EDUCATING ENVIRONMENTAL ENGINEERS FOR THE 21ST CENTURY

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For more than twenty years, engineering educators have been receiving advice on changes in the undergraduate civil engineering curriculum. The advice has been proffered in forms ranging from modest suggestions to strident demands. It can be found in publications ranging from professional journals to reports prepared by national commissions. The advisors range from concerned critics to distinguished presidential advisors.

However, the entrenched educators, for reasons that only they can explain, have largely ignored almost everything suggested or proposed. They have stonewalled, equivocated, jawboned, haggled, quarreled, quibbled and resisted in every way imaginable all but the most modest changes.

Examine the civil engineering curriculum of the late 1960s or early 1970s at an engineering school of your own choosing. Compare it to the civil engineering curriculum of the same school today. It is unlikely that you will find any significant change. There might be a course or two more in the humanities and social sciences than there were twenty years ago. Also, a course in either oral or written communication might have been added. Finally, you might find a "capstone" design course today that wasn't there when we first began welcoming the returning Vietnam veterans. Most surprising of all, in many cases you will find that the number of credits required to complete the baccalaureate degree is actually less now than it was when man first walked upon the surface of the moon.

Now, think for a minute about how the world has changed in those twenty years. Think about what we know now that we didn't know then. Perhaps more important, think about what we now know we don't know that we thought we knew then. Isn't it unconscionable that the basic education we provide young people entering the civil engineering profession today is so little different from what it was twenty years ago?

Nowhere within the field of civil engineering has the need for change been more obvious than in the environmental engineering specialty. And nowhere else have the demands for change been more insistent. Admittedly, some changes have occurred. The course we once called "Sanitary Engineering" has been relabelled "Environmental Engineering," and it now includes discussion of air pollution and hazardous waste disposal in addition to water pollution and solid waste disposal. That's clearly a step in the right direction, but only a tiny step. It doesn't begin to address the larger problems faced by today's practicing environmental engineer, and it is wholly inadequate to meet the needs of the environmental engineer of the 21st century.

Like other specialty areas, knowledge in the field of environmental engineering can be subdivided into the following broad categories: philosophy, policy, processes and problem-solving approaches. To see where changes in current environmental engineering practices are needed, let us examine each of these in turn.

Philosophy in any area of subject matter knowledge deals with the great ideas and ideals of the subject. Understanding of the philosophy underlying a given subject is fundamental for successful endeavors in that area. To understand the philosophy in a given subject matter area, one must be

exposed to writers and thinkers who have explored ideas and shaped the beliefs, ethics and thinking of those who are knowledgeable in the area. Reading, writing, and thinking about the work of people like Rachel Carson, Barry Commoner, Rene Dubos, Donella and Dennis Meadows and others like them is essential for engineers who want to understand the ideas that underlie the way other educated people think about the environment. The study of relevant philosophy is one of the weakest parts of undergraduate engineering education in all specialty areas, but in no other area is it as debilitating as it is in the field of environmental engineering. Other professionals with far less understanding of effective problem-solving approaches often have a far greater understanding of the fundamental environmental issues and concerns than engineers have.

Policy is the vehicle through which philosophy is transformed into action. Policy evolves from and is based upon an understanding of philosophy, but it is shaped by history, heritage and politics. Environmental engineering is probably ahead of most other specialty areas in engineering in that most environmental engineering courses include at least a cursory review of relevant national legislation in the various areas of practice. The unfortunate circumstance is that where such information is provided, it is almost always limited to a description of the legislation insofar as it pertains to problem-solving approaches. There is very little discussion of the conditions and circumstances that produced the legislation; almost no understanding of why a particular set of standards or practices is mandated and why other equally plausible, and perhaps superior, approaches are ignored; and virtually nothing about how successive legislative acts and policies in a given field are related to one another and to other acts and policies in other related areas. Without this knowledge the engineer is severely handicapped in understanding why a particular problem-solving approach is employed.

Process leads one from policy to problem solving. In environmental engineering, process includes things such as planning, public involvement, social and environmental impact assessment, economic and financial feasibility evaluations, elections and referenda, and budgeting and financing projects. Some of these subjects are mentioned in passing, but few get any significant treatment in today's civil engineering curriculum. Even as basic a process as planning, which underlies every civil engineering project of any size, is given such cursory treatment in civil engineering curricula that there is today no well-known textbook on civil engineering planning. Where texts dealing with planning topics do exist, they are likely to be in the area of environmental engineering or one of its closely related subdisciplines. However, they tend to focus more on techniques than on concepts, and they rarely provide the kind of information about philosophy and policy that is needed to develop real understanding of the rationale for the planning process.

