A Multi-disciplinary Fifth-Year Certification Program in Water Resources for Biological and Agricultural Engineering Students With a Capstone Interdisciplinary Project Course

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Abstract

The Biological and Agricultural Engineering Department at the University of Georgia is moving toward a fifth-year certification program in water resources designed to broaden engineering students' basic science backgrounds and foster the interdisciplinary perspective necessary to prepare them for a career or graduate studies in water resources. Presently, the environmental and natural resource management areas of emphasis within the Engineering Department offer five courses specifically related to water resources. For students to complete the engineering degree requirements in four years, they have limited latitude to pursue water resource courses outside the department. It is a position held by many natural resource and environmental faculty, whose careers integrate the necessary disciplines needed to identify and evaluate water resource issues and implement solutions, that students, and hence society, would benefit from the offering of a program that provides the education and practical experience necessary to broaden the engineering student's view of how water resource issues should be approached while concurrently rewarding them with certification in their extended endeavor. Courses for this program will be offered through, and in conjunction with, Biological and Agricultural Engineering, Environmental Health Sciences, Forest Resources, Crop and Soil Science, Ecology, Geography and Geology. The focal point of the program is the combination of non-engineering water resource educational exposure with an interdisciplinary capstone project requiring engineering students to team with students from other disciplines to work on a comprehensive water resources project, thus providing them the real opportunity to develop essential interdisciplinary problem-solving skills. Beyond the educational benefits, such certification would also provide tangible credibility for students when applying for jobs.

Introduction

The combination of technical and interpersonal skills required to identify, evaluate and implement appropriate solutions for issues that are inherently multi-disciplinary is rare in a time when specialization is often emphasized. Often, this even more prevalent in academia where a microbiologist might make a career of studying a particular bacteria or a chemist the uptake

kinetics of a certain pesticide. While the significance of such research into the nature of things cannot be overemphasized, it is in the application of basic research that scientists and engineers can come to an impasse. If this scenario is then clouded with a political extension, we have the proverbial sticky wicket to say the least. The question remains, "Who is best suited to oil the wicket for it to operate smoothly and with the least amount of wear and tear"? One solution lies with the individual who is not only technically competent in the various aspects of the issue, but who also possesses the interpersonal skills to mesh the necessary facets into a workable solution. Nowhere is the need for such an individual more critical than in issues concerning water resources. The quantity and quality of water has emerged as one of the most critical and sensitive issues in the engineering, scientific and political arenas, an oftentimes tenuous association in and of itself. This fact alone dictates that the approach taken with identification, evaluation and implementation of water resource issues be not only multi-disciplinary in concept but also interdisciplinary in practice. It has been proposed that there remains a need for a water resources professional who is not only well-trained in a particular specialty but also has a working knowledge of how and where other critical aspects of water resources fit in the overall picture[1]. Moreover, aside from technical competence, such an individual must possess skills at forging from a consortia of ideas and information a solution that is mutually acceptable, both scientifically and politically, to those representing diverse but integral specialties within water resources.

As the core of engineering is the application of mathematics and the basic sciences to benefit society, we see the engineering student as a prime candidate to fill the societal need for the versatile water resources professional, a need that will magnify with time. In this paper we describe a fifth-year water resources certification program through the Biological and Agricultural Engineering Department at the University of Georgia that will take great strides down a non-traditional path to prepare its students to meet this need by providing them with an interdisciplinary educational perspective as well as practical experience in how engineers must function as a member of a diverse group.

Objectives of the Program

From the understanding of the basic scientific principles to the application of these principles for better management practices or compliance with government regulations, the spanning of this gamut has no doubt spawned the need for a well-cultivated engineer. The objective of this paper is to discuss an interdisciplinary water resource certification program under consideration by the Biological and Agricultural Engineering (BAE) Department at the University of Georgia, in conjunction with other University departments offering water resource courses, and how the program will prepare the engineering student to take on the additional responsibilities forthcoming in the water resources area. The program will offer students a fifth-year certificate upon completion of 30 semester hours in core water resource courses, culminating with a capstone group project comprised of students from different disciplines. For engineering students, the objectives of the program are:

