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■ *PROCEEDINGS*

Sixth Conference on Environmental Engineering Education

Environmental Engineering Education in the Year 2000

■ Development of Baccalaureate Environmental Engineering Programs and Degrees

■ Inclusion of Hazardous Waste Topics in Curricula including Innovative Technologies

■ Future Concerns in Graduate Environmental Engineering Education

Edited by

Kenneth J. Williamson
and Marlis R. Miller

Sponsored by

American Academy of Environmental Engineers

Association of Environmental Engineering Professors

Western Region Hazardous Substance Research Center
Stanford University
Oregon State University

In cooperation with the Environmental Engineering Division of the American Society of Engineering Education

Supported by the National Science Foundation

1960 Harvard - 1967 Northwestern - 1973 Drexel - 1980 University of Toronto - 1986 Michigan Tech - 1991 Oregon State

Proceedings

SIXTH CONFERENCE ON ENVIRONMENTAL ENGINEERING EDUCATION

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Future Concerns in Graduate Environmental Engineering Education

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Conference Co-Chairs
Kenneth J. Williamson, Representing AEEP and WRHSRC
H. Gerald Schwartz, Jr., Representing AAEE

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INTRODUCTION AND SUMMARY

Kenneth J. Williamson
Conference Co-Chair

The profession of environmental engineering is committed to the use of scientific principles for: the protection of human population from adverse environmental factors; the protection of local and global environments from deleterious effects of human activities; and the improvement of environment quality for man's health and well-being.[1]

Several important issues have emerged since **The Fifth National Conference** that were the central focus of the **Sixth National Conference**. These are the development of independent undergraduate environmental engineering programs, the inclusion of hazardous waste topics within curriculum, and the need to develop strategies to promote of innovative technologies for the solution of pressing environmental problems. Faculties in almost all major universities are involved in discussions to decide future directions in relation to these topics.

In recognition of these emerging issues within the profession, the governing boards of the Association of Environmental Engineering Professors(AEEP) and the American Academy of Environmental Engineers(AAEE) co-sponsored **The Sixth National Conference**, with additional support from the Oregon State Department of Civil Engineering, the Western Region Hazardous Substance Research Center (WRHSRC), the Environmental Engineering Division of the American Society of Engineering Education, and the National Science Foundation,

This Conference was one in a series on environmental education that began in 1960:

The First National Conference, 1960, focused upon the teaching of unified concepts in environmental engineering. It was sponsored by the American Sanitary Engineering Intersociety Board (predecessor of AAEE), NSF, Harvard, and M.I.T.

The Second National Conference, 1967, emphasized the multi-disciplinary characteristics of environmental engineering education. Support was obtained from NSF and the U.S. Public Health Service.

The Third National Conference, 1973, dealt with issues of environmental quality goals and manpower needs. Support was provided by the U.S. EPA.

The Fourth National Conference, 1980, focused upon curriculum issues related to excellence, and the relationships between undergraduate and graduate education.

The Fifth National Conference, 1986, focused on issues related to the integration of air, water, and land disposal, the use of computers, and the importance of design in engineering curricula. The Conference was attended by several hundred educators and was a focal point for addressing the broad-based problems encountered in undergraduate and graduate teaching.

The Sixth Conference focused on the issues of the development of independent undergraduate environmental engineering programs, the inclusion of hazardous waste topics within curriculum, and the need to develop strategies to promote the use of innovative technologies for the solution of pressing environmental problems.

Conference Planning, Issues and Format

The sponsoring organizations appointed a Planning Committee for The Sixth Conference on Environmental Engineering Education. The members were:

Kenneth J. Williamson, Co-Chair, Representing AEEP and WRHSRC, Professor of Civil Engineering, Oregon State University

H. Gerald Schwartz, Jr., Co-Chair, Representing AAEE, Vice President, Sverdrup Corporation

C. Robert Baillod, Representing AEEP, Chair of The Fifth Conference, Professor of Civil and Environmental Engineering, Michigan Technological University

John Ferguson, Professor, Department of Civil Engineering, University of Washington

Paul L. Busch, Representing AAEE, Vice President, Malcom Pirnie, Inc.

Greg Peterson, Director, Technology Transfer, CH2M Hill

David Hendricks, Professor, Colorado State University

James Johnson, Professor, Howard University

N. Bruce Hanes, Professor, Tufts University

The Committee met in Chicago in November, 1990, at a meeting planned by Andrew Chang under the sponsorship of NSF, to delineate the major issues of the proposed conference. The format was similar to previous conferences and was based on preparation of position papers on major focal issues by Task Committees. A second meeting was held in June, 1991, to complete final plans and to finalize the position papers. The three focal issues were:

1. Development of Independent Undergraduate Engineering Programs. As with all fields of engineering, environmental engineering was born under the auspices of civil engineering. While most civil engineering programs are dominated by structural engineering, civil engineering remains a conglomeration of structural plus transportation, geotechnical, water resources, surveying, and environmental engineering. The expansive information base required for competence within these six sub-disciplines has forced continual discussions as to educational priorities. The lack of adequate "space" within most undergraduate programs appears to be the primary reason for the restriction of most environmental engineering programs to a major emphasis at the graduate level. Such a restriction has broad implications as to pools of students for preparation in this field and to educational paths required of students to enter the environmental profession.

The current interest in environmental issues has prompted a tremendous interest in environmental engineering. It is not uncommon to poll undergraduate civil engineering students and find over 50% with a primary interest in environmental engineering. Students strongly wish to enter the environmental engineering profession and many have little interest in the traditional civil engineering curriculum. These students often want a degree path that would be a combination of water-related engineering and environmental science.

This new popularity of environmental concerns has prompted a strong movement within academia to develop undergraduate environmental engineering programs independent of civil engineering. For example, the University of California is developing a totally new undergraduate degree in Environmental Engineering. Also, M.I.T. has begun to offer a Bachelor of Science degree in Environmental Science Engineering. It is not clear whether this movement can be considered a "bringing down" of graduate programs or a "breaking away" of an undergraduate program. Whichever, such moves can be considered a significant departure from our history where environmental engineering comprised a minor part of most students undergraduate programs.

In relation to undergraduate environmental engineering programs, four separate systems appear to be evolving:

-limited environmental engineering in the undergraduate program, dominant graduate program (example, Stanford University);

-significant number of undergraduate and graduate environmental engineering courses with requirement of significant courses in all civil engineering sub-disciplines (example, University of Washington);

-significant number of undergraduate and graduate environmental engineering courses with wide range of freedom to choose courses from various sub-disciplines (example, University of Maine);

-undergraduate environmental program only (example, new program being developed at University of California at Riverside).

The Conference examined the strengths and weakness of each of these approaches and discussed which approach appears most suited to education in the year 2000.

2. Inclusion of Hazardous Wastes. Within the last five years, the management of hazardous substances and the treatment of hazardous wastes have become a dominant theme in environmental engineering. The management of hazardous substances and wastes has become a multi-billion dollar industry involving almost all civil engineering consulting firms. In the past, our graduates were typically employed in the water and wastewater fields, but now, for graduating M.S. students, the dominant field of employment is in the area of hazardous waste treatment and site remediation.

This significant shift in the environmental engineering field has brought pressure on universities to change curricula to include courses in hazardous substances and wastes. On campuses everywhere, Engineering Departments have found that if they fail to offer such courses, Colleges of Science will offer them. This inclusion of hazardous substance management and waste treatment into the "standard" environmental engineering curriculum has produced multiple difficulties of which the most important is the increased amount of information, concepts, and topics to be covered. Into an already full curriculum, numerous topics have appeared that are "absolutely" necessary. Such topics include advanced chemical and thermal treatment methods, bioremediation, groundwater hydrology and transport, sorption reactions, hazardous substance management and legislation, transport of organic and inorganic compounds, toxicology, site remediation, risk assessment, and waste minimization among others. Discussions abound among environmental engineering faculty as to "what to add" and "what to remove".

It is proposed to address the topic of "what" of the hazardous waste field needs to be included in environmental engineering curricula and "how" can it best be taught. The organization of hazardous waste courses at some major universities will be described, and the relation of this material to water and wastewater treatment fundamentals discussed.

3. Promotion of Innovative Technologies of Treatment of Pressing Environmental Problems. The U.S. EPA, through the Technology Innovation Office, has identified the lack of implementation of innovative technologies by the consulting community to be a serious problem in relation to environmental management. The problem is especially acute in relation to Superfund site remediation and, as such, related directly to the environmental engineering community. Many environmental problems lack proven technologies for treatment or remediation. The most notable examples are clean-up efforts at the numerous hazardous waste sites throughout the nation. Innovative methods are being met with considerable resistance by the engineering community due to a variety of regulatory and institutional impediments.

There appears to be a serious need to introduce environmental engineering students to strategies to improve innovation. Students need to address within their education how to responsibly use unproven technologies. In addition, students need to be introduced to the fact that many times in their careers they will be faced with problems that do not have "textbook" solutions. The proper strategies to act, even under conditions of great uncertainty, need to be included into our graduate level curriculum.

It was proposed to involve the Technology Innovation Office and the professional consulting community into presenting material regarding the use of innovative technologies that can be more easily included into coursework. The Technology Innovation Office is in the process of developing case studies and practical examples to be shared with the conference participants, and much of this material will directly relate to hazardous waste coursework.

Conference Position Paper Development

Task Committees were formed to prepare position papers on each of the focal issues. The Co-Chairs of these committees were:

Conference Co-Chairs

KENNETH J. WILLIAMSON, Professor, Department of Civil Engineering, Oregon State University, Corvallis, OR

H. GERALD SCHWARTZ, JR., Vice President, Sverdrup Corporation, Maryland Heights, MO

Development of Baccalaureate Environmental Engineering Programs and Degrees

C. ROBERT BAILLOD, Department of Civil and Environmental Engineering, Michigan Technological University, Houghton, MI

WILLIAM C. BOYLE, Department of Civil Engineering, University of Wisconsin, Madison, WI

Inclusion of Hazardous Waste Topics in Curricula, Including Innovative Technologies

JOHN F. FERGUSON, Department of Civil Engineering, University of Washington, Seattle, WA

GREG PETERSON, Director, Technology Transfer, CH2M Hill, Corvallis, OR

F. MICHAEL SAUNDERS, Department of Environmental Engineering, Georgia Institute of Technology, Atlanta, GA

PAUL L. BISHOP, Department of Civil and Environmental Engineering, University of Cincinnati, Cincinnati, OH

DAVID HENDRICKS, College of Engineering, Colorado State University, Fort Collins, CO

Future Concerns in Graduate Environmental Engineering Education

RICHARD G. LUTHY, Department of Civil Engineering, Carnegie Mellon University, Pittsburgh, PA
FREG G. POHLAND, Department of Civil Engineering, University of Pittsburgh, Pittsburgh, PA

Conference Program

The Conference Program centered around the focal issues as related to environmental education in the year 2000. Each position paper was summarized and discussed by the respective committees. Then, Conference participants joined one of the three committee work groups and developed a report of recommendations concerning the focal issue. On the third day, these work groups presented their reports and refined position statements at the Plenary Session. Other activities were available to participants to present various approaches to environmental education, including poster sessions, discussion groups, and facility tours.

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1. Patterson, J.W., "Environmental Engineering Education: Academia and an Evolving Profession," Environmental Science and Technology, 14, 524-532, 1980.

2. "Proceedings, Fifth Conference on Environmental Engineering Education," edited by C. Robert Baillod, American Academy of Environmental Engineers, Association of Environmental Engineering Professors, Houghton, MI, 1986.

