Integrating Environmental Engineering and Sustainability into Engineering Science and General Engineering Programs

Dr. Brenda Read-Daily, Elizabethtown College

Brenda Read-Daily received a B.S. in Civil Engineering at Bradley University, a M.S. in Environmental Engineering at the University of Notre Dame, and a Ph.D. in Environmental Engineering also at the University of Notre Dame. During her graduate studies, she conducted multidisciplinary research combining microbiology with engineering design. Her research interests include optimizing biological nutrient removal processes in agricultural drainage and wastewater treatment processes in order to mitigate pollution. She is currently developing undergraduate research opportunities examining nitrogen removal in tile drainage systems.

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Introduction

Environmental engineering has undergone major changes in the past two decades. Of the fourteen grand challenges listed by the National Academy of Engineers, three are related to environmental engineering and sustainability: providing clean water, managing the nitrogen cycle, and improving urban infrastructure. However, despite the obvious importance and recent growth of environmental engineering, it has had a bit of an identity crises over the years ^{1,2}. Environmental engineering started out as an offshoot of civil engineering with the label of sanitary engineering but overtime evolved to be its own distinct field¹. It has also become a highly multidisciplinary field where many different areas of engineering and science combine^{3,4}. Interestingly, environmental engineering is increasingly being integrated into other engineering disciplines such as mechanical and chemical where there is a heavier emphasis on pollution prevention and resource reduction¹. Given the current trends, environmental engineering is an integral part of sustainability education. At its core environmental engineering is an important part of sustainability. Within the field itself, environmental engineering has further embraced the sustainability by incorporating the triple bottom line (environment, society, and economics)³.

A search of ABET-accredited programs reveals that there are currently sixty-four environmental engineering programs. In addition to these programs, there are many additional civil engineering curriculums where environmental engineering is offered as a concentration. Despite these numbers, environmental and civil engineering programs offering environmental engineering concentrations pale in comparison to those for other engineering disciplines such a civil (no environmental concentration), chemical, electrical, or mechanical. While these distinctions separate one discipline from another, there is a growing trend for more broad-based and multidisciplinary engineering.

In particular, general engineering and engineering science programs offer broad-based engineering programs. These programs are largely found at small private liberal arts institutions that do not have the numbers to support the numerous engineering disciplines⁵. They provide students with an ABET-accredited engineering degree rooted in fundamental engineering courses, but also allow students immerse themselves in the humanities. The graduates from these types of programs are a small, but growing portion of the overall pool of matriculating engineering students⁵. However, the number of engineering science programs has increased by 68% over the past thirteen years. Despite the general nature of engineering science, many of these programs offer concentrations in specific disciplines so students receive sufficient specialization to find jobs in the desired field⁵.

This research focuses on the growing number of general engineering and engineering science programs offering environmental engineering concentrations with some integrating sustainability into their curriculums. This paper provides an overview of what classes existing general engineering programs offer within their environmental engineering concentrations. As the field of engineering shift towards placing a heavier emphasis on sustainability, it is important to start a broader conversation about how general engineering and engineering science programs can integrate environmental engineering to equip future engineers.

Methodology

Using the Accredited Program Search tool at ABET's website, a search was conducted for all the programs offering engineering science or general engineering programs with Bachelor's degrees in the United States. Sixty-four schools had engineering science degrees and two had engineering degrees. Of the schools offering engineering science degrees, any schools with separate departments dedicated to different branches of engineering were eliminated. For instance the University of Illinois at Urbana Champaign has an engineering science degree option, but it also has separate departments for Civil and Environmental Engineering, Mechanical Engineering, Electrical Engineering etc. The schools that were selected for this paper were ones that housed their engineering science or general engineering degrees within one engineering department. While Taylor University and Tarleton State University offer a separate bachelor of science in environmental engineering, they were included in the analysis because the remainder of the program is a general engineering program where students receive a Bachelor of Science or Bachelor of Engineering, and environmental engineering is the only separate bachelor's degree.

After determining the relevant general or engineering science programs, department websites and college course catalogs were checked to determine which concentrations were offered within each program. These results were compiled in a spreadsheet, and the programs offering environmental, civil, or other related type of engineering were further evaluated by examining course plans. The course plans were checked for what specific environmental engineering and sustainability-related curriculum was being offered as a part of the engineering curriculum. Specifically, course titles and course descriptions were searched for the key word "sustainability" or sustainability themes.