1) to convey to the engineering student the biological, physical, chemical and political interfaces that comprise water resource issues and emphasize the necessity of integrating

the expertise of these disciplines into successful avenues for the identification and evaluation of problems and implementation of solutions

2) to develop, through an interdisciplinary capstone project, rudimentary interpersonal skills necessary for the identification and evaluation of problems and implementation of solutions

Meeting these two objectives will serve to prepare engineering students for a career in water resources

An Academic and Practical Approach to Multidisciplinary Education

Previous advances in multidisciplinary approaches to engineering education have focused on capstone design courses. Engineering faculty at Brigham Young University have developed a two-semester multidisciplinary senior design course for mechanical and manufacturing engineers to team together on industrial projects[2]. Both Auburn University and the University of Wyoming have developed courses for engineering students to team with business students on design projects[3,4]. The Colorado School of Mines has begun moving away from narrow training of engineering students through the development of a capstone course in multidisciplinary engineering design that will provide engineering students the opportunity to solve the type of problems faced by practicing engineers[5].

The Biological and Agricultural Engineering Department at the University of Georgia is developing an approach that incorporates the multidisciplinary concept prior to a multidisciplinary capstone course. While it is essential to educate engineers in how to work effectively as a member of a team, the focus of this program is to underpin that education with foundational water resource courses taught by faculty in disciplines outside engineering, followed by a capstone interdisciplinary project. This will not only provide the engineering student with practical experience working with a multidisciplinary team, but it will be prefaced with educational exposure that will enable engineers to understand the way scientists and policy-makers perceive water resource issues, the way they think and their rationale behind their positions.

The Role of Colleges and Universities

Traditional water resource education has for the most part followed a compartmentalized approach where individual disciplines emphasize their particular expertise in the subject. While well-intentioned efforts are oftentimes made to include other aspects under the instruction of the same faculty, this should not be misconstrued as a multi-disciplinary perspective. Engineering programs in particular might be strapped for excess hours to allocate towards achieving anything comparable to what is needed to provide even a faint attempt at such an endeavor. Nonetheless, with its far-reaching implications into the environmental and socioeconomic arenas, an inter-disciplinary approach to water resources education is vital. Several engineering programs such as Agricultural, Biological, Civil, Sanitary and Environmental, have evolved over the years to incorporate water resource education into their curricula. However, offering only an engineer's view might fail to provide the biological, chemical and political views essential for addressing

the myriad interactions inherent in water resource issues. The quantity and quality of water resources are the issues of concern while the physical, biological and chemical sciences might define the areas in which these issues are examined (FIG 1). From usage to impacts to implementation of solutions, it will require an engineer educated and seasoned in an array of basic science disciplines to manage and guide a water resource issue from beginning to end and to develop an interfacing mechanism to address water resource issues for the good of society. Within these disciplines is expertise in oftentimes highly specialized aspects of water resources. The interface between these areas is what trumpets the call for a multi-disciplinary view and an inter-disciplinary approach to the identification and evaluation of water resource issues followed by the implementation of solutions.

A challenging variable in the water resources equation is the political. Much of what engineering produces from its application of the basic sciences results in an increase in creature comforts for society and improves quality of life. Engineering accomplishments are sold based on their merits and appeal, and society is engaged through marketing. With regard to water resources, the impact of engineering accomplishments is often channeled through a political outreach. Local, state and federal agencies institute laws and regulations based on sound scientific principles to assure clean andsafe water resources for society. Engineers are often the individuals addressing these local, state and federal officials on how to best implement technology to accomplish this. The engineering student must then be prepared to handle the technical aspects of the basic science and engineering principles and convey them to a non-technical audience[6]. This will require a practical understanding of environmental policy at various levels. While teaching water resources policy to science and engineering students is necessary, it also presents special challenges which would be best handled through a department particularly keen on the subject[7].

Impetus for the Program

In his plenary address to the 1993 ASEE Centennial Conference, Chancellor L.K. Monteith of North Carolina State University said,

During my twenty-five years in engineering education there has been a continuing trend to increase specialization in the undergraduate curricula. In part, this is driven by faculty interests to attract students for graduate study. The net result is a loss of perspective and a loss of focus for undergraduate programs[8].