HISTORY OF ENVIRONMENTAL ENGINEERING CONFERENCES

Opening Remarks

Perry L. McCarty
Stanford University
Stanford, CA

On behalf of the Western Region Hazardous Substance Research Center I, too, would like to welcome all of you. It looks like quite a distinguished gathering here. I was fortunate enough to be present at the first meeting that was held at Harvard at 1960. I'd just completed my first year as assistant professor at MIT and was thrilled to death to have an opportunity to meet with professors from all over the country to address pretty important issues.

It wasn't actually the beginning of environmental engineering education. Actually, it began some time before that. Jerry Roick, who had been at many of those meetings and was at the fourth recalled some of the earlier history in the environmental engineering field and he pointed out that William, Tons, and Sedgewick, as far as the records indicated, gave the first course in sanitary engineering in 1889 at MIT. So that's a little over a century ago. It's interesting that Sedgewick was a biologist and not an engineer. He got his Ph.D. from the Johns Hopkins University, and went to MIT at about 1883. His research work was on toxic gases, which he worked on with another professor there, William Ripley Nichols, a professor in chemistry. Nichols had written a book on water supply which was primarily from a chemical perspective but it did cover elements of filtration, sedimentation, and so, in essence, was encouraging sanitary engineering. I think it is important to recognize that many people outside of engineers have contributed to the profession. In fact they recognized the real problems of infections, infectious diseases, spreading the word about the germ theory and disease, and seeing the importance to do something about it. The profession responded remarkably. The next 20 or 30 years brought in treatment filtration, flocculation, sedimentation, and disinfection and the real diseases of cholera, typhoid, dysentery that were killing many throughout the country, and were the most deadly diseases around then, were essentially solved within 30 years - something that we can all be quite proud of as far as the profession is concerned.

But, going on from that beginning, by the 1950s (preceding the first conference), there was a major problem before us that wasn't really being addressed, and that was of water pollution. At that time many of the attempts were to classify rivers and permit only a few of them to really retain a pristine character where fish could thrive. Many other streams were allowed to reach the point where they were not noxious to odors and unsightly, but little else. The public at that time did not think that clean surface waters were something worthy of their tax dollars and not much was being done. However, the public health officials and professionals in that area felt in the 1950s that the time was there to act.

Some other perspectives on the 1950s. Vanover Busch led the scientific wartime effort, and toward the end of the war President Roosevelt asked him to develop a plan for peace time science. From that, in 1945 Busch developed a report called "Science, The Endless Frontier" and from that flowered a great growth in both engineering and science. In 1950 also the federal activities in water supply and pollution control were under the Public Health Service within the Department of Health, Education and Welfare. The research armed the Public Health Services and the National Institutes of Health, and they were growing as well during the 1950s with this new stimulus in science and engineering.

One of the things that the Public Health Service developed was a fellowship program for doctoral students, and it was one of the things that helped me get through my program. There were no research grants available at the time, but the fellowship supported my doctoral work. The other thing that happened about that time was the development of a traineeship program for master's students. That is still part of the Public Health Service, but we have moved away from the Public Health Service, and we do not have them anymore. But at that time, they came into being and really brought in a lot of money and support for students in this area. In addition, they were supporting the building of buildings and laboratories, and so there was a great flourish of activity in the developing of new programs.

Another thing happened in the 50's. In 1955 the American Sanitary Engineering Intersociety Board was formed with the idea of certifying those who were qualified to practice in sanitary engineering. It was a concern about the quality of people and they defined the sanitary engineer at that time as someone who included public health, air pollution, industrial hygiene, radiation hazards, water and wastewater. So they started a program in 1955 to certify people.

Now, when the federal funds came in and this great proliferation started, many universities were interested in expanding the program, and the well-established schools began to fear that the quality of the graduates would be really lessened by new universities that didn't have the background or the faculty to try to train these individuals with the funds. And that was one of the strong reasons for bringing together the first meeting in Harvard in 1960. There was some thought among the established schools that maybe we should be like the schools of public health where there are a certain number of established ones, and they receive the funds to train individuals under some fairly rigorous guidelines.

However, at that time, those who were in the mode of establishing new programs with the funds were becoming quite disturbed because they didn't want to be shut out from this process. And I think it was very important to have this meeting at Harvard because it was open meeting; these decisions were not made behind doors by the established people. It was an open meeting in which everyone came. There was a lot of tension, as I recall, at that first meeting, but in the interactions that developed and the exchange of views, they weren't shut out. But what happened was the establishment of a curriculum that included elements of science, chemistry, and microbiology, as well as engineering and design that would lead to a credible program. As also indicated, there was a minimum of full-time faculty who would be required to establish such a program. That was an important element that came out of that meeting and it was important not only for those with established programs in agreeing together what constituted a viable education, but also to those who wanted to start new programs to convince their administrations what was involved and for the Public Health Service in giving awards to use some kind of criteria against which to base their judgments.

Partly from that came the ASEIB, this intersociety board. Then, following the recommendations in 1964, four years after, pushed for accreditation of programs through the ECBD, and the concept there was that the graduate degree was the first recognized degree in sanitary engineering and that one had to achieve that graduate degree before you could become accredited. In fact, in establishing this concept, it further (and this may be important here because this is 1964) expressed disfavor on the continuation of sanitary engineering options at the undergraduate level. The thinking at that time was that the undergraduate emphasis was not sufficient for someone to obtain the breadth of knowledge that was required for the field, and so they encouraged it to be at the graduate level. And that had ramifications because this tended to discourage the growth at the undergraduate level.

Another thing that happened subsequent to that meeting, in 1962, was formation of the American Association of Professors in Sanitary Engineering. Within the next seven years after that things started to develop more in the field. The ASEIB decided in 1967 to change its name because of the broadening scope to the Environmental Engineering Intersociety Board while the professor's organization retained the title of Sanitary Engineering. So the second meeting, which was held in 1967, had as its title "Environmental and Sanitary Engineering" because the two groups that were sponsoring the meeting had different perspectives on what the name of the field should be. But that was one of the major emphases for the second conference. How broad is this field that we are talking about? We are gathering together here. A lot was discussed on curriculum, but what are the bounds of this field? There were those who promoted adding transportation and land use planning, and so forth and so on, because they are all parts of the environment and they are designed for the environment, etc. It was not quite clear by the time that meeting was over what it should be, but one thing was clear: that everyone wanted to change the name to environmental engineering and that was the time when it officially happened, and the professor's organization shortly followed after that and did change their name to the present one.

The next meeting (the second one) was in 1967 at Northwestern. The third one was in 1973 at Drexel. Between 1967 and 1973 a lot happened in the United States and throughout the world. We had tremendous cultural change, a lot of things I do not want to go into. In 1970, Dennis Hayes and Earth Day came about. There was a real change. So when the conference was held in 1973, it was interesting to look through the summary there, and it noted in the first thing of the conference summary and it said "In the 1960s and early 1970s, the American people suddenly became aware of their environment. Americans discovered ecology. Environmental quality has become a national goal during the decade preceding this meeting." And that was the truth. It had a dramatic change in all directions. So that conference was pretty important in broadening our aspect, our outlook, and defining what is it that we are doing. I think a lot came from that.

There was one group on land planning and on looking through it there is a little statement in there but it was really a statement, I think, that was looking at the future and what we are seeing today. I would just like to quote from their report. It said, "Growing populations and declining energy resources may have a profound effect on the way we use our land. Contemporary concern for environmental quality has produced a revolutionary new concept that land is not only a commodity suitable for private development but also a depletable resource that must be protected for the public good." And I think that statement has held true; it not only brought in expansion of public parks, the preservation of wilderness and the development of preservation of wetlands, but also, I think, we can look at our RCRA and CERCL laws and Superfund and what we are trying to do there as really thinking what we used to think about pollution of the rivers and pollution of the land and trying to restore that. I think that concept was the theme, probably not to the ramifications as we see it today, but it was certainly there.

Another thing at that meeting that they talked about that applied to what we are doing here is a quote from the summary following the Confernce: "As in most academic discussions, familiar philosophical issues arose. As always among academics, there were those who drew clear distinctions between education and training. At the undergraduate level, there were the usual generalists versus specialists arguments. At the graduate level, there were the traditionalists, exponents of the tried and true, and the innovators, those who wished to respond to the new challenges. And typically among educators, there was faith in the educational process, a conviction that as new areas of expertise developed in the field the solution was not to choose between either/or but to solve the problem with more." Within that kind of tongue-in-cheek statement the group did define environmental engineering, and I think this is something for us to think about because in their recommendations, and again I want to quote, "As a list of possible interests continue to multiply and threaten to broaden the scope of environmental engineering to almost unmanageable proportions, the graduate education committee sought to bring the important professional areas into focus by distinguishing three domains of environmental engineering: (1) the major professional fields, (2) specialty areas, and (3) other fields with environmental concerns." And the major professional fields were then designated as air quality, water quality, solid waste management, and industrial hygiene. In each of the four, fit the criteria of an established body of knowledge involving quantitative measurements and design characteristics that constitute an engineering curriculum. Another importance in there is they considered specialty programs, something like radioactive substances. Now, in the past, that was put almost at par with water supply and air. But here they felt this is typical of a specialty and were suggesting that monitoring and control of radioactive substances when considered analogous to other contaminants was felt to fall within the scope of air, water, and solid waste, and in industrial hygiene activities leaving only as they quoted there "the safety aspects" which might be identified as a special area. Reflecting on hazardous waste as we will be at this meeting, we need to think about this and how to fit it into curriculum and what is it? Is it some kind of a specialty or is it a major part of what we are doing?

Another sidelight that happened at the third conference is that they recommended the development of undergraduate environmental engineering education. Now here is going back and saying it should be encouraged through distinct degree programs, option programs with established departments, or through interdepartmental programs. And this, then, gave encouragement for undergraduate education so that in our next meeting in 1980 in Toronto, the fourth meeting, this is one of the major themes.

The committee here had developed a very long and thoughtful report that indicated there were, in 1980, about 22 undergraduate programs in environmental engineering, and they discussed a lot of the same issues we are going to discuss here. The committee recommended, "There is a need to provide the manpower necessary to address the environmental questions of the future." So their emphasis was on manpower needs. "Such a need can be met partially by a baccalaureate degree in environmental engineering." And that concept was very heavily discussed and debated. One of the strong opponents stated then that the baccalaureate program was a disservice to both the student and the professor by narrowing job options in an early stage of the student's education. That was one side. The need, the manpower, was at the other side. And, I think, the emphasis there was on manpower development, maybe rather than on building a better foundation for those who go on to graduate school and that is something I think we need to look at. In any event, at that time, after this heated discussion, a vote was taken to pass that as a recommendation and thought, and it was narrowly defeated.

By the time of the fifth meeting in Michigan Tech that was not under discussion. I think that the heat of that time was enough to lay off for a few years. At Michigan Tech emphasis was placed on computers, design, and, very important to our talks here, on integrated approaches to environmental engineering and I'd like now to quote from that particular committee: "An integrated approach incorporates parts into a whole, it seeks a solution that has integrity, that is sound and complete. It stresses understanding of (1) the multimedia nature of the movement, distribution, fate, and effect of substances that have entered the environment; (2) the coordinated treatment and management of gases, liquid, and solid materials so problems are not shifted unduly from one medium to another; and (3) the use of both anticipatory [and by that they meant recycling and resource reduction] and reactive [that meant treatment and management measures]. An integrated approach can apply to both natural and engineered systems and can involve both analysis and design." The conference voted and recommended from that statement that environmental engineering programs should include educational elements that focus on multimedia problems and incorporate an integrated approach to their solution. Now, in here, this integrated approach was suggested, not as something by itself, but as something that should be integrated within the other fields that we feature, the land, water, air, and public health. I think we need to think about that and reflect on that at this meeting.