Problem solving is, of course, the one area in which the civil engineering curriculum is strong. For environmental problem solving, the civil engineering curriculum undoubtedly provides a greater exposure to information concerning state-of- the-art approaches than any other course of study. The civil engineering graduate is generally well-equipped to understand and employ proven solutions to common environmental problems. Unfortunately, without the knowledge of philosophy, policy and process that is needed to underpin their problem-solving abilities, civil engineers are increasingly being relegated to a role somewhat akin to that of a super technician. For a profession that has prided itself on conceiving, designing, and constructing great projects, that's a bitter pill to swallow.

Some might argue that the primary mission of engineering education is to produce problem solvers. Therefore, they would argue, focusing our educational efforts on problem solving is altogether fitting and proper. Given the explosion of scientific and engineering knowledge in the last forty years, they say, what is needed is more attention to problem solving, more emphasis on scientific theories and principles, more practice in deriving, developing and employing analytical techniques.

After all, they argue, few others working in the environmental area have either the interest or the inclination toward problem solving that the civil engineer possesses. And that argument is a compelling one. It is an argument that cannot be ignored, for without problem-solving ability efforts to understand philosophy, policy and process become academic exercises that contribute little to man's prospects for living in harmony with the natural environment.

The argument, then, is not that we should reduce educational efforts directed toward continuation and enhancement of the environmental engineer's expertise as a problem solver. Rather, we should precede and combine those efforts with studies of environmental philosophies, policies and processes. Some would argue that these latter educational efforts are most properly the dominion of those engaged in supplying the humanities and social science components of an engineering education. In most schools, if we rely on those courses and teachers as a source of knowledge for the things engineers need to know about environmental philosophy, policy and processes, we will be sorely disappointed. Those teachers believe (and it is difficult to dispute their belief) that the limited opportunities which exist in engineering curricula for exposing engineering students to humanities and social sciences need to be devoted to broader human concerns than those which would be addressed if these courses were restricted to discussions of environmental and engineering issues. Furthermore, in many schools the teachers of these courses are not themselves prepared to do what needs to be done for the environmental engineering student.

If this teaching is to find its way into the environmental engineering curriculum, the proper place is probably within the context of existing courses. The best teachers are probably the existing teachers of these courses. The material that needs to be learned is material that already exists. It is not necessary to wait for it to be developed. Best of all, much of it can be learned outside of the classroom and laboratory through reading and writing assignments that are carried out on the student's time rather than on the instructor's. Consequently, inclusion of this type of learning does not necessarily mean that other types of subject matter will have to be deleted from existing courses. That's not to say that there won't have to be some adjustments in the amount of student effort devoted to learning how to solve problems as opposed to why a particular solution approach is necessary or desirable (unless one assumes that there is infinite elasticity in students' time allocations!).

Ideally, one would hope that teachers would see fit to emphasize and reinforce student reading and writing assignments with classroom discussions and laboratory activities that expand the student's understanding and appreciation of the relevance of philosophy, policy and process to problem solving. Much of the best writing on these matters, by its very nature and because of the frame of reference of its authors, is not very explicit on the relationships among issues, ethics, processes and real-world problem solving. Many students are not intellectually mature enough to fathom these relationships on their own, given the nature of the existing materials. For these reasons, engineering teachers who want their students to understand the importance of this knowledge will have to develop teaching strategies that communicate the notion that these assignments, although different from most typical engineering assignments, are not simply "busywork," but vital and integral elements of learning the body of knowledge essential to environmental problem solving.

Although some engineering teachers might be uncomfortable with assignments that explore philosophical, ethical, social, economic and political dimensions of problems such as acid rain, deforestation of tropical rain forests, global climate change and hazardous waste disposal, an appreciation for the scope and complexity of these dimensions is fundamental knowledge for those who would hope to produce impenetrable solutions. Engineers who cannot understand these dimensions are crippled, and they are unlikely to be able to act in a truly professional capacity as problem solvers in the

21st century.

In conclusion, improving the education of environmental engineers for the 21st century is not primarily a matter of more and better laboratories (although they are probably needed), or a matter of more and better courses (although the education would undoubtedly be improved by adding courses—probably through the addition of a fifth year to the undergraduate curriculum or by recognition of the master's degree as the entry-level credential), or a matter of more and better teachers (although we all recognize the need to continue to improve our teaching abilities). We can achieve significant improvements in educating environmental engineers by merely recognizing and emphasizing within the context of our existing environmental engineering coursework the importance of reading, writing and thinking about the philosophical and ethical bases for environmental issues confronting society and about the policies and processes that support and prescribe our efforts to solve environmental problems.