We could not be more agreeable with Dr. Monteith's assessment and can only add that, with water resource issues, the loss of an interdisciplinary perspective due to increased specialization can be crippling.

Interdisciplinary centers fostering creativity and change in engineering research and education have been proposed as a necessity for engineering education to meet society's emerging needs[9]. This certification program, we hope, will be the first steps along a path that ultimately merges into such an effort.

Over the past years the BAE Department at the University of Georgia has maintained a working

relationship with several departments on campus through the offering of engineering technology courses in water resources. These courses are offered for non-engineering students only and serve to provide an engineer's perspective on water management and water quality minus some of the mathematical rigor normally associated with these subjects in an engineering curriculum. The feedback from other departments regarding these courses has been very favorable, recognizing the need to educate their own students in the engineering principles of water resources. Through this instructional outreach to other departments, an informal water resources faculty has been formed with members from several departments. From this interdisciplinary effort the need for such a program became even more evident.

At the University of Georgia, water resource courses are taught in at least eight departments, with each course designed to emphasize a particular physical, biological or chemical aspect of water resources. In practice, these basic sciences are interrelated and serve as the basis for identifying issues and evaluating impacts and effects on water resources. Through interdisciplinary efforts with experts in these areas, the research, extension and outreach programs of the University's Biological and Agricultural Engineering Department use engineering principles to apply these basic sciences and implement better management practices within domestic, commercial, industrial and agricultural water use that bring surface and groundwater into compliance with state and federal regulations. Such is the approach to practical water resource issues. However, educational efforts emphasizing this interface of the physical, biological, chemical and political are lacking at the undergraduate engineering program level. As for future needs for educating individuals to be adept in handling water resource issues, this can be best measured by the increasing domestic, commercial, industrial and agricultural water use and the regulatory demands on this use. As long as there is water use there will be regulations, and as long as there are regulations there will be the need for individuals to identify and evaluate the issues and implement solutions while also communicating to the general public the basis and benefits for these practices.

There are two areas of emphasis within the Biological and Agricultural Engineering programs that require water resources course work: the Natural Resource Management emphasis within Agricultural Engineering and the Environmental emphasis within Biological Engineering. The Natural Resource Management emphasis allows 6 semester hours of elective course work outside the engineering department while the Environmental emphasis allows 3 semester hours at most. If a student desires a working knowledge of water resources, he/she is allowed only 1-2 courses with which to diversify their understanding and perspective. This is insufficient. At this point it might be said that such students could pick up the necessary courses after graduation. This would not however give the recognition that is necessary for highlighting their accomplishments. Validation of these efforts through University certification gives credibility to the student and the University in the eyes of potential employers as well as the general public.

Meeting Objectives of the Program

The water resources faculty will guide the certification program, and while the certification will itself be formalized, there will be no formal water resources department. The program will be open to any student who can meet the prerequisites for the core subjects (Table 1). It will consist

of 30 semester hours, approximately one year, and will require students to take a minimum of 21 hours outside their undergraduate discipline. Core subjects may be taken consequent with or subsequent to undergraduate course work. Students will work through their own departments and water resource faculty members within that department will act as their advisor/mentor.

Objective 1,

> "to convey to the engineering student the biological, physical, chemical and political interfaces that comprise water resource issues and emphasize the necessity of integrating the expertise of these disciplines into successful avenues for the identification and evaluation of problems and implementation of solutions",

will be met through the exposure to outside teaching of various physical, chemical and biological perspectives. As the engineering student is taughted to "think like an engineer" during his/her undergraduate course work, there can be no better means for obtaining a multi-disciplinary perspective of water resources than by going outside the box of engineering and learning from the experts themselves in those disciplines.