Also, at that meeting in the keynote address, Ernie Goyna and Charles Schorber noted some issues that we need to think about and how we fit in and they are pretty broad. And here is the quote, "The most difficult challenges for the future environmental engineers will be those that arise from the basic nature of an overpopulated industrialized society. These include the demonstrable health related problems associated with the protection of groundwater, control of nonpoint source pollution, regulation of toxics and disposable hazardous waste. Growing issues involving multimedia considerations must be addressed. Familiar examples includes acid precipitation, residuals management, ocean disposal, water re-use, environmental consequences of biotechnology, and ozone in the upper atmosphere. Global environmental issues will profoundly influence the future training of the environmental scientist and engineer." And that certainly is a broad perspective. I think we see most universities are trying to come to grips with all of these and it is certainly, I think, much broader than all of us put together and much broader than all scientists and engineering put together. It involves policies, societal concerns, and many issues, and universities are addressing these. Questions for us are: how do we fit into this big picture and where are we going?

In this sixth meeting that we are having today we have defined certain things, hazardous waste, very important item. Just to clean up the legacy of the past, 40 billion to a trillion dollars are the estimates as what the costs could be. We are hiring a lot of our students in this area at the moment. Also, we are thinking about how do we meet the needs with undergraduate environmental engineering programs. I would just like to list or state what I see as some of the issues and reflecting on what we've seen in the past.

We learn from the comments, the discussions, that have gone in our past conferences, we can see these issues have come up over and over again.

Addressing the undergraduate curriculum, I think we need to ask ourselves: (1) to what extent should we increase the emphasis on undergraduate education in environmental engineering? And, (2) if we agree that extensive change is desirable, how might this be done? Should we develop environmental engineering as a separate discipline, as an option under existing specialties such as civil engineering, by some other means, or all of the above? Important here, I think, is how will such changes affect our offerings at the graduate level and how we address the differences in backgrounds of students coming from different undergraduate engineering science programs. Will these undergraduate degree programs tend to increase or decrease the diversity of our graduates, and will they be more or less capable of addressing the broad problems they will be called upon to help solve during their professional lifetimes? I think those are some issues we need to wrestle with in the deliberations.

Concerning hazardous waste, among the questions I think should be addressed are: (1) to what degree should elements of hazardous wastes and hazardous substances be incorporated into the educational program? (2) Is it appropriate to develop a special field for hazardous substances on par with the fields of water supply and wastewater, air pollution, and solid waste, or should hazardous substances be incorporated into such programs only as a specialty item? (3) Should the emphasis be on hazardous waste, per se, or the intermediate aspects of contaminants as with the focus at the last conference?

Judging from the last conferences, I am sure we are going to have a lot of lively discussions. Also, based on the previous conferences, I am also sure that we will all return home with a much better understanding of the issues we are going to face and better knowledge about how to approach them. I think the beneficiaries will be ourselves and our students, and, I hope, society and the environment as well.

ENVIRONMENTAL ENGINEERING EDUCATION IN THE YEAR 2000 - WHAT IS NEEDED

Keynote Address - Academic Perspective

Walter J. Weber, Jr.
The University of Michigan
Ann Arbor, MI

The proper management of our environment is a challenge of escalating magnitude and profound consequence. Popular media carry regular accounts of our disregard and failure to meet the challenge adequately. The massive and purposeful discharge of oil into the Persian Gulf, and the continuing oil-well fires in Kuwait, are only the more recent of flagrant abuses by man of his environment. Outdated industrial facilities in eastern Europe have left the air, water, and land in that region severely polluted. The Chernobyl nuclear reactor in the Soviet Ukraine spewed tons of radioactive material into the atmosphere a few years ago, causing widespread contamination and forcing the evacuation and indefinite abandonment of the surrounding area. Megascopic trauma, such as the destruction of rain forests in South America and volcanic eruptions in the Pacific Rim, have inestimable effects on the global environment.

Our country is certainly not exempt from major environmental problems. The number of rail and highway accidents involving toxic chemical spills is increasing at an alarming rate, up 50 percent in 1990 according to the National Transportation Safety Board[1]. The recent derailing of a train in California led to the dumping of a railroad tank car of herbicide into the Sacramento River, killing nearly every aquatic species over a stretch of 45 miles, and jeopardizing the water supply of millions of Californians. Across the country, water containing radioactive materials is seeping into aquifers near sites at which nuclear material has been processed and disposed. High and low level nuclear wastes continue to accumulate, even as plans for more adequate disposal facilities are challenged and debated. Hazardous waste disposal sites number in the thousands nationwide, leaking underground storage tanks in the hundreds of thousands. The air in regions such as the Los Angeles basin seems permanently polluted. Municipal and industrial landfills are rapidly becoming filled. Acid rain is impacting the quality of lakes, rivers, and forests everywhere. Pollutants from a variety of sources threaten human health as they pour into water supplies and food chains.

These sound like environmental versions of Waterloo, Little Bighorn, and Dunkirk sans bateaux, rolled up in one!

In the face of such dire prospects, one can hardly afford, as suggested by the title assigned to this lecture, to be entirely *academic* in his perspective of need. Let us rather consider a perspective by Russell Train, Chairman of the World Wildlife Fund and the Conservation Foundation, on the state of environmental issues, a perspective that is certainly more than academic. In testimony before the Senate Committee on Foreign Relations in 1989, Train stated that:

> "Global environmental problems inevitably will become the principal focus of international affairs. The single overriding long-term issue facing the world community is how to achieve and maintain a sustainable balance between growing human populations and the natural systems of the earth upon which all life and all human activity depend"[2].

I suggest that it is in *this* perspective we must ask ourselves, what is needed?

WHAT IS NEEDED?

For starters, let us say that appropriate environmental management requires highly trained professional specialists having broad abilities, enabling them to address complex and divergent environmental problems, and coordinate the efforts of others having more highly specialized skills required for each specific problem. That is, clearly, a safe "mom and apple pie" position to take in articulating needs for the future of environmental engineering education. Planned or not, our current intellectual stock in trade in environmental engineering education has emerged in form and grown in substance over the past thirty years to meet just such a perceived need; that is, for persons with a clear understanding and command of technical issues involved in environmental problems, as well as a sound sense of the social, economic, and political consequences of these problems, and, eventually, of their solutions.

If this is so, what more should we do? Have we done enough? Are we sure enough of that? What questions need we face in deliberation of what is further needed? Certain of these questions must necessarily deal with fundamental, soul-searching issues, while others relate more to logistics and to matters of curricular "accounting".

In any event, there are questions to ask. By way of example, I profer a few of the more general of those commonly posed:

-What is environmental engineering?
-What will our graduates do?
-Is there a need or place for an undergraduate degree?
-What material should comprise a program core?
-What alternative foci should be included?
-And what other program elements?
-Is ABET accreditation necessary, or even desirable?
-Should we be organized as a department of environmental engineering?
-Or perhaps even as a part of an organized school of the environment?

I suspect we each have our own perspectives on what the answer to each of these questions is or should be, but which of these answers will stand the test of consensus and time? It is axiomatic that the answers at which we arrive will depend to some extent on how we structure the questions. It is essential then, to ensure that we fully know and address the character and detail of significant questions.

Although I do not have all the right answers, or necessarily even the right questions, I welcome this opportunity to share my thoughts about how the identification and articulation of the questions might proceed. I believe there are three issues that should be placed and maintained in perspective as specific questions are asked and answers posed, namely: the *origins and roots* of our field; some prevailing *physical truths*; and, the *attitudes and philosophies* with we approach the teaching and practice of our art. To support these suggestions, I call upon the accumulated wisdom and gathered words of many others, most particularly Petroski[3], Copernicus[4], and Luthy et al[5].

Let us begin with our *origins and roots*, and examine, in an historical context, the question of curricular core for the discipline of environmental engineering, as it exists today. It is my thesis, in starting with our origins, that an appreciation of whence we came may yield a better understanding of where it is we should go.

WHAT IS ENVIRONMENTAL ENGINEERING?

Environmental engineering was initially, and is still in many ways, a specialty of more traditional engineering disciplines, such as chemical, civil and mechanical engineering. The discipline had its earlier origins as a specialty of civil engineering, in what, in reference to the field's original primary concern with the design of water distribution and sewer systems, was called sanitary engineering. As a specialty of chemical engineering, the focus generally has been on processes to reduce wastes emanating from industrial facilities. As a specialty of mechanical engineering, the focus tends to be on reduction of air pollution from machines, such as automobiles, power generation plants, and incinerators. The professional societies for each of these traditional disciplines maintain environmental divisions, apart from professional societies working in particular environmental areas, such as the Water Pollution Control Federation, the Air and Waste Management Association and the American Water Works Association. The American Academy of Environmental Engineers, sponsored by thirteen different professional groups and societies, acts as an umbrella organization for the discipline.

Despite the strong roots of environmental engineering in traditional disciplines, there is an acknowledged need for people specifically trained in the area, since so many environmental problems cross traditional disciplinary boundaries. ABET, the Accreditation Board for Engineering and Technology, currently requires that, at a minimum, an accredited program in environmental engineering must provide instruction in three of the following areas: air pollution control engineering, water quality engineering, solid wastes engineering, and environmental health engineering[6]. Few universities have the resources to cover enough of even this minimum number of focal areas to justify a separate environmental engineering major, especially at the baccalaureate level. The common alternative has been to maintain environmental engineering as an undergraduate concentration area within a traditional engineering discipline, generally in civil engineering, but occasionally in chemical or mechanical engineering, and to develop the first recognized professional degree designation at a post baccalaureate (M.S. or M.S.E.) level.

These are the contemporary curricular realities, dictated in significant measure by our historical disciplinary origins. The issue of roots is important as well in contexts other than curriculum characterization, most particularly in the context of attitudes and philosophies. I would like to address that issue further, but first, lest I be accused of becoming *too* mellow in my middle years, I would strike a curricular position about which, in my mind, there is no equivocation; that is, the *foundation* upon which the core of environmental engineering should be built.

Despite the many socio-politic and socio-economic vagaries we confront routinely in pursuit of our mission, our ability to help man save himself and maintain the quality of his environment is ultimately constrained by our knowledge of the physical, chemical, and biological aspects of so doing. This knowledge must be structured firmly on what I call *physical truths*; in the realm of science, mass must be conserved, and thus, in the realm of engineering, it must be balanced.

It is necessary that environmental engineering programs, however they are structured or administratively housed, produce graduates who appreciate all of the implications of an environmental problem -- social, economic, political, public health. It is a reality, however, that environmental issues are so complicated that it is not feasible to train an environmental specialist who "knows it all."

In the face of this difficult task, we must help our students develop the attitudes and abilities that will enable them to work hand-in-hand with lawyers, science policy makers, legislators, and public health officials to achieve an environment in which hazards and risks are minimized, for our generation as well as for future generations. First and foremost, however, environmental engineering and science students must master the science and technology of their own specialties.

My conviction regarding a strong science foundation is evidently shared by the Committee on Future Concerns in Environmental Engineering Graduate Education convened for this conference, who, in their position paper state:

> "A lesson from the past is that graduates must be prepared for change. As it is not possible to predict with certainty what skills will be needed in the future, students must be educated in the fundamental fields so that they will be equipped to deal with change. This requires training in the sciences as well as engineering; and it requires development of communication skills. --- The

educational atmosphere should include a mix of natural sciences and engineering, and combine engineering with the humanities and social sciences."

I am in total agreement with the Committee statement and position on this issue. The part of their statement I would choose to emphasize most, however, is that our " ... students must be educated in the fundamental fields ...," which I interpret to embrace fully the *physical truths*. I will elaborate by way of a simple statement and then, hopefully having secured this high ground, move on to the "marshes and wetlands" of environmental engineering education.

