Location, Location, Location: The Value of Disciplinary Adjacency in Enhancing Environmental Engineering Programs

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Abstract

Since the field was largely born out of civil engineering, most of the initial environmental engineering degree-granting programs began in civil engineering departments. Many have stayed there. However, 10 of the last 25 environmental engineering programs accredited by ABET have emerged in departments that do not include civil engineering. The rationale for aligning environmental engineering programs with other disciplines can be based on numerous factors including diversity of perspectives within the department, collaboration opportunities, facilities requirements, and efficiency. This study examines the distribution of ABET-accredited environmental engineering programs across departments, to include specific program adjacencies and trends over time. In addition, the study examines faculty perspectives on the departmental alignment of environmental engineering programs, to include the faculty's overall satisfaction with their program's adjacencies, and the advantages and disadvantages of its particular alignment. Furthermore, it examines faculty perspectives on the program adjacencies that they believe would be most useful, as well as the reasons why. These faculty perspectives can be used to inform the actions of academic institutions who are forming new environmental engineering programs, or those considering a program realignment. In addition, they can inform faculty in existing programs of potential inter-program collaborative possibilities, regardless of which department currently houses their program.

Introduction

Environmental engineering has long been tied to civil engineering. Indeed, its history can be traced back to the hydraulic engineering used to provide water to ancient civilizations in Asia, Greece, Rome, Persia and South America (Anderson 2002). According to Anderson (2002) the first Sanitary Engineering (later to be called Environmental Engineering) program began at Massachusetts Institute of Technology in 1889. The program, located in the Civil Engineering Department, incorporated courses in sanitary chemistry and sanitary biology. Although similar programs at Harvard University and University of Illinois soon followed, formation of additional programs was limited until after World War II (Anderson 2002).

The emergence of Environmental Engineering as an independent discipline grew out of the nation's environmental revolution and the creation of its first set of comprehensive environmental regulatory initiatives from 1970-1980, including the Clean Air Act, Clean Water Act, Safe Drinking Water Act and the Comprehensive Environmental Response, Compensation and Liability Act (AEESP, 2016). Although the discipline of environmental engineering continues to address problems in air, water and soil, it has evolved substantially over the past two decades. In addition, numerous environmental engineering faculty have revised their research and teaching foci to address expanding areas in the field including areas related to energy, climate change and the broader field of sustainability, among other topics (AEESP, 2016). The discipline of environmental engineering has no single, widely agreed-upon definition (NAS, 2018) likely because it continues to evolve.

While many environmental engineering programs continue to reside with the civil engineering departments from which they were born, the evolving nature of the field raises the question as to whether this is the optimum alignment. Usually, environmental engineering programs are not large enough to justify their own independent department, and thus they are aligned with other programs for reasons such as efficiency, logistics, facilities, pedagogy, and collaborative research. For example, there are certainly many advantages to be gained by collocating environmental engineering with departments that have similar lab requirements (e.g., chemical engineering, biological engineering, or environmental science). In addition, programs such as chemistry, environmental health, and petroleum engineering provide numerous collaborative research and course cross-listing opportunities.

Finally, solutions to problems in many of the emerging areas of environmental engineering will require technology but with a greater emphasis on social and economic considerations (AEESP, 2016). Consequently, future environmental engineers must have greater collaboration with economists, policy scholars, and businesses and entrepreneurs to understand and manage issues that cut across sectors (NAS, 2018). The National Academy of Sciences (NAS, 2018) recently reported that environmental engineering programs should ensure that their faculty, "engage with colleagues in the social sciences to develop learning opportunities relevant to understanding the social, cultural, economic, legal, policy, and political contexts of environmental engineering challenges." In addition, there is a need to develop humanities electives that exist at the intersection of the humanities and all engineering programs to provide a liberal arts foundation for engineering students (Chong et al., 2014). An unconventional solution, such as co-locating engineering and humanities programs in the same department, can address these needs by helping to provide environmental engineers both breadth and depth (Figure 1).