Objective 2,

> "to develop, through an interdisciplinary capstone project, rudimentary interpersonal skills necessary for the identification and evaluation of problems and implementation of solutions",

will be met through a group capstone project that will require group members of different disciplinary backgrounds to solve a water resource problem. It is often included in engineering education research papers that one goal in an undergraduate engineer's education should be to "learn to work effectively as a member of an engineering team"[10]. While this is true in certain cases, the water resources engineering student must also "learn to work effectively as a member of an interdisciplinary team of engineers, scientists, and politicians". Such interdisciplinary problem-solving experience is best obtained by working firsthand with people of various scientific stripes under the guidance of mentors who themselves have such skills. Such is the purpose of the capstone project. Projects that have already been proposed are given in Table 2 and reflect real needs for real customers. Complete solutions for these projects will require an interdisciplinary approach.

Benefits of the Program

The benefits of this interdisciplinary certification program will be institutional as well as educational. At the institutional level, the University of Georgia will benefit from the establishment of a conduit between engineering and basic sciences, not only of technical information but of philosophical thinking, reasoning, approaches, etc. The University is in a strong position with its excellent engineering, basic sciences and ecology base to harness their scholarship into a combined effort in water resources. Improved or created faculty interaction within these departments and schools will cultivate the environment for more efficient and productive research, outreach and extension, thus bolstering the University's ability to fulfill its

mission as a land grant college. Educationally, engineering students will be better prepared to handle water resource issues in the real world as they will have gained exposure to and experience with critical non-engineering components of water resources. Moreover, non-engineering students will learn engineering skills and develop problem-solving abilities not addressed in a non-engineering curricula. Such a two-way avenue of teaching and experience will be the solid foundation necessary in the highly interdisciplinary field of water resources.

Conclusions

Engineering as a profession and, for the purposes of this paper, water resource engineering education, cannot function independent of the basic sciences. While engineering may be the intersection where the basic sciences and mathematics converge to form applicable solutions for society, we should never fall victim to viewing it as an island. Rather, we as engineers must bridge out to other disciplines and draw upon their expertise, not only for the sake of society, but for the sake of preparing our students to practice engineering as is required today. The very essence of engineering is embodied in it being the interface between the basic sciences and society where the engineer takes the principles of basic science and puts them in the hands of mankind for practical use. As for water resource issues, the basic physical, chemical and biological sciences merge quickly and the engineering student must be educated in the issues with which he/she must deal.

We believe the need for the individual to oil the sticky wicket within water resources can be met in the engineering student, but it is not going to be accomplished through the inclusion of additional material in existing engineering curricula. We as instructors must utilize the resources and expertise of other departments and let the experts in those fields help educate our engineering students. The result will be a better educated, more experienced and better equipped engineer for addressing and solving water resource issues and problems.