The National Science Foundation sponsored a workshop on environmental engineering undergraduate curricula last November in Riverside, California ... many of you were there. You will recall we were each asked to identify aspects of our field that we though were particularly important for inclusion in such curricula. My response, while not profound, reflects the profound feeling I have about physical truths, and why they must comprise the core of our educational programs.

> "Transformations in the form and character of constituent components and species (biological, chemical, and physical) underlie and dictate the significance of environmental quality parameters and the processes which affect them. These transformations, in turn, are governed by well defined and quantifiable mass and energy relationships, and regulated by the conditions of the "reactor" systems in which they occur. An understanding of the governing relationships and system conditions, coupled with an ability to describe and integrate these relationships and conditions in comprehensible form (i.e., to model), is fundamental to the characterization and quantification of any and all environmental systems, and is thus fundamental to any environmental engineering program.[7]"

The earth does indeed rotate about the sun, and about its own axis, and that profound physical truth has stood the test of five centuries. Enough and finis, point made! Hale and farewell Niklas Koppernigk, and forward once more to our past. As we explore our revolutionary roots, and examine past successes and failures of our profession to help us plan better for its future development, few of us can call upon personal experiences extending back more than thirty years or so. To be sure, the past thirty years have witnessed dramatic developments in our field.

At the time of our first educational conference at Harvard in 1960[8], environmental engineering was in fact basically water supply and water pollution control engineering. Management of the public water supply was of utmost importance at that time. We were undergoing rapid expansion both in population and industrialization. Raised standards of living meant greater demands for water. The manufacturing industries have developed enormous needs which, when coupled with increased household use, had raised the annual per capita consumption of water from 40-50 gallons per person per day in the 1930s to more than 200 gallons per person per day by the late 1950s.

A further significant consideration in the environmental issues of that time was that the chemical industry had invented and marketed a large variety of complex and non-biodegradable synthetic chemical products. The extant waste treatment technologies were not capable of completely removing or degrading such compounds, so once they entered the water cycle as components of wastewaters, they began to cause widespread and persistent pollution in streams, rivers, and lakes.

Upland water resources were being taxed as populations moved to suburban communities built on previously remote lands. Political, social, public health, and engineering problems and conflicts developed in the wake of increasing demands for water and increased contamination of available sources.

Water was the main environmental concern of the 1960s and 1970s, but by the mid-1980s, much of the technology and legislation required to adequately address the management of surface waters had been developed and put in place. Environmental engineers began to turn their attention to other major problems, especially those associated with the uncontrolled disposal of hazardous chemicals. Such materials as agricultural pesticides, transformer oils, and chlorinated solvents had been routinely buried in unsecured landfills all over the country during the preceding eighty or more years, without any real appreciation of possible long-term environmental and public health consequences. If immediate or short-term hazards were not apparent, it was generally considered safe and acceptable to bury industrial and municipal wastes underground. The situation was complicated by the fact that undetected leakages from underground tanks used to store fuels or other chemicals were contaminating the subsurface environment over the same period. In the 1970s we began to develop the analytical capabilities required to detect and evaluate the long-term effects of exposure to such hazardous wastes. The concepts of carcinogenicity and mutagenicity began to take shape. The cross disciplinary horizons of our field marched forward by at least 20,000 leagues.

In retrospect, I think we can take a measure of pride in how well our profession has accommodated and responded to the rapidly changing demands placed upon it in the past thirty years, particularly given the vagaries of socio-political-legal conditions under which we have had so often to perform. To borrow an out-of-context, yet appropriate, comment by Alan Burnham in a recent issue of *Physics Today*:

> "I do not think the bureaucracy has evil intentions - the contrary is true. The problem is that the lawyers and accountants who are becoming increasingly responsible for decisions affecting the progress of science and engineering don't seem to understand either science or engineering. Pushed in inappropriate directions by an increasingly paranoid and scientifically illiterate public, they could unintentionally stifle all technical progress in this country while trying to address legitimate public concerns.[9]"

I attribute whatever success we have had in a field seemingly marked by such caprice not to our great wisdom, but to the legacy of humanistic insight and social responsibility provided by such wise teachers as Gordon Fair, Thomas Camp, and Earnest Boyce. I, for one, gleaned as much by way of logic, relevance and motivation from the experiences these great teachers shared with their students as I learned by way of technical expertise from the sound science they taught. Had not that appreciation of context and insight been revealed to me as a student, I doubt that my later experiences would have been as meaningful as they have been in helping me, if not command, at least understand and adapt to the changing needs of our profession.

There is, I believe, a real and present danger of losing sight of this important aspect of the educational process as we try to cram more and more information into our environmental curricula. This is another thought I share with the Committee on Future Concerns, who in their position paper make the case for the *citizen engineer*.

> "The first canon of the ASCE code of ethics states: Engineers should hold paramount the safety, health and welfare of the public in the performance of their professional duties. We reason herein that this ideal requires more than the competent completion of assignments. Modern society needs "citizen engineers" who ask questions, pursue inquiries, and participate in discourse beyond their assignments and contract obligations. We are concerned that, unless deliberate steps are taken, education might not adequately prepare such citizen engineers."

These last thoughts lead me to the third arena in which we seek questions to answer and answers to question; *attitudes and philosophy*.

In this context, what program elements should our curricula embrace? As a strawman, I place communication skills near the top of the list, after basic truths. It is my thought that to communicate our knowledge effectively to those who have no command of our language, we must learn to speak theirs. Certainly this thought bears on the ability of our graduates to communicate, but it also relates to our ability to communicate with them. This goes not only to the issue of attitudes and philosophies that we teach, but also those with which we approach the job of teaching.

It is, as pointed out by Petroski, a reality that engineering courses are often taught in an impersonal manner, providing little if any historical background to the state of the art, or to the characters of those by whom it was developed[3]. Material is often presented in isolation rather than in the context of its application. It is often argued that the amount of material that must be covered makes this necessary, and that the analytical skills being taught do not lend themselves to personalization.

It is true that our crammed technical curricula leave little time for thought provoking digressions. It is just as true, however, that students are more apt to appreciate presentations of solutions to equations describing contaminant transport in subsurface systems when those presentations are spiced with considerations of how the water supply of Glen Avon might have been contaminated by chemicals stored in the remote and seemingly secure Stringfellow bedrock pits. A brief discussion of the morning's news about a soil sterilant spilled by a derailed tank car, and how it became dispersed in the Sacramento River, is a wonderfully engaging prefix to the development of nitty-gritty abstractions of turbulent mixing in open channels.

That students find engineering more interesting and understandable when it is placed in a real-world context is obvious. It is perhaps less intuitive, but just as certain, that history taught to reveal the interrelationships of things and people, technology and culture, engineering and society, can make the educational process much more meaningful and valuable for our students. This aspect of the educational process should occur positively and regularly by design of curricula and their content, rather than as a happenstance of the way an individual may or may not teach.

So much for communicating history and relevance to our students. What of that aspect of the attitude and philosophy issue that goes to imparting a desire and ability on their part to communicate effectively in the socio-politic environment in which they must function? I again invoke a position taken by the Luthy, et al. Committee, namely:

> "We need to help students understand more of the possible leadership roles than they may assume. . . [They] need to become more involved in emerging social and political issues revolving around their field. . . environmental engineers should undertake a participatory role in helping to structure and articulate rational environmental policy. Students should learn more of their place in a complex society. . . [and] help the profession by working at the interface between policy and technology."

No issue with which a practicing environmental scientist or engineer deals is without its cultural, social, legal, economic, environmental, aesthetic and ethical components. It is essential, therefore, that we at least sensitize our students to the broader nature and implications of technology. If this is begun in the educational process, our graduates will begin careers with a maturity and perspective that many now come to only after years of practice, experience, and frustration.

Technology has always been embedded inextricably in social and cultural contexts. The massive efforts to devise and construct public water treatment systems in the 19th century, among the great engineering projects of that time, provide dramatic example of the complex interactions involved in the commissioning and implementation of large-scale environmental systems. The technology itself was crucial, of course, for without it there would have been no hope of reversing the rampaging path of death strewn by cholera and typhoid fever. But it is not the technology of those engineering accomplishments that gives them color and timeless character. Rather, these deeds compel our attention because they speak of timeless forces - human nature, social inertia, politics, and economics - that seem no different today than they were then, or perhaps ever.

Petroski, in *In Context*, draws upon a work entitled *What Engineers Know and How They Know It*, written by Walter Vincenti, professor emeritus of aeronautics and astronautics at Stanford University.

"Countless technological triumphs may be offered to refute any contention that there is a lack of understanding of engineering among engineers; technological efficacy, however, is not equivalent to technological savvy. The triumph of airplane design stands in contrast to the frustrations and anxieties of air travel. The successes of our interstate highway system are in contrast to the horrors of gridlock in our cities. The miracle products of chemical plants are in contrast to leaking barrels of hazardous wastes. The dream world of personal computers contrasts with the nightmare of trying to resolve a computer billing error. Such dichotomies of modern technology seem to raise serious questions about just how much engineers really do know, especially when it comes to the impact of their work on society.[3]"

I have come full circle on the points I have pursued, and perhaps have chased some of them several times around the May pole. In closing, I return to our original question of *what is needed*, and how well we fulfill the original mom and apple pie response in our education of environmental engineers. We have come a long way since our first meeting in 1960, but so have the problems. We have gained ground in the arena of physical and biological sciences, though there is yet much more to do. I am afraid, however, that we have lost ground to the increased complexity of socio-politic and socio-economic problems, and to the enlarging global horizons across which we must function.

Engineering is popularly viewed by the lay public as an unfathomable art, practiced by incommunicative people. Environmental engineering is further shrouded in the mysteries of hazardous and toxic chemicals having unpronounceable names and incomprehensible acronyms. This mystique is in no small measure traceable to the ways in which engineers and non-engineers are educated. Engineering students, on the one hand, are all too sparingly exposed, if at all, to the social contexts of the profession they are to practice. Thus many, when cast into the practice of an engineering profession in a socially and politically dominated climate, are often confused and unsure of themselves, and of what they know. Although they may very well be capable of out-reach and communication, and usually are, the situation is not one which encourages them to do so; so they seldom do. The counterpoint is that non-engineering students are seldom attracted to, or have the prerequisites for, even introductory level engineering courses. Thus, those who are most likely to become the policy makers and business leaders of our society are rarely capable of speaking the language of those who will lead our technology. It is, I believe, incumbent upon those who ... "can, but seldom do" ... to take the lead in communicating the understanding and knowledge required to achieve and maintain the sustainable balance referenced by Train in his treatise on environmental concerns.

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ENVIRONMENTAL ENGINEERING EDUCATION IN THE YEAR 2000
A RANDOM WALK

Keynote Address - Practitioner Perspective

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INTRODUCTION

What an exciting time to be an environmental engineer facing a myriad of environmental challenges - from the control of air toxics to the clean-up of hazardous waste dumps, from waste minimization to recycling systems; from the treatment of contaminated aquifers to the clean-up of oil spills; from water conservation to water reclamation; and from rehabilitation of the underground infrastructure to global warming. Our problems and concerns are ever broadening and ever more complex.

Twenty-five years ago, I left the hallowed halls of academia with a freshly printed diploma and entered the practice of engineering. I had planned to be a teacher, and perhaps someday I will, but circumstances dictated that I enter the consulting business. At the same time, environmental engineering was dominated by the concerns of water and wastewater. I, like many others, received a traineeship from the U.S. Public Health Service, without which I would have been a bridge designer.

Today's new environmental engineering graduate may still design a water or wastewater treatment plant, but he is just as likely to develop a genetically engineered bioremediation system for a Superfund site or design a sophisticated system to collect and control air toxics. Classic environmental engineering programs dealing with water and wastewater no longer provide a sufficient educational base on which to build a career in environmental engineering.