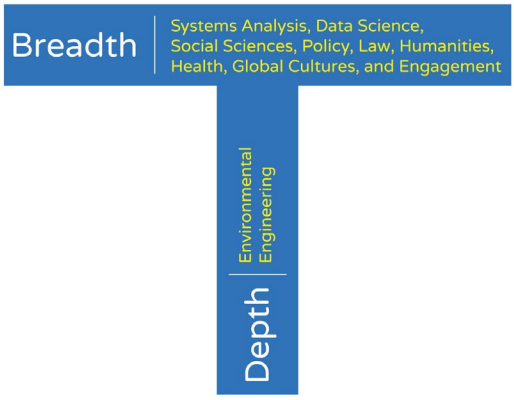

Figure 1. The T-shaped environmental engineer is conversant in social sciences, public policy, engineering science and design (NAS, 2018).

Our objective in this study was to examine the departmental alignments of ABET accredited engineering programs, and faculty perspectives on the advantages and disadvantages of specific program adjacencies. We also present an example of the type of "unconventional solution" mentioned above in order to illustrate the possibilities of a non-traditional alignment. This will inform the actions of academic institutions who are forming new environmental engineering programs, or those considering a program realignment. In addition, the results of

this study can inform faculty in existing programs of potential inter-program collaborative possibilities, regardless of which department currently houses their program.

Methods

Using data available from ABET and institutional web sites, we analyzed the current distribution of accredited environmental engineering programs across departments, to include specific program adjacencies and trends over time. The intent of this analysis was to get a sense of where environmental engineering programs currently are, and what types of alignments are becoming more common.

In order to further investigate the trends identified above, we investigated faculty perspectives on departmental alignments. Specifically, we used the results of an online survey that the ASEE Environmental Engineering Division emailed to its members. The six-question survey (Table 1) was voluntary, and results were anonymous. There were a total of 28 responses to the on-line survey, a response rate of approximately 9%.

Table 1. Questions from online survey of ASEE environmental engineering division.

#	Question	Responses
1	Co-locating environmental engineering with the following programs enhances student education and faculty development: a. Architecture b. Biological Science/Engineering c. Chemical Engineering d. Chemistry e. Civil Engineering f. Earth Science g. Environmental Science h. Environmental Health i. Geographic Information Science j. Geography k. Humanities l. Life Science m. Petroleum Engineering n. Plant Science o. Social Science	*(each program a-o rated as one of the following):* Strongly Disagree Disagree Neutral Agree Strongly Agree
2	Please list the name of the department **at your institution** with which the environmental engineering program is aligned.	Free text
3	How satisfied are you with your current department alignment?	Very Dissatisfied Dissatisfied Neutral Satisfied Very Satisfied
4	Please list one advantage of your environmental engineering program's alignment.	Free text
5	Please list one disadvantage of your environmental engineering program's alignment.	Free text
6	Are there advantages or disadvantages to having environmental engineering co-located with other disciplines? Please explain.	Free text

Results

Currently, fifty percent of the 74 accredited environmental engineering programs reside in a department of "civil and environmental engineering" (department affiliations of all ABET accredited environmental engineering programs are presented in Appendix A). Moreover, an additional 16 environmental engineering programs are linked with civil engineering along with an additional discipline. However, department alignment trends have started to change over time. While 72% of the first 25 programs to be accredited (and which remain accredited today) followed the "civil and environmental engineering" alignment of the first program at MIT, 40% of the last 25 ABET accredited programs are not aligned with civil engineering (Table 2). In addition, 56% of the last 25 ABET accredited environmental programs that are aligned with civil engineering are also concomitantly aligned with an additional discipline (not including construction management, which is typically considered a subdiscipline of civil engineering). Conversely, only eight percent of the first 25 ABET accredited programs (that remain accredited) were in a department that included civil engineering, environmental engineering, and an additional discipline.

As seen in the listing of all programs in appendix A, it is rare for a department to be comprised solely of environmental engineering; indeed, only three out of 74 programs fall into this category. One reason for this may be that the small size of most programs makes it more efficient to combine the discipline with at least one other program. Survey respondents stated that in general the advantages to being aligned in departments with other disciplines included logistics (faculty, courses, labs, etc.), collaborative opportunities, accreditation, and the exposure to the foundational principles of other disciplines which environmental engineers receive. Disadvantages mostly focused on diversion of resources (focus, faculty, funding, etc.) to disciplines other than environmental engineering, especially when environmental engineering was the smaller program in a particular department.