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Figure 1

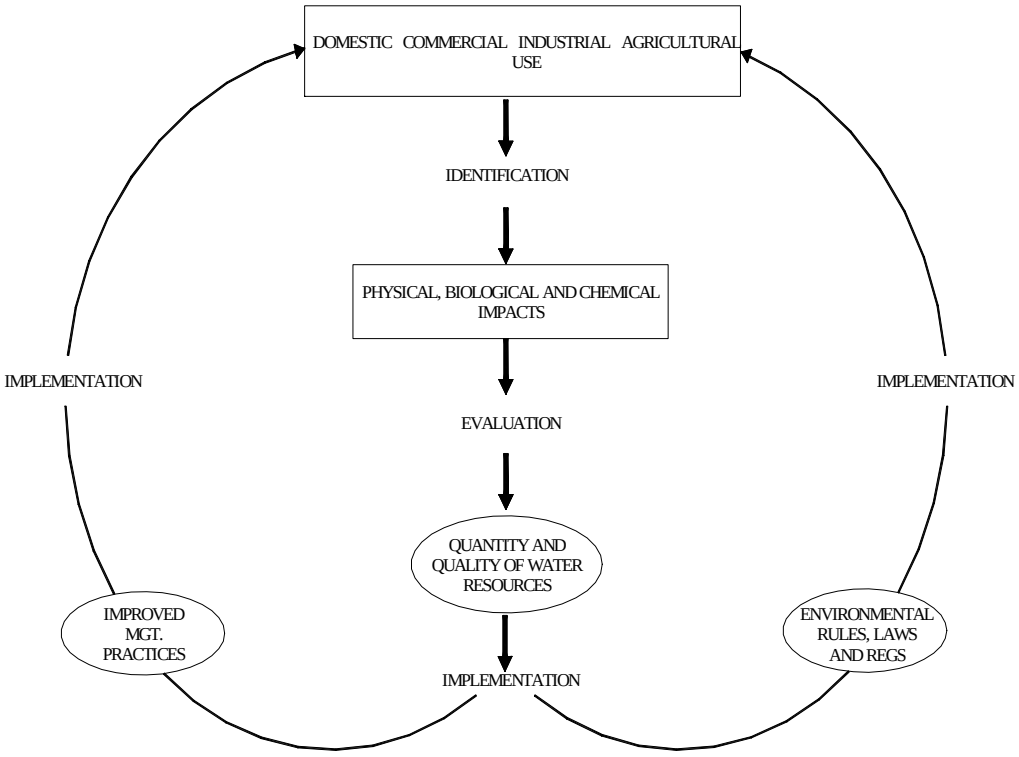
DOMESTIC COMMERCIAL INDUSTRIAL AGRICULTURAL USE
IDENTIFICATION
PHYSICAL, BIOLOGICAL AND CHEMICAL IMPACTS
EVALUATION
QUANTITY AND QUALITY OF WATER RESOURCES
IMPLEMENTATION
IMPROVED MGT. PRACTICES
IMPLEMENTATION
ENVIRONMENTAL RULES, LAWS AND REGS
IMPLEMENTATION

TABLE 1

CORE SUBJECTS

Fluid Mechanics Water Quality
Surface Hydrology Subsurface Hydrology
Aquatic Biology/Limnology Ecological Toxicology
Fluvial Geomorphology Policy/Economics
Capstone Project

LIST OF CORE CLASSES

LISTING	HRS	CLASS
ENGR 2150	3	Fluid Mechanics
ENGR 3050	3	Soil and Water Resource Conservation
ENGR 3070	2	Turf and Landscape Irrigation Systems
ENGR 3410	3	Introduction to Natural Resource Engineering
ENGR 3440	3	Water Management
ENGR 4120	3	Quantitative Methods in Hydrology
ENGR 4440	3	Environmental Engineering I
ENGR 4450	3	Environmental Engineering II
ENGR 4470	3	Unsaturated Zone Hydrology
ENGR 4460	3	Natural Wastewater Treatment Systems
CRSS/FORS 3060	4	Soils and Hydrology
FORS 4110	3	Forest Hydrology
FORS 4120	3	Quantitative Methods in Hydrology
FORS 4130	2	Field Methods in Hydrology
ECOL 3500	4	Ecology
ECOL 3520	3	Ecological Applications
ECOL/FORS	4	Limnology
EHSC 4490	3	Environmental Toxicology
EHSC 4610	3	Water Pollution and Human Health
EHSC 4350	3	Environmental Chemistry
GEOL 4220	3	Hydrogeology
GEOL 4110	3	Principles of Geochemistry
GEOL 4420	1-3	Introduction to Research in Geochemistry
GEOG 4020	3	Fluvial Geomorphology
CRSS 4600	4	Soil Physics
CRSS 4670	3	Environmental Soil Chemistry
EHSC 4250	3	Environmental and Public Health Law

FORS - Forest Resources CRSS - Crop and Soil Sciences
EHSC - Environmental Health Science ECOL - Ecology
GEOG - Geography GEOL - Geology

Table 2

- Aerobic Bioremediation of the Colombia County Municipal Solid Waste Landfill
- Management of Storm Water for a Residential Area of Metro-Atlanta
- Wastewater Treatment System for Egg Processing Industry
- Design of a Recreation Facility in Whitehall Forest
- Separating Feathers from Wastewater
- Controlling Storm Water Discharge Associated with Industrial Activity
- Total Water and Waste Management System for a Dairy Operation
- Design of a Filtration System for Hazlewood Bakeries
- An Irrigation System for Gugino's Greenhouses
- An Irrigation Water Storage Facility