Results and Discussion

In the United States there are sixty-four institutions offering ABET-accredited engineering or engineering science degrees with forty-two housing engineering science programs within a single engineering department (Tables 1-3). Engineering science or general engineering programs tend to be found at smaller institutions. Privately funded institutions made up a majority (69%) of these schools (Tables 1 and 2). Of the engineering departments offering engineering science degrees, only four (9.5%) offer environmental engineering concentrations: Dartmouth College, Geneva College, Mercer University, and Messiah College (Tables 1 and 2). Notably, all of these schools are private institutions. In addition to these, Calvin College and Swarthmore College provide civil/environmental engineering concentrations. Another ten (23.8%) schools offer concentrations in civil engineering. These findings are contrasted to the number of schools offering computer, electrical, or mechanical engineering concentrations: sixteen (38.1%), twenty-eight (66.7%), thirty (71.4%), respectively (Tables 1-3). This result is not surprising given that environmental engineering programs are outnumbered by mechanical, electrical, and computer engineering programs nationally.

Looking more specifically at curriculums offered at these schools, they all shared common engineering cores of courses in physics, calculus, chemistry, and mechanics. Of the sixteen schools offering civil, civil/environmental, or environmental engineering concentrations, thirteen

offered an environmental engineering course that provided either an introduction or a survey of the field (Table 4).

Table 1. Concentrations offered at Privately Funded Universities with ABET-Accredited Engineering Science Programs

	Andrews University	George Fox University	Harvard University	John Brown University	Letourneau University	Loyola University Maryland	Mercer University	Muskingum University	Olivet Nazarene University	Oral Roberts University	Robert Morris University	Roger Williams University	Texas Christian University	Trinity University	Union University	Walla Walla University
Biochemical																
Bioengineering																
Biomedical			X		X		X			X	X					
Bioprocess																
Biotechnology																
Chemical														X		
Civil		X			X											X
Computer	*	X				X	X		X	X						X
Electrical	*	X	X			X	X		X	X			X	X	X	X
Engineering Management																
Environmental			X				X									
Geological									X							
Industrial							X				X					
Manufacturing																
Materials						X										
Mechanical	X	X	X			X	X		X	X	X		X	X	X	X
Renewable Energy				X												
Robotics																
Software								X			X					
Sustainable Design																
None												X				

*Concentration offered in conjunction with another discipline for example, civil and environmental engineering concentration.

Table 2. Concentrations offered at Privately Funded Colleges with ABET-Accredited Engineering Science Programs

	Calvin College	Dartmouth College	Dordt College	Elizabethtown College	Fort Lewis College	Geneva College	Harvey Mudd College	Hope College	Messiah College	Smith College	Swarthmore College	Sweet Briar College	Trinity College
Biochemical								X					
Bioengineering													
Biomedical		X	X						X				X
Bioprocess		X											
Biotechnology		X											
Chemical	X	X	X			X		X					
Civil	*		X			X			X		*		
Computer	X	X						X	X				X
Electrical	X	X	X	X		X		X	X		X		X
Engineering Management		X											
Environmental	*	X				X			X		*		
Geological													
Industrial													
Manufacturing													
Materials		X											
Mechanical	X	X	X	X		X		X	X		X		X
Renewable Energy													
Robotics													
Software												X	
Sustainable Design				X									
None			X		X		X			X			

*Concentration offered in conjunction with another discipline for example, civil and environmental engineering concentration.

Table 3. Concentrations offered at Publically Funded Universities with ABET-Accredited Engineering Science Programs

	Arizona State University Poly	CUNY, Staten Island	East Carolina University	James Madison University	Marshall University	McNeese Sate University	Murray State University	Southeast Missouri State University	Southern Utah University	University of Texas Brownsville	University of Southern Indiana	University of Tennessee Martin	Western Illinois University
Biochemical													
Bioengineering										X			
Biomedical			X				X						
Bioprocess													
Biotechnology													
Chemical						X							
Civil	X				X	X						X	X
Computer		X						X		X			*
Electrical	X	X	X				X	X		X		X	*
Engineering Management													
Environmental													
Geological													
Industrial			X									X	X
Manufacturing													
Materials													
Mechanical	X	X	X			X	X	X		X		X	X
Renewable Energy													
Robotics	X												
Software													
Sustainable Design													
None				X					X		X		X

*Concentration offered in conjunction with another discipline for example, civil and environmental engineering concentration.