Table 2. The twenty-five most recent environmental engineering programs to become ABET accredited.

Institution Name	Department	Accreditation Date
Tarleton State University	Engineering and Computer Science	10/1/2007
Rutgers, The State University of New Jersey	Bioenvironmental Engineering	10/1/2007
Florida Gulf Coast University	Civil and Environmental Engineering	10/1/2008
City University of New York, City College	Earth and Environmental Engineering	10/1/2009
Portland State University	Civil and Environmental Engineering	10/1/2010
The Ohio State University	Civil, Environmental and Geodetic Engineering	10/1/2010
State University of New York College of Environmental Science and Forestry	Environmental Resources Engineering	10/1/2010
University of Georgia	School of Environmental, Civil, Agricultural, and Mechanical Engineering	10/1/2010
Michigan State University	Civil and Environmental Engineering	10/1/2011
Saint Francis University	Environmental Engineering	10/1/2011
Texas A&M University - Kingsville	Environmental Engineering	10/1/2011
Colorado School of Mines	Civil and Environmental Engineering	10/1/2012
Clemson University	Environmental Engineering and Earth Science	10/1/2012
Purdue University at West Lafayette	The Division of Environmental and Ecological Engineering	10/1/2012
University of California Merced	Civil and Environmental Engineering	10/1/2013
University of Michigan	Civil and Environmental Engineering	10/1/2013
University of Notre Dame	Civil & Environmental Engineering & Earth Sciences	10/1/2015
Duke University	Civil and Environmental Engineering	10/1/2015
The University of Alabama	Civil, Construction and Environmental Engineering	10/1/2015
University of Minnesota - Twin Cities	Civil, Environmental, and Geo- Engineering	5/14/2016
The University of Toledo	Civil and Environmental Engineering	10/1/2016
University of Pittsburgh	Civil and Environmental Engineering	10/1/2016
Bucknell University	Civil and Environmental Engineering	5/1/2017
Central State University	Water Resources Management	5/1/2017
University of Cincinnati	Chemical and Environmental Engineering	10/1/2017

The first question of the faculty survey (results in Figure 2) revealed some correlation with our analysis of the ABET programs above. Indeed, 93% of the faculty agreed or strongly agreed that collocating environmental engineering with civil engineering enhanced student education and faculty development. However, it is notable that almost the same proportion (92%) felt the same about chemical engineering, with none disagreeing. In addition, a majority also felt that colocation with biological science, chemistry, earth science, environmental science, and environmental health would be beneficial for the same reasons. The only field which a majority disagreed or strongly disagreed would be beneficial was the humanities.