Our profession differs from most in that it is not driven principally by economics or competition, but rather by legislation and regulation, which in turn reflect the broad desire of our society. Thus, a fairly good view of the future in the environmental field can be garnered from an examination of current and proposed legislation. As I have said before, through the environmental crystal ball float the acronyms of environmental legislation - Clean Water Act, Clean Air Act, TOSCA, OSHA, RCRA, CERCLA, SARA. What are the trends that will influence our field and our educational programs?

-It is almost axiomatic that regulations always become more stringent, are rarely relaxed, and are never repealed.

-Society is striving for a risk-free environment, zero contamination, but is slowly beginning to take into consideration risk assessment in setting objectives.

-Trace toxics in the environment is, and will continue to be, the single largest issue in our business.

-Increasingly, the legislation crosses media boundaries, weaving a complex web of environmental regulations. Consideration cannot be restricted to one media, but must consider the impacts on all media - water, air, and land.

-In the face of increasingly complex esoteric environmental problems, we will still have to face the mundane issues of water and waste-water treatment, rehabilitation of the underground piping systems, and the disposal of solid residuals.

You have perhaps heard of the "random walk" theory of stock market investment. This afternoon, I would like to take a random walk through environmental engineering education - giving you my views on a variety of topics from undergraduate environmental engineering degrees to practitioner participation in education. I hope it does not turn out to be a mine field.

MEETING THE FUTURE NEEDS

Let me begin with the broad educational needs of environmental engineering as viewed by this practitioner, a practitioner whose company covers the gamut from process development through design, construction, and operations. As we look to new graduates, we are seeking three general types of employees - first, good basic civil engineers; second, advanced degree environmental engineers; and third, scientists, specifically chemists, biologists, and geologists.

There are many projects that a basic civil engineering background can readily accommodate. We are facing billions, perhaps trillions, of dollars of expenditures for repairing and replacing our infrastructure, especially the buried utility pipelines that undergird our metropolitan areas. Moreover, large environmental design or construction assignments require engineers experienced in the <u>management</u> of those activities, albeit with some familiarity with chemical and biological processes, but not necessarily process engineers. For example, we would be delighted with a new graduate specializing in construction management, but with some environmental engineering exposure - better yet, a civil/environmental engineer with a masters degree in construction management.

For those more sophisticated biological and chemical systems, we clearly need highly trained specialists in environmental engineering. These individuals must be well grounded in science and engineering fundamentals, capable of analyzing complex problems and developing creative approaches for treating trace toxics and bioremediating contaminated soils. The education of these individuals is the principal focus of this conference.

Finally, we have found that we can use individuals with basic science degrees, preferably advanced, to support the engineering functions. Chemists, biologists, and particularly geologists are invaluable in hazardous waste remedial investigation and feasibility studies.

My purpose in describing these broad categories is to impress upon you the need for diversity. There is no one curriculum that would satisfy all of our needs. We are seeking top-flight environmental engineers with masters and doctoral degrees, but we must also have strong civil engineers and the support science and engineering disciplines in order to address the entire spectrum of environmental problems.

Yet there are some common threads that I believe should permeate our educational process. First, and foremost, the need for good science and engineering fundamentals - chemistry, biology, transport phenomena - is essential. Better grounding in theoretical fundamentals will carry you through a lifetime of environmental engineering practice while the design of secondary clarifiers may have limited application in the next century.

At the same time, there is a growing dichotomy between the need for more technical education and the recognition of the value of a broader exposure to liberal arts. If I could choose but one attribute that I would like to see in the new graduate, it is the ability to write - to communicate. The young engineer who can express him/herself well will usually rise to the top in practice.

Coupled closely therewith is a strong appreciation of humanities and liberal arts. They provide a broader appreciation of society's needs and motivations, help create the "renaissance" engineer. History, economics, political science, English are important elements of the environmental engineering curriculum. And so, we are asking for more in both technical and liberal arts courses and yet expecting to accomplish these objectives within the same time constraints.

Recognizing that the curriculum is already overloaded, there are even more demands. One must not overlook the value of management training for today's engineers. Employers are generally prepared to train the new graduates in design and management, but some appreciation of management concepts would be helpful. Realize that the best engineers often become the best managers and rather rapidly leave the purely technical field. One particular concept that needs to be introduced and reinforced is that engineering today is accomplished as a team, not as an individual.

And finally, I strongly believe in the need for an engineering education if we are to best serve society and solve the environmental problems of today and tomorrow. Sometimes, I feel we lose sight of the importance of the engineer. Engineering is the application of science to meeting the needs of mankind. It takes special training to develop the logical discipline to translate scientific concepts into beneficial projects. The scientist can provide the theoretical basis and the social scientist can help determine society's needs, but the engineer is the critical element, the tool, for creating better solutions to environmental problems.

UNDERGRADUATE ENVIRONMENTAL ENGINEERING DEGREES

With the explosive growth in the environmental engineering field, there is growing pressure to develop more specialization at the baccalaureate level. This is a complex issue. On the one hand, I believe that there is a need to begin to specialize in environmental engineering during the undergraduate program and yet, as I mentioned earlier, there is a need for more fundamentals and more humanities. In essence, I see a need for more education, not less.

But let us step back and examine the basic civil engineering undergraduate program. What could we give to specialize in environmental engineering? Certainly, we could look at the structural courses, highways and surveying, and suggest that some of these could be replaced with environmental courses. Some appreciation of structural design and a survey course in other civil subdisciplines would still be useful.

As we approach the concept of the baccalaureate degree in environmental engineering, we must retain the fundamental premise that we are training engineers and that the product of these programs must be capable of engineering practice. My review of existing and proposed baccalaureate programs in environmental engineering suggests that these graduates will lead useful and productive engineering careers. They will have ample job opportunities upon graduation, but I am concerned that the curricula simply do not provide enough time or content to adequately train environmental engineers. B.S. environmental engineers are probably better prepared to enter graduate school than standard civil engineering undergraduates and, in this regard, the undergraduate program is a real benefit. In terms of the marketplace, however, I view the baccalaureate degree in environmental engineering much as I view a baccalaureate degree in business administration. It is a useful degree, but it is much less marketable than the masters degree.

Undergraduate environmental engineering education, however, may be a superb opportunity for civil engineers to regain the high ground - to attract greater numbers and higher quality students. Environment is the issue of the 90s and it will attract our best and brightest. Traditionally, environmental engineering has resided within civil engineering, and I would prefer to see the civil engineering departments creatively address the issue. The departments must offer environmental options, to promote these programs, and not make them subservient to structures, highways and other subdisciplines. Eventually, I think many environmental programs will take on a life of their own and become separate or affiliated departments.

SPECIALIZATION VERSUS GENERALIZATION

Another issue facing environmental education will be, and needs to be, the issue of specialization at the graduate level. In years past, environmental engineering itself was a specialty, but now we must consider air pollution, hazardous waste management, waste minimization, and water and wastewater engineering. Ideally, at the graduate level, one would acquire a broad appreciation of environmental engineering while recognizing the need to achieve a fairly high degree of specialization. Once again, the focus should be on scientific and engineering fundamentals. Transport phenomena in water, air, or soil, for example, have many similarities. The biochemistry of wastewater plants and in situ bioremediation systems have many commonalities. The fundamentals are the same, or nearly so. We cannot expect a masters or doctorate specialist in air quality to design a wastewater treatment plant, but we can expect that individual to have some appreciation for the problems encountered in another media.

QUALIFICATIONS FOR GRADUATE SCHOOL

As many of you know, I was the Kappe Lecturer for AAEE in 1989. It was a delightful experience. One of the questions that I was asked frequently was whether one needed an undergraduate engineering degree to pursue a graduate degree in engineering. I must admit a strong prejudice on this particular point, for I believe that an undergraduate engineering education is a unique experience. A degree in pure science cannot and should not be equated with an engineering degree.

The issue is whether individuals with degrees in chemistry, biology, and geology can enroll in graduate environmental engineering programs and become engineers. As I have said before, more science makes better environmental engineers, but all science does not an engineer make. In my experience, individuals lacking the undergraduate engineering background are of less utility, at least in the consulting engineering business. They are less likely to lead projects and, interestingly, they seem less willing to use the team approach to solving problems - perhaps that is because science programs foster an individualistic approach to problem solving.

Having said this, I also recognize that a science background is often better preparation for the up-front investigations, particularly in the area of environmental contamination. The chemistry and biology influencing soil contamination or the geophysics involved in subsurface material transport must be understood. There is a very strong need for environmental scientists, but I would prefer the degree to be in environmental science, not engineering.

Alternatively, some programs require non-engineers to take a core engineering curriculum in addition to their regular graduate program. In many ways, this approach is the best of all worlds - for the student acquires an appreciation of the engineering method and yet brings an enhanced scientific background to his studies. It is a powerful combination.

OUR ROLE IN SOCIETY

As citizens of this great country, we are all part of grand process, whereby the collective understanding and will of the people controls our future. As citizens, we have an obligation to be involved in the political process, but most engineers deliberately avoid political involvement. By their very nature, engineers are logical thinkers. They seek the truth as though there is a correct answer to any engineering problem. Some will say that politics is the antithesis of logical thinking - it is the art of compromise.

I would argue that it is imperative that engineers become more involved in the political process, particularly in the environmental field. Each of us has an obligation to share our best technical knowledge with the public and in terms that are understandable to the layman, to advise them on risks, costs, and benefits associated with environmental control. To some, there is a greater obligation, of greater involvement - local, state, or even national politics.

It behooves the universities to incorporate an appreciation of political science into their curriculum. Coupled with that exposure should be coverage of professionalism and ethics. We need to turn out engineers with high ethical standards, professionally motivated, and yet who understand and can operate within our political process. All too often, engineers develop and devise the "best" technical solutions in a vacuum; technical solutions that are totally rejected by society. My company is involved in the dioxin clean-up at Times Beach, Missouri. It calls for the incineration of about 100,000 cubic yards of contaminated soil. The local citizenry objects vociferously to the construction and operation of a hazardous waste incinerator at that location. Technically, incineration is clearly the soundest solution available, but its implementation demands public education and political involvement. Consider also the disposal of radioactive waste, and the seemingly futile search for sites in states that will agree to the safe storage and management of these materials. Fifteen states allow hazardous waste land disposal. The best technical solutions can only be achieved with active involvement with the community.

DESIGN IN THE ENVIRONMENTAL ENGINEERING CURRICULUM

A particularly acrimonious issue between some practitioners and some academicians is the issue of whether or not a professional engineering license should be required to teach a design course. Some would argue that requiring design courses are a waste of time and money for graduate students pursuing advanced degrees for purposes of teaching and research. I strongly disagree. The ultimate purpose of research is to solve problems in the real world - problems that usually will require a design solution.

If for no other reason, therefore, some appreciation of design is valuable to the researcher, if only in a tangential way. Furthermore, if one becomes a professor of environmental engineering without any exposure to design, can one expect to teach design effectively? Finally, many of us wind up far afield from the academic direction on which we embarked as a doctoral student.

On the issue of courses taught by licensed engineers, I take a middle ground. I believe that it is essential that design courses be taught by someone who has an understanding of design, whether registered or not. I would offer that it is preferable that the faculty be licensed professional engineers, but I also recognize the difficulty of achieving registration in some states without several years of full time practice. I recently heard one distinguished professor (and professional engineer) use the term "academic practitioner" - I rather like the phrase. We should encourage our registration boards to re-examine the requirements for practical experience as it relates to full time teaching faculty.

ACCREDITATION

One of the most contentious issues in engineering today is the question of accreditation. Some practitioners believe the ABET process is dominated by academics with a far too theoretical focus, i.e., "eggheads." On the other side are the academics who view the ABET requirements, particularly on design content, as unduly restrictive and the practitioner reviewers as "bozos." While there may be some truth on both sides, I, for one, am distressed at the growing friction. If allowed to fester, all parties will suffer, especially the students.