Table 4. Environmental Engineering Concentration Electives Offered at ABET-accredited Engineering Science and General Engineering Programs

Institution	Concentration Offered (CE, ENV, or CE/ENV)	Environmental Engineering	Hydraulics	Hydrology or Hydrogeology	Water/Water Resources	Wastewater	Other Offered within the Engineering Department	Offered Outside the Engineering Department
Arizona State University Polytechnic	CE				X	X	Solid Waste, Environmental Systems Project	
Calvin College	CE/ENV	X	X				Environmental Engineering Design	
Dartmouth College	ENV	X					Sustainable Design, Sustainable Resource Engineering	
Dordt College	CE	X						
Geneva College	ENV	X	X	X	*	*	Environmental Monitoring, Transport Processes, Air Pollution Control, Solid and Hazardous Waste	X
George Fox University	CE	X			X			
LeTourneau University	CE	X	X	X	*	*		
McNeese State University	CE		X	X		X	Pollution Control	
Mercer University	CE	X	X	X		X	Public Health	
Messiah College	ENV	X		X				X
Harvey Mudd College	None	X					Mass Transfer and Separation Processes, Transport Phenomena	
Harvard University	ENV	X		X	X			
Marshall University	CE				X	X		
Swarthmore College	CE/ENV	X			X			
Tarleton State University*	ENV	X		X	X	X	Environmental Systems Modeling, Texas Water Management	
Taylor University*	ENV							X
University of Tennessee at Martin	CE		*	*				
Walla Walla University	CE	X		X		X		
Western IL University	CE							

*Topics in both subjects were covered in one course.

Courses in hydrology, hydraulics, water resources management, or wastewater were also common to the civil or environmental engineering concentrations as is the case in traditional environmental engineering programs. Interestingly, several of the schools with civil engineering concentrations offered more environmental engineering courses than schools with environmental engineering concentrations. LeTourneau University, for example, offers a concentration in civil engineering, but within that concentration, students can further specialize in water resources. This is evidenced by its selection of courses including an introductory environmental engineering course, hydraulics, hydrology, and water resources, and wastewater. Other schools rely more heavily upon curriculum offered outside of their engineering department as environmental engineering electives such as: organic chemistry, biochemistry, environmental science, geology, and ecology. Taylor University and Messiah College, for example, were schools that satisfied most of their requirements for the environmental engineering concentration or major outside of their departments. Harvey Mudd College does not specifically offer an environmental engineering concentration, but students are able to take environmental engineering courses as electives.

While it is apparent that a variety of environmental engineering courses are offered within environmental engineering concentrations, few schools had classes that had the word “sustainability” in the course title. Dartmouth College offers courses in Sustainable Design and Sustainable Resource Management (Table 1). Even upon closer examination at course descriptions, few provided specific topics of sustainability or mentioned typical sustainability themes going beyond environmental protection. This result is similar to what Wooschlager (2013) found when he examined sixty ABET-accredited environmental engineering programs on their level of sustainability integration based on metrics of mentions of sustainability or sustainability concepts in program education objectives, student outcomes, courses, and department websites. Only 7% had a strong integration of sustainability. Upon looking closer, at all programs some merely paid lip service to sustainability while others such as Columbia University, Cornell University, Northwestern University, and South Dakota School of Mines made transformational changes to curriculum in order emphasize sustainability⁶.

For those programs that are already offering environmental engineering as a concentration, further work can be done to enhance the connections to other disciplines using sustainability. Modification or adaptation of traditional courses in environmental engineering may be an easy way to bridge these gaps. Most programs offer some type of introduction or survey of environmental engineering, and such a course may provide an ideal spot to include the themes of social and economic impacts of engineering solutions. Additionally, more specialized courses in topics such as water and wastewater treatment can emphasize resource choices and designs in light of societal and economic impact. Increased focus on the triple bottom line as opposed to the environmental outcomes only is necessary in the rapidly changing field. In particular, general engineering and engineering science programs can capitalize on this growing trend by carefully weaving environmental engineering coursework with a particular emphasis on sustainability into their curriculums.

Conclusions

Environmental engineering has undergone major changes in the past few decades, arguably with the most important being the integration sustainability and heavier emphasis on multidisciplinary solutions. Given these trends, general engineering and engineering science programs have a unique opportunity to capitalize on this trend, particularly those schools offering environmental engineering concentrations. Based on this study, there is room for more general engineering and engineering science programs to provide environmental engineering concentrations as only 9.5% currently do so. This 9.5% comes exclusively from privately-funded colleges and universities. A closer look at the programs offering environmental engineering curriculums showed that few specifically focus on sustainability in their courses based on course descriptions and titles. Like those programs with majors in environmental engineering, general or engineering science programs can improve their current curriculums by incorporating themes of sustainability within traditional courses and thus establish more links to other disciplines. Given the strong interest in the environment and sustainability by many students, engineering science and general engineering programs may find adding an environmental engineering concentration an attractive option. Current programs offering environmental engineering concentrations should consider ways to increase the coverage of sustainability themes and topics within their traditional courses.

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