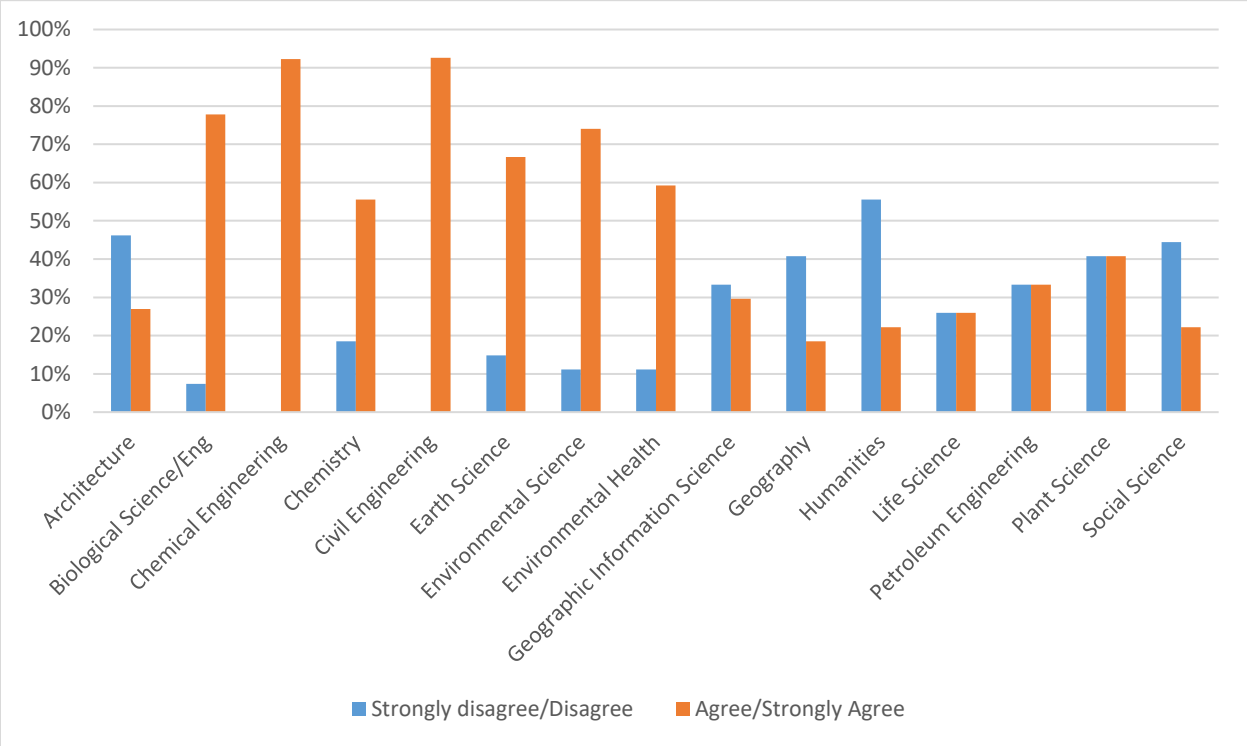

Figure 2. Responses to the question "co-locating environmental engineering with the following programs enhances student education and faculty development," rated on a five point likert scale by members of the ASEE environmental engineering division. (Responses: n=27 for all but architecture and chemical engineering, in which n=26 due to lack of one response for those two choices only; the 28th respondent did not answer this question at all. There was one write-in response as well (mechanical engineering).

Figure 3 shows the departmental alignment of the faculty who took the survey. It generally mirrors overall trends in the field, with the majority aligned with civil engineering. For a variety of reasons, most respondents (22/28) were satisfied or very satisfied with their alignment, with only four dissatisfied, one neutral, and one not responding to that question. Reasons for satisfaction and dissatisfaction varied, depending upon the specific department with which the program was aligned.

Of the 17 faculty whose environmental engineering programs were aligned with civil engineering departments in some way (civil engineering, civil and environmental engineering, etc.), 14 were satisfied, two dissatisfied, and one neutral about the arrangement. Many cited the related nature of certain aspects of the disciplines (e.g., water resources, infrastructure) as a benefit, with some efficiencies to be gained in faculty, facility, and course utilization as a result.

In addition, many said that they appreciated the incidental exposure that both civil and environmental engineers got even in the non-overlapping portions of each other's fields. A common theme of the stated disadvantages to such an alignment was that such programs tended to have less emphasis on chemistry and biology because the overall focus of the department was elsewhere. Two respondents stated that civil engineering students were largely uninterested in chemistry, thus making it more difficult to recruit those majors for an environmental track and reducing the cross-disciplinary exposure opportunities.