Why do we have accreditation? I am not familiar with the history of engineering accreditation, but it seems to me that its intent is to assure society of a standard of engineering education quality so as to protect the entering freshman, as well as the ultimate employer, from substandard academic programs. It provides assurance that our engineering graduates have mastered certain fundamentals and achieved specified levels of training before embarking upon a career.

I understand that my alma mater, CALTECH, dropped its accreditation and that other prestigious universities have, or are considering, this action as well. I suspect that the faculties of these elite schools feel that they do not need accreditation, that their level of academic quality is apparent to all. But I would argue that they are doing a disservice to their students and to the profession. If accreditation is a measure or standard of quality, then failure of the top schools to seek accreditation reflects adversely on that standard of quality and thereby on the engineering profession. Moreover, many states require graduation from an accredited school before one can seek to become a professional engineer and, therefore, these schools prevent their own students from achieving registration.

Other accredited schools undoubtedly respond by saying "the hell with that, we don't need them." To the contrary, if the CALTECHs, or MITs, or Stanfords of the country drop accreditation, it will migrate like the wave from a pebble dropped in a pond. Others will decline to expend the time and effort to maintain accreditation and it will become meaningless.

It is imperative that the practitioners and academics recognize their common purpose and solve the obvious problems that exist with the ABET process. We need to involve practitioners who understand the educational delivery system, not dogmatists who mandate inflexible requirements. We need to provide the flexibility to accommodate both the highly theoretical engineering institutions and the more practice oriented engineering programs. Diversity in engineering programs should be a strength.

The unique problem in environmental engineering relative to graduate level accreditation must be addressed. The Engineering Dean's Council opposes dual registration of undergraduate and graduate levels and yet, in most institutions, environmental engineering is only a graduate program. Currently, most graduate environmental programs are not accredited, and it seems unrealistic to believe that such accreditation will become widespread in the near future.

Engineering accreditation, especially in environmental engineering, is among the most difficult problems that must be solved in the years ahead.

SPECIALTY CERTIFICATION

A related area is a seemingly growing interest in specialty certification in engineering. The American Academy of Environmental Engineers is one of the few specialty certification organizations and it co-sponsors this conference. The American Society of Civil Engineers is actively examining the entire question of specialty certification and you can expect to see a position taken on this issue within the next year. If the profession does not adopt specialty certification voluntarily, as in the medical profession, one may well see individual states legislating such certification.

Ultimately, one may expect that specialty certification will also be tied to accreditation, possibly to specialties such as environmental engineering. Perhaps more important than specialty certification is the issue of continuing education. Few states require continuing education as a requirement for maintaining a license, but one finds it difficult to argue with the concept. As we begin to approach the issue of continuing education, I suggest that you in the academic world will have to become involved.

THE PRACTITIONER'S ROLE IN ENVIRONMENTAL ENGINEERING EDUCATION

Finally, I want to address the issue of practitioners in the educational process. The concept that academic programs should incorporate practicing environmental engineers into the curriculum is wholeheartedly endorsed by most engineers. The problem is how to accomplish this objective consistently and effectively. Will our best or even our good engineers take the time to be a real participant with the university? Will their employers provide the time, or perhaps extra remuneration, to participate? How does that participation take place?

Quite frankly, most of us in practice, as you in academia, are very busy and it is difficult to find time to participate on campus. Let me examine a few current efforts and suggest some alternatives. First, some schools do utilize practitioners to teach courses on a part time basis, and usually these are design oriented. Another concept might be to establish an "engineer in residence" wherein an experienced engineer would participate or reside on campus full time for a few weeks or even a semester. This approach would provide an extraordinary opportunity for the students and faculty, not only to interface in class, but to share their research ideas with the practitioner. The obvious question however, is how such a resident program would be funded; perhaps employers would be willing to subsidize this type of extended leave.

The Kappe Lectures, begun in 1989, are another important effort to involve senior practitioners in academic programs. I visited a dozen campuses and made every effort to meet with both students and faculty in small groups. It was an exciting experience and I hope the students gained as much as I did. But, such a lecture series has limited impact unless it is expanded on some type of regional basis.

What about the possibility of post-doctoral fellowships for academically inclined graduates at environmental engineering companies? Or sabbaticals for faculty? Such fellowships would clearly anticipate that the individual would return to the academic world after six months, a year, or two in practice. Funding for this program might be fairly easy to secure from participating firms.

SUMMARY

We are fortunate to be environmental engineers - the future is extraordinarily bright. For those of us in practice, the opportunities continue to grow exponentially. For those of you in academia, there will continue to be a strong demand for your products - your students and your research. I hope that this Sixth Conference on Environmental Engineering Education will help foster a closer relationship between those of us in practice and those of you at the universities. We are concerned about your programs. You are the people who keep us on the cutting edge. You are the people who provide us with the trained and skilled engineers for today and tomorrow.

Practitioners are not a monolithic group - speaking with one voice. But, I do believe that I speak for most practicing engineers, wanting to share our thoughts and to participate with you in developing environmental education programs to meet the needs of the future. Like you, we are often too busy to take the time to meet and discuss our common problems. But, we must seek more frequent forums than every six years to share our concerns.

As you debate critical issues in environmental engineering graduate education, the need for undergraduate environmental programs, and the structure of hazardous waste curricula, keep in mind that diversity - of opinion and of institutions - is what keeps us strong. I am privileged to have had the opportunity to address you this afternoon. I look forward to participating with you over the next two days - quite probably changing my opinions by the time I speak to you again on Tuesday.

ENVIRONMENTAL ENGINEERING IN THE YEAR 2000

Keynote Address - Public Perspective

Dennis Hayes
Founder of Earth Day 1970 and 1990
Green Seal, Palo Alto, CA

When the late humorist Robert Benchley was an undergraduate at Harvard, he spent most of his time working on the Harvard Lampoon and took some great pride in never attending any lectures. He was in some softer subjects, the social sciences and the humanities. And, there, if you are fairly good with words, you can get through it; it is not like having to take an engineering course and going in having not read the book and not heard the lectures. There you can at least get a C and a D in humanities if you've done nothing, ordinarily. There was an exception. He walks into this class on international affairs to take his final examination having no idea about anything that was said in the entire term, saw that the final exam consisted of one question: "Please discuss at length, first from the perspective of the European economic community and then from the perspective of the United States, the new proposed fisheries agreement for the North Atlantic." Benchley sat there for about 15 minutes absolutely stymied, having no idea what this agreement was, let alone how either of those entities would approach it, and then decided to approach it honestly. He began his answer, "I know nothing about the North Atlantic fishing treaty as it would be viewed from the perspective of the Europeans or the Americans and, hence, today I am going to discuss it from the perspective of the fish."

And that is sort of the role that I am playing with you here this afternoon. I actually did teach engineering for six years at Stanford but that was because the engineering requirements were so very great that if they wanted students to learn any economics or political science they had to give it an engineering number, and they brought me in to teach it. I have also had no experience at all as a practitioner. I think you can make a case, I am not going to go on into it in great detail, but I think you can make a case, however, that the public with regard to environmental engineering is somewhat in the same position as the fish with regard to Mr. Benchley.

Twenty years ago, in 1970, an absolutely unprecedented event took place. Somewhere between 20 and 25 million Americans rose up, came together on an issue, and began to change the way that America does business. If you look at environmental courses that were set up, by and large, there was this great explosion in 1970 and 1971. If you look at legislative history, it is an incredible explosion at the federal level, the state level, the Clean Air Act, the Clean Water Act, the Occupational Safety and Health Act, the defeat of the SST, issue after issue after issue, from your perspective, the Environmental Education Act of 1971. All of these things hit with a burst during that brief period of time.

And, in some large measure, to a degree that it is sometimes difficult to remember in perspective of today, it was a children's crusade. There were a lot of conservation organizations but, by and large, they were worried about all of this new environmental activism that was coming down, and they played sort of a peripheral role in it for the first few years. The people who coordinated the Clean Air Act of 1970 were essentially all under 25 years of age, in the environmental perspective, the environmental lobbyists. And that first Earth Day in 1970 was, in essence, put together by kids. The idea for an environmental teach-in first came from Senator Gaylord Nelson, but the people who organized it were on the campuses of the country.

Whenever you have an event like that, it emerges from a certain sort of context. We had one in 1990 and it emerged from the context of the 1980s. We had one in 1970 and it emerged from the context of the 1960s, and the essence of what I am going to be discussing in this brief little talk about the public context of environmental education is the difference between something that arises in the 1960s and something that arises in the 1980s. I think, in 200 years of national history, you will not find two decades more dissimilar than the 1960s and the 1980s.

I was an undergraduate in the 1960s. I went to Stanford University. Those of us with an activist thrust at Stanford were always somewhat jealous of our colleagues across the bay at Berkeley who always seemed to be getting into something. Often, getting into jail. But despite our relative calm at Stanford, my senior year at the university we seized and occupied the president's office, three times. We seized and occupied the applied electronics laboratory; we seized and occupied the computer center; we seized and occupied the undergraduate admissions office; we seized and occupied the undergraduate library. We had a reunion in 1989 and I went around the room and asked easily two dozen people: "Why did we seize the undergraduate library?" Nobody had the slightest idea.

The activist's countercultural attitudes of that period were important. I am going to talk just a bit about this sort of generational attitude. This comes from the guy who worked on the Earth Day campaign. It was all over and it is like a political campaign; you are just going 20-21 hours a day week after week after week seven days a week and then the event happens and it is over, and nobody has been elected. You go through this decompression and when it is all palliated by kids, you come to this awkward realization that you have to go out and get a job. And, in the modest way that this guy viewed things, he decided that what he really wanted was a job where he would not hurt anything too badly. He thought about it a while and decided he would try to be a mailman, went down to the post office, picked up the Civil Service form, began routinely filling it in, and the first parts he handled pretty well: name, address, phone number, education. Then, he came to the question: "Do you favor the overthrow of the United States government by force, revolution, or violence?" Being a true child of the 60's, he assumed it was a multiple choice, and circled "revolution".

It was, in short, a totally, totally different era. And one that was dominated on the college campuses of that time by a feeling of horror coupled with the feeling of generational arrogance. We looked around us at a war in southeast Asia that a great many of us thought should not be fought; had racism; and had the destruction of the physical environment, both in our cities and our wilderness areas (at that time the big one in 1969 was the Santa Barbara oil spill, but there were myriad other issues as well from those raised around pesticides by Rachelle Carson to freeways destroying the intercity). We had this attitude that we were going to do things differently; that we were going to pass on to our kids a far better world than we had inherited from our parents. It manifested itself in a lot of generational expressions: "never trust anyone over 30" was a popular one that I personally abandoned some years ago.

It was an attitude that, in retrospect, was simply wrong. We thought of ourselves as the first generation raised on television, so maybe somehow that would make us better. We certainly knew we were the first generation with Strontium 90 in our bones from atmospheric nuclear testing. We thought that somehow the context within which we were raised, the post-World War II context, was going to be so different from the pre-World War II context that we would blossom up. There were people writing books about the greening of America who talked about this generation inheriting the nation, and, basically, in a fundamental incomprehensive cultural revolutionary way, transforming this society.

Those of you who listened to Walt Weber's presentation earlier today, if there had been any confusion at all before, came to a bleak understanding that we have not transformed this society. It sounded like a description of Dunkirk without the boats. It is bleak. In area after area after area and in particular in the environmental field since that is what we are addressing today, not only have things not improved, essentially every global issue has gotten substantially worse over the course of the last 20 years: talking about human population growth which now harvests directly and indirectly about 40 percent of the net biological productivity of the planet, on through endangered species, to ozone destruction, to global warming, to toxic waste, to ocean pollution, to what have you. Even the relatively easily solved problems, the ones where we have had the nation's attention focused upon them for protracted periods of time and there is not too much ambiguity at least about what some of the central aspects would be of a solution, things like energy are still problems. We walk up to the problem, make very little or no progress, and walk away from it. In 1978, 67% of the American public thought that the energy problem was the nation's highest national priority. Today, substantially less than 1% believes that. Nothing has changed. We have certainly made no significant advances nationally in energy policy, but we have walked away from the issue and you can make that case time after time after time for a wide variety of different issues.

In 1990, something like 1970 took place again, except this time it was incomparably bigger. Instead of 20 to 25 million Americans, we had more than 200 million people in 141 countries around the world come together on another huge event, in part designed in some countries to grab their policy makers by the lapels and say: "Hey, we are serious; this stuff is important." But this time, somewhat differently than before, we were also metaphorically grabbing ourselves by the lapels saying: "We cannot really rely upon government to do all of this stuff."

There is a reason for that change and I am going to briefly address it. One thing that we learned over the course of the last 20 years is that generational arrogance was misplaced, that there is a huge amount of stuff that we just do not know. No, I'm not talking now in the realm of opinions, even in the realm of facts, vast things that we all assumed were truisms before turn out to not be true. We got ourselves blindsided. Things like CFCs, and, if you had talked to industrial chemists around the United States at the time of the first Earth Day in 1970 and said: "Hey, you guys have gotten yourself in a bit of a soup with pesticides and a bunch of other things. Give us an example of some clear achievement, something that does a lot of good and does not do any harm." I would bet on just about every short list of four or five such substances you would find CFCs - wonderful compounds. Excellent efficient refrigerants, nontoxic, noncarcinogenic, essentially inert. When they had that movie "The Abyss" and somebody wanted to go down to the bottom of the ocean and was afraid that his lungs were going to be crushed if there was any kind of air so they had to have some kind of oxygenated fluid in him, what they pumped through him was oxygenated CFCs. It was a fluid. They are that safe. It was not until four years later that Professor Sherwood Rolland at the University of California at Irvine built the first theoretical model that indicated that maybe these things might hydrate up into the stratosphere and have a chlorine atom chipped off. It would then start catalyzing the destruction of ozone and go on for a very, very, very long time, maybe a century. And it was not until 1985 that we learned that not only was that happening, but happening at a far more rapid and more geographically concentrated way than any those early models had suggested. In fact, when the British researchers who discovered the Antarctic ozone hole discovered it, they did not announce it. They did not publish their findings for a full year. They went back and repeated them because they were so much at variance with all the models that existed for how CFC should act in the stratosphere that they assumed that it was an instrument error. It could not be right. CFCs moved from a place on everyone's short list as one of the true triumphs of modern industrial chemistry to being one of the greater threats faced by the planet. It is the one thing that has managed in the last few years to mobilize international agreements and protocols. Probably the one big achievement that will come out of the United Nations Environmental Development Conference in Rio de Janeiro will be a protocol on halons and CFCs and other ozone depleters. That is a fairly dramatic shift over 20 years. And we can go on to issue after issue after issue where, if they are not quite that dramatic, what we knew as facts then have proven not to be facts at all, and it has contributed a new sense of modesty.

Second, we have learned that government can play important roles but that there are significant limits on those roles in the best of times. We have passed strong legislation. Probably annually, as a result of laws that are passed in the United States we spend about 100 billion dollars differently than we would have if those laws did not exist. And we have made some progress as the result of that but much of it is much more limited that you would expect with that kind of expenditure. Moreover, with regard to government, we are now at a position where you can be virtually assured there will be no major initiatives that cost money. The bleak fact is we are broke. The last ten years have seen the United States go from being the nation that is the world's greatest creditor nation to being the world's greatest debtor, seen a tripling of our national debt. Last year, just the interest on the national debt came to just under 300 billion dollars. This year it will be somewhat more than 300 billion dollars. That is equal to not only the environmental budget for all the agencies in the federal government wrapped together, but you throw in the Department of Agriculture, the Department of Commerce, the Department of State, the Department of Justice, the EPA, the CEQ, the Department of the Interior, the Department of Transportation, and NASA. The interest of the national debt is greater than all of those things combined. And this year's deficit will be about 40% higher than last year's deficit as a result of the collapse of the savings and loan industry coupled with Desert Storm. It is going to be 100 billion dollars larger than any deficit ever experienced by any other country in human history. You come in with any new initiative to the federal government today and you get laughed at in Congress and in the Administration. There is nothing new coming down in social policy, nothing new coming down any place except as you can whittle dollars away from something and put some of those savings into the new program.

So granted all of that, there is a compelling need, if we are going to begin to address some of these major issues, to look to some place other than government. In fact, two important developments make that, in fact, a relatively promising avenue. One is that we were not entirely wrong back in 1970. There are some significant changes as people from our generation have gotten tenured professorships, have moved into industry, and have gotten positions of substantial stature in companies that make a difference. An old friend of mine, John Bryson, founder of the West Coast office of the Natural Resources Defense Council, is now the Chairman and the Chief Executive Officer of Southern California Edison. What has he done? About three months ago Southern California Edison announced an energy policy that puts to shame anything that the United States government has done in the course of the last 20 years. John has committed the company to reducing carbon dioxide emissions by 10% by the year 2000 and by 20% by the year 2010, at a time when the service area increases by between 30 and 35% and without turning to nuclear power. And, he has laid out a fairly elaborate strategy to get from here to there. A formidable kind of commitment. You see the commitments that are made by 3M, commitments being made by company after company, and there is something going on now within the industrial hierarchy. I have been having a series of meetings recently with IBM on environmental issues and there is a degree of responsiveness that you simply never found there even five years ago. I do not know how to explain that transformation. I know part of the explanation, which is what we will talk about next. But, there is something in addition that is happening within the corporate culture, within, I hasten to add, some corporate cultures.

The other thing though, and perhaps the more profoundly important thing, is the change in public attitudes. Three years ago if you went around the United States and conducted a public opinion poll and asked: "Are you an environmentalist?" essentially everybody agreed with James Watt being the notable exception. But, essentially everybody says: "Yes, I am an environmentalist" in those vague terms, and then you start following up in a focus group and you say: "What does that mean? What do you do differently than someone who isn't an environmentalist?" They sort of weasel around and most people did not have much of anything to say. A few contributed money to environmental organizations, a handful recycled, but the general response was one of impotence. We are talking about global warming, rain forest destruction, ozone holes. I gave a talk to a group about five years ago, a women's organization, about rain forests and some of the issues that are going on, particularly in the South American rain forest, and this woman came up to me afterwards and said: "You know I have lost five ferns in a row in my office. You really want me to take over the Amazonian rain forest?" There was this big gap between what we perceive ourselves as capable of doing and the enormity of these huge problems that are out there, and what has shifted now is that the perception that seems to have gone through a transformation in the last two years. Frankly, the big peak in that shift was that Earth Day 1990 with our fortune cookie bumper strip: "Who says you can't change the world?" and the 50 simple things to do for the planet Earth; how to save the world without sweating hard or even breathing hard. Tons of books started coming down and people started recognizing that there were things that in the aggregate made a difference. It depends upon an act of faith that everybody else is going to be doing some stuff too, but these are not irrelevancies.

Back in 1970, there was this thing a number of companies published in, full page ads. From Pogo. You have all heard this, right? "We have met the enemy and he is us." The environmental activists of that period, myself among them, by and large said: "What are you talking about? We have met the enemy and he is Exxon. We have met the enemy and it is the Department of Defense. We have met the enemy and it is not me. I may pollute a little bit but Exxon really pollutes." And then we started getting these figures, like Americans last year who changed their own motor oil and threw the used motor oil into the garbage where it went out to a landfill; or worse, surreptitiously threw it in a storm sewer - disposed of the equivalent, according to the EPA, of 16 Exxon Valdezes of used motor oil. "I only pollute a little bit. Exxon really pollutes." But if you have 260 million relatively affluent people doing something like that, you have an enormous aggregate impact. And one, incidentally, that does not get solved by law. Every single bit of that oil disposal is illegal; you cannot put your used motor oil in the garbage or pour it down a drain. That is flat out against the law, and yet 16 Exxon Valdezes worth of oil went that direction. You get into things like lighting. You start replacing all of the inefficient lights in the country with the most efficient lights that make sense and suddenly you find yourself saving, depending on how you do your calculations, somewhere between the equivalent of 50,000 and 75,000 megawatts - as much as 75 large nuclear power plants worth of baseload generating capacity. You have just as much light as you did before, you just start treating lighting as an investment; you spend more for your light, you spend less for your power plants and get a far more efficient kind of lighting. But, suffice it to say that in category after category from the automobiles we drive to the refrigerators we own to how we insulate our houses, the impact on energy is just absolutely astonishing. And in other areas, from diet to probably the most profoundly important one, the decision about how many children we are going to have, decisions that have to be made by individuals - somehow we need to get individuals to make those right choices.

With regard to this shift, something today, depending upon how you ask the question, between 80% and 95% of the public says when asked: "Do you want to buy environmentally superior products?" they say: "Yes". Then you start putting them in the focus groups again and say: "Why aren't you?" and it turns out they do not trust anybody. If you are an environmentalist, when you walk into a supermarket today, you think you have died and gone to heaven. Everything there is biodegradable, photodegradable, degradable, recycled, recyclable, organic, green, natural. It has birds and bunnies and squirrels and trees plastered all over it. And the public does not believe a word of it. The figures for distrust of both manufacturers and retailers are in fact rather chilling. The most trusted company in the country on environmental claims in Proctor and Gamble. 1.8% of the American public believes their claims. These are really difficult kinds of times for companies.

One thing that appears to be very useful for manufacturers who are making superior products and doing it in an environmentally sound fashion, and for people who would like to buy the right products, is to have someone who is an independent certifier who would come in, who does not have a stake in trying to sell anything to anybody, and examine categories of products and say: "These are where we would draw the line." And this is not to say these things do not have an environmental impact - everything has an environmental impact. Even if you stand nude and drink water out of a crystalline mountain stream, as long as you breath you are going to have some environmental impact. But reasonable people getting together in a consensus process that involves environmental activists and academics, and manufacturers, and governmental regulators, and others would say: "This is a reasonable place to draw the line. This is what we can do today technically. This is as good as you should be if you are going to be having people buying products for environmental reasons." There are some products that for a while are not going to be bought, principally by most people, for environmental reasons. If you buy an automobile, in the United States it is tied up with status and sexuality and all sorts of things. But for a huge number of products, like that motor oil, toilet paper, dish washing compound, laundry detergents, light bulbs, by and large we do not have huge emotional investments in those things. We do not even have very much brand loyalty. The principal determinant for why someone buys a particular laundry detergent is whether or not they have received a 25¢ coupon in the mail. That is the big switching device. A huge number of people say if they could really believe that one is better than another environmentally and as long as it does the job and gets your clothes clean (which practically it seems to be a fairly serious problem for some environmentally sound detergents), a huge number of people would be delighted to buy the one that some outside group says is good enough: some entity that operates like an environmental Underwriters Laboratory.

So that is sort of the next wave that at least I am involved with in the environmental movement is to try to mobilize consumers directly. At a time when around the world marketplace economics are becoming triumphant, where we are seeing this emerge in the Soviet Union and Eastern Europe, there is wrapped up in the ideological underpinnings that make a market function an intellectually reasonable way for a society to order its resources, a belief that people possessed of good information about the products they are buying and acting in their own enlightened self-interest will simultaneously be making a series of choices that serve social goals. But if that is to work, people have to have good reliable information about the things that they care about. What do they care about? They care about the price, no particular ambiguity there; you go down to the store and you know what the price is. They care whether it works; well you might buy one and get taken but you are not going to buy two and get taken unless you are fairly stupid. That is what happened to the American automobile industry. People bought cars for a long time and as the industry fell apart with its products people started buying something else. But one thing that people care about for a huge number of products today and that they need to have information on if that market is to function well is the environmental impact of products, and there is no way to get that by yourself. You cannot go down to the factory at the which the product was made and monitor it environmentally as well as the factories where all the ingredients for it were made and monitor them. It is very hard for a person to tell what a detergent does after it goes down the drain. You can sometimes see what the impact of these things are as you use them, but if you vented the CFCs from your automobile air conditioner you would not see what the consequences are of that. Somebody that you trust has to tell you.

And that is why we have set up this organization called Green Seal that is trying to do precisely that. And I am going to give you, for those of you who are interested in it, the address for Green Seal in just a minute or two because one of the things we really want to do is to involve people like you in our process. As we propose draft standards, we would like to have a list of academics, among others, that we can send them to; people who have some competence and no particular axes to grind, who will send us back comments and say "looks terrific" or "it has this fundamental flaw," or "you ought to change these three things and it is going to be substantially better," or "did you know what they are doing in Germany? They are doing this." We need to have that kind of information flow in. We put together the organization. We have issued our first draft standards for tissue papers, for facial tissue, for toilet tissue. Just the day before yesterday we did it for re-refined motor oil. We are out working on fine paper products, and on laundry detergents, and on light bulbs right now. These things are slowly coming down the pike. Hopefully, it will begin to send a very strong message from a concerned public as market shares shift from things that do not have green seals to products that do have green seals. This is the way to go. The people care about this.

Over and beyond everything else, my personal view is that it is a better way to get this kind of decision made than legislatively. I have worked in the legislative vineyards for a decent part of my adult life and, frankly, it is an enormous exercise in frustration.

The Clean Air Act of 1990, which has, as far as I can tell, few ardent fans anywhere as a result of a 12 year lobbying struggle, has compromises laced through the entire thing. Finally, you passed a bill and at the time that it passed that is as strong as it will ever be. Now they go into regulatory rule making where suddenly you've got seven environmental people in Washington, DC, flanked off against maybe 1500 attorneys drawing $350/hour arguing whether the apostrophe should be on the inside of the "s" or the outside of the "s" and it has significance whether the apostrophe is on the inside of the "s" or the outside of the "s". And they will whittle away in a way that we really cannot respond to because we do not have the troops, we do not have the resources, and it will be weakened substantially in each of its passes as it comes through. Then it goes out for implementation. And then you see in localities and states across the country these things being granted variances and continuances and extensions because they have economic impacts, and some of those things just get continuances and variances for year after year after year after year. And for some companies, if the consequences of this behavior is a fine, we have now dozens and dozens of examples where companies have simply decided to pay the fine as a cost of doing business because the fine is cheaper than cleaning up their acts. If, on the other hand, they begin to lose market share, if somebody iss doing an irresponsible job with a particular product and there is another set of products out there that is performing beautifully, and people start buying that one because they care about the environmental impact you do not have a 12 year legislative struggle, you do not have apostrophe questions, you do not have all these local battles. Nobody is going to watch the erosion of market share over something like this; they are going to turn themselves around and it is the kind of way to mobilize direct action that the environmental movement has long needed and failed to have.

It has failed to have it because it has tried to build itself as a political organization with people paying dues to have mercenary armies in Washington, DC, fight legislative battles for them, and we do not seem to be able to get bigger than about 10 to 12 million people who will become "card carrying, dues paying environmentalists". And that is not enough to turn the country around this way. The political significance of an uncertain issue is not enough to prevail but the people who are prepared, at least in polls, to buy the right stuff is more than enough to begin to make significant changes and to make it directly. I should say that we are working together with Underwriters Laboratories in this; they are in alliance with us. They will be performing all of the tests and all of the factory inspections here and in 74 other countries in areas where they have got the competence to do it. We figure at the moment that will be about 80% of all of our tests and inspections. If we can get that set up, it imposes upon us a responsibility to be right and that is why we need your help. Therefore, I will give you this address for those of you who would like to be on the mailing list and to get our materials routinely, and we would love to get your comments. It is Green Seal, 1875 Connecticut Avenue, Washington, DC, 20009.

All of the speakers today have skirted a little bit around the question that we were supposed to address which is engineering education in the year 2000. Let me make just a couple of brief comments from this public perspective once again and bring this to a close.

One quick one. The education of an undergraduate and of a graduate is to some extent a function of professors standing at blackboards and students scribbling down things in notebooks. There is an old definition that a lecture is the most efficient means of transferring the professor's notes to the students' notebooks without it passing through a human mind. That is part of the educational process, but while students rip themselves away from their parents' breasts and go off to college campuses and this brand new kind of environment, they are often open to new kinds of influences. They experiment with things. They are alive with the kind of vitality that they will perhaps never again experience, a level of growth they may never again experience in their lives and they pay attention to everything from cultural norms (that is why this emergence of racism on college campuses is so deeply troubling, why the free speech debate is so deeply troubling) and they pay careful attention as well, sometimes without even knowing that they are doing it, to the hypocrisy between what people say and how institutions perform.

Those of you who are involved with environmental studies academically have, I think, some responsibility to be involved with it in a physical way as well. We have some of the most grotesquely inefficient buildings in the United States in our engineering faculties across the country. There is absolutely no reason why we should not begin to set these things up as models of what we are trying to build as a society. Brown University has set up this wonderful new program called "Brown is Green". Sounds sorts of like something out of "1984" and George Orwell, but the program is in fact a wonderful one to try to transform it into an environmentally superior campus, and they are going through methodically and systematically trying to set things up. Students will pay attention to the kinds of diets they have in the cafeterias. They pay attention to what kinds of eating utensils they have. I attended this morning an absolutely fabulous brunch designed for people at this conference. It was great but every single thing that was used as a serving utensil was a throwaway. I do not mean to focus upon that one, but it is illustrative that we do not think about this stuff, even those of us who are supposed to be at the core of this and recognize the depth of the crisis that we are currently facing.

We need to think about all those subliminal messages that are being sent to students as well and not just count on the students to get things straightened up. On a lot of campuses they will. At UCLA the students put together this enormous inventory of what was going on environmentally with UCLA with great support from the administration. The report that got turned out showed that UCLA was the third largest defiler of the Los Angeles environment and included a whole series of recommendations for what the campus should begin doing on everything from its buildings to its vehicular fleet to start shaping up. Students will sometimes take that leap but you have lots more judgment; lots more experience. They will turn to you for some kind of wisdom, and you should be taking the lead in that sort of thing.

Second, I think it is critically important that engineers begin to integrate a far larger number of disciplines into your curriculum. And, third, it is ridiculous to bring me in to teach political science and economics given an engineering number so these people could graduate from Stanford with enough engineering credits to be able to graduate. It is important, especially in the undergraduate years, that students get a broad exposure in environmental engineering to biology, to epidemiology, to economics, to a variety of topics that are not currently required and, in many cases, are not even possible within the context of the engineering curriculum.

And perhaps, I will close on this, the most important thing to be taught to students which is the responsibility of their parents, it is the responsibility of their coaches, it is the responsibility of all of their teachers and of everyone who is an adult, everyone who comes in contact with someone who is growing up is through example and also through talking about it, in case studies and in classrooms, convincing them to do the right thing. They are going to be leaving your schools and they are going to be thrown into a competitive environment. They are going to have a bunch of peer pressure leapt on them to get out to a place where they can start buying BMWs. They will, like me, have a daughter going off to college next year sometime. They will have career opportunities that will present themselves; they will have things that they get rewarded from and things that are irrelevant. And they have to operate in that environment. They have to operate successfully if they are to advance. They have to pay attention to all of these myriad aspects of decision making, but you should also convince them that in the course of making particularly important decisions that they have to step back from all that context now and then and think in a broader sense about the world, think in a broader sense about what is important to them. I think it is important for engineering students to spend some time in some redwood groves, out in the wilderness, out in some deserts, where they can look up at the vastness of the cosmos. There is some wisdom that we can all learn from 3000 year old bristle cone pines, from butterflies that weigh less than a quarter who manage to migrate thousands of miles each generation on the basis of something that is programmed in them genetically. There is something out there to be learned from paying careful attention to the species that are now vanishing at the rate of one an hour, the rain forests that are being shredded at the rate of two acres per second, something to be paid attention to in terms of the poor in this country and the destitute of the world. And when they are making an important decision, and a lot of your students are going to be making important decisions, in addition to everything that their employers expect of them, we the public, you their teachers have also to expect of them that they step back and think of this broader context and then ask themselves: "What is the right thing to do?" and then do it.

DEVELOPMENT OF ENVIRONMENTAL ENGINEERING BACCALAUREATE PROGRAMS AND DEGREES

Position Paper

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INTRODUCTION

The decade of the 1990s is witnessing a remarkable awakening of the global public awareness of the environmental pollution problem. This awareness, like the problem itself, knows no national boundaries and extends from the Americas to Europe, Africa and Asia. The difference between this awareness and the awareness of the 1970s is that now the global public has a better understanding of the resources required to solve the problem and seems more willing to commit these resources. Accordingly, we are seeing an unprecedented growth of the "environmental market" and in the demand of that market for resources, products and educated personnel.

Originally, education of the environmental engineering professional was focused on the graduate level and emphasized water and wastewater engineering. However, in view of the growth of the size and complexity of the market served by the profession, it is appropriate that the profession closely examine the benefits to be gained from an increased emphasis on baccalaureate environmental engineering programs and degrees.

The purpose of this paper is to discuss: a) the need for environmental engineers; b) the skills and competence required of these engineers; c) curricular alternatives for producing these engineers with emphasis on environmental engineering baccalaureate programs and degrees.

DEFINITION AND SCOPE OF ENVIRONMENTAL ENGINEERING

To begin any discussion of environmental engineering, it is helpful to consider its scope. Many definitions of environmental engineering have appeared in the literature:

<u>American Society of Civil Engineers</u>

According to the purpose statement of ASCE's Environmental Engineering Division, environmental engineers are concerned with, "... solution of problems of environmental sanitation, notably in the provision of safe, palatable, and ample public water supplies; the proper disposal of or recycle of wastewater and solid wastes, the adequate drainage of urban and rural areas for proper sanitation; and the control of water, soil and atmospheric pollution, and the social and environmental impact of these solutions." Moreover, environmental engineers should be "... well informed concerning engineering problems in the field of public health, such as control of insect-borne diseases, the elimination of industrial health hazards, and the provision of adequate sanitation in urban, rural and recreational areas, and the effect of technological advances on the environment."[3]

<u>Second Conference on Environmental Engineering Education</u>

The Second Conference on Environmental Engineering Education formally adopted the definition of environmental engineering as, "... that branch of engineering that involves the application of scientific principles to the prevention, control, and management of environmental factors that may influence the physical and emotional health of man and his well being."[17]

Third Conference on Environmental Engineering Education

A paper by Gilbertson presented at the Third Conference defined environmental engineering as, "... that branch of engineering which is concerned with the application of scientific principles for (1) the protection of human populations from the effects of adverse environmental factors, (2) the protection of environments, both local and global, from the potentially deleterious effects of human activities, and (3) the improvement of environmental quality for man's health and well-being."[12]

American Academy of Environmental Engineers

The AAEE Bylaws define environmental engineering as, "... the application of engineering principles to the management of the environment for the protection of human health; for the protection of nature's beneficial ecosystems and for environment related enhancement of the quality of human life."[1]

Some key elements which arise from these definitions are: scientific principles, engