, *thematic electives* allow students to focus their individual programs.

Ecological basis courses are intended to develop students' knowledge of ecology, that will form a foundation for ecological engineering design. They must be chosen from an approved list of courses intended for science and engineering students, that were identified for their ecological science content. Ideally, the courses will be complementary. We selected 34 courses in 10 departments at the University from which students may choose. The list includes courses in terrestrial, aquatic and wetland ecology, botany, fisheries, limnology, restoration ecology, and the effect of pollution on ecosystems.

Thematic electives further define the particular emphasis of a student's program. As noted in Table 1, a student must formally justify how selected courses, in combination with the rest of the courses taken by the student, contribute toward specific knowledge, skills and abilities appropriate for future work or study in the area of ecological engineering. The list of thematic electives is less restrictive than the ecological basis list, and in fact, all ecological basis courses are valid thematic electives. We have so far suggested 27 additional courses in 10 departments, in addition to the 34 ecological basis courses, for a total of 61 acceptable thematic electives. The additional courses include hydrology, geomorphology, resource management, economics, and land-use planning.

Table 2 lists three example combinations of ecological basis courses and thematic electives. It is likely that students will first identify thematic electives that match their career or future study goals, and then pick ecological basis courses that support those goals.

Table 2. Ecological basis courses and thematic electives for three example ecological engineering programs.

Example 1: Aquatic theme	
Ecological Basis courses	**Thematic electives**
FE 332: Ecological Basis of Forest Engineering UHF 201: Ecology for Urban Environments ESC 322: Forest Ecosystems ESC 326: Wildlife Habitat and Silviculture UHF 473: Principles of Restoration ANTH 457: Ecological Anthropology	FISH 311: Biology of Fishes FISH 325: Introduction to Aquaculture BIOL 473: Limnology CIVE 462: Ecological Effects of Wastewater ESC 440: Case studies in Ecosystem Management

Example 2: Physical landscape theme	
Ecological Basis courses	**Thematic electives**
FE 332: Ecological Basis of Forest Engineering ESC 411: Soil Microbiology ESC 322: Forest Ecosystems ESC 440: Case Studies in Ecosystem Management FM 424: Forest Stand Dynamics ENVH 472: Environmental Risk and Society UHF 201: Ecology for Urban Environments	GEOL 411: Introduction to Geomorphology GEOL 412: Fluvial Geomorphology GEOL 413: Hillslope Geomorphology ESC 311: Soils and Land use problems

Example 3: Fish passage and restoration issues	
Ecological Basis courses	**Thematic electives**
FE 332: Ecological Basis of Forest Engineering FISH 311: Biology of Fishes BIOL 473: Limnology FISH 450: Salmonid Behavior CIVE 461: Biological Problems in Water Pollution	CIVE 250: Environmental Pollution CIVE 345: Hydraulic Engineering CIVE 474: Hydraulics of Sediment Transport ESC 311: Soils and Land use problems

Discussion and Conclusions

Our proposed ecological engineering curriculum is driven, in part, by our personal interest in developing a systematic practice of engineering design based on ecology. It is also driven, though, by an increasing frequency of student inquiries and expressed interest in a curriculum that teaches engineering design principles for problems that involve natural systems. We have also observed an increase in the number of engineering projects where either the goals or constraints on projects include the protection, creation or rehabilitation of natural systems.

We have chosen to develop the curriculum "on the coat tails" of the existing forest engineering program. However, once the curriculum is implemented and subscribed to, we believe it will diverge from our existing forest engineering program and any environmental engineering program. It will diverge because the scientific basis does not lie in understanding forests primarily as natural resource or raw material producing systems, nor in the physical/biological processes for treating industrial or municipal wastes. Rather, the basis lies in the interactions among multiples species and their physical environment, and how we may design systems that meet human needs while protecting the environment that provides for those needs.

As ecological engineering evolves, the need for, and ability to create, specific courses will occur, and we intend to respond to that need. At the present time we envision courses in biological systems analysis, environmental measurements and sensors, and ecological engineering design.

Finally, in addition to creating new courses, we must evaluate how physical sciences, especially mechanics and thermodynamics, as well as other undergraduate core courses, relate to ecological engineering. Relevant material should be retained and taught in a manner appropriate for ecological engineering students.

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