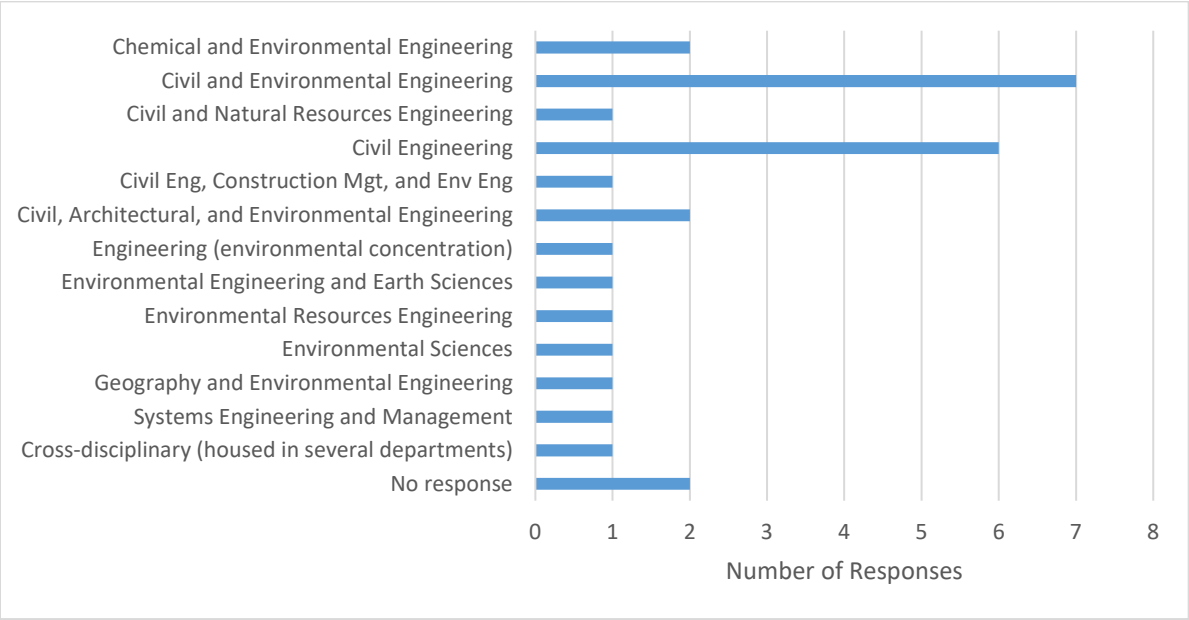

Figure 3. Responses to the question "Please list the name of the department at your institution with which the environmental engineering program is aligned" (n=28). Note that it is possible that some of the respondents are from the same institution.

The two faculty whose programs were aligned with chemical engineering were both satisfied due to the closely related nature of the disciplines. However, both mentioned that environmental engineering tended to be overshadowed by chemical engineering, though the collocation did make double majoring in both fields easier.

Environmental engineering faculty in departments other than civil or chemical engineering had a variety of comments, but they were generally pleased with their program's alignment. For example, faculty from environmental-focused departments such as environmental engineering and earth sciences, environmental resources engineering, or environmental sciences were all satisfied with their alignment, appreciating the related nature of the fields or the ability to more easily add specialized topics such as renewable energy into the program. Also satisfied was a respondent from an institution whose environmental engineering program was cross-disciplinary and housed in several departments, because the program had greater breadth and specialization options for students. One respondent whose environmental engineering program was aligned with the systems engineering and management department was dissatisfied, stating that while it was nice to have the interaction with systems engineering/engineering management students, they would have preferred interaction with "related engineering/science programs (civil, chemical, biology, etc.)"

Discussion

The modern environmental engineer will need system-level strategies for climate change adaptation, smart transportation, disaster resilience, sustainable development, etc., and the civil engineering discipline may be best suited for this paradigm, if the typical civil engineering curriculum changes to emphasize systems-level thinking, innovation and engagement of other fields (personal communication, David Dzombak, October 2018). Some institutions have already evolved to provide a broader emphasis in this area, such as Arizona State University's Fulton Schools of Engineering. Here, the schools' names and curricula are broader, such as School of Sustainable Engineering and the Built environment, which includes ABET accredited civil, environmental, and sustainable engineering.

The engineering and environmental-focused departmental alignments for environmental engineering certainly make sense for a number of logistical and pedagogical reasons mentioned above and in the introduction. However, there is potential in other more unusual alignments which allow environmental engineering graduates to better leverage social sciences as they consider solutions to problems in many of the emerging areas of environmental engineering. One example is the Department of Geography and Environmental Engineering at West Point. Offering four majors unified around its focus on "People and Planet," the department provides the opportunity for engineers, physical scientists, and social scientists to study alongside each other and to learn from one another's various worldviews through countless day to day conversations. The disciplines of geography, geospatial information science (GIS), environmental science, and environmental engineering overlap in various ways; however, the most far-reaching opportunities lie at the nexus of all four, where cadets and faculty from multiple disciplines can work together to solve the "wicked problems" that demand creative solutions. Although environmental engineering students only take one required course in geography, they have the opportunity to take elective courses from and interact with faculty from all four disciplines.

Indeed, engineers are more effective when they are able to empathize with their customers, so that they can ensure that the solution meets the customer's needs. A company may make the most advanced smartphone in the world, but if people can't figure out how to use it, the venture will fail. Indeed, one of the reasons Apple's products have been so successful is the intuitive nature of their use (Isaacson, 2012).

Numerous visionaries have emphasized this point. For example, in their article "Building a Bridge between Engineering and the Humanities," Julio Ottino and Gary Morson (2016) state that "by its very nature, engineering is creative and directed to human uses. All too often, however, engineering education postpones or overlooks both." The solution, they argue, is to enable engineers to view the world from the perspective of humanists. Doing so would enable the empathy and creativity that enhance engineering design, a point reiterated by Kahlid, et al (2013).

Fareed Zakaria, *Washington Post* columnist, made a similar argument in his 2017 Bucknell University commencement address. There he stated that "one of the things I've noticed in reading and reporting and talking to the people who make this world is that the fundamental

insight you still need to have to succeed in this world is not just about technology, it's about how human beings use technology."

The opportunities provided by a department such as the one at West Point with such a diverse collection of disciplines (geography, environmental science, environmental engineering, and GIS) creates the opportunity for this and is consistent with the ideas recently proposed by the National Academy of Sciences (NAS, 2018). For example, one of the department's courses titled "Environmental Engineering for Community Development" focuses on engineering in context in the developing world– i.e., developing solutions with respect to political, social, environmental, and economic factors, instead of just engineering ones. A water treatment system for a remote village may be highly effective, but if it cannot be operated or maintained by the people whom it is supposed to help, it is of no real use. In the same way, latrines that generate biogas for people to use as cooking fuel may sound like a good idea, but if they are equipped only with western-style toilets they may not be culturally acceptable and the whole project will fail. Through these two small examples, one can see how a geographer and an engineer can create a better solution by working together than they can individually.

The same can be said for the efficiencies and opportunities gained by other disciplines within the department working together. Physical geographers, environmental scientists, and environmental engineers have the requisite background to teach several courses that straddle these disciplines. Geospatial information science runs through the curriculum, supporting everything from the mapping of major league baseball team affiliations by region, to the modeling of pollutant dispersion in Arbil, Iraq for the air pollution engineering course.

Conclusion

Our analysis of the departmental alignment of ABET accredited environmental engineering programs indicates that while most are in a civil engineering department, there is a recent trend toward alternative alignments. Most faculty surveyed are satisfied with their departmental affiliation (whatever it may be), due to a number of reasons including efficiency and collaborative opportunities. More unusual or broader alignments (such as with the humanities and social sciences) are rare, but could provide some unique opportunities.

Of course, the department to which a program belongs does not necessarily limit opportunities for faculty or students. Certainly faculty and students can reach across organizational boundaries for collaborative research, course enrollment, or other reasons. However, it does make it somewhat less likely; indeed, the effect of proximity can be far-reaching. The person with whom you share the breakroom might just have the idea that helps you solve that intractable problem.

Thus, institutions considering the possibility of beginning a new environmental engineering program or re-aligning an existing one should consider carefully the advantages and disadvantages of its departmental affiliation, many of which may be mentioned above. There seem to be many good options, and thus the choice may ultimately come down to the faculty's goals and areas of focus for their particular program.

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Appendix A. Departments that are affiliated with Environmental Engineering (n=74)

Department	Number
Bioenvironmental Engineering	1
Chemical and Environmental Engineering	2
Chemical, Biological, and Environmental Engineering	1
Civil & Environmental Engineering & Earth Sciences	1
Civil and Environmental Engineering	37
Civil and Environmental Engineering and Land Surveying	1
Civil Engineering and Environmental Science	1
Civil Engineering, Construction Management, and Environmental Engineering	1
Civil, Architectural and Environmental Engineering	4
Civil, Construction and Environmental Engineering	4
Civil, Environmental & Ocean Engineering	1
Civil, Environmental and Geodetic Engineering	1
Civil, Structural and Environmental Engineering	1
Civil, Environmental, and Geo- Engineering	1
Earth and Environmental Engineering	4
Engineering and Computer Science	1
Environmental Engineering	3
Environmental Engineering Sciences	1
Environmental Health and Engineering	1
Environmental Resources Engineering	2
Environmental Science & Engineering	1
Geography and Environmental Engineering	1
School of Environmental, Civil, Agricultural, and Mechanical Engineering	1
The Division of Environmental and Ecological Engineering	1
Water Resources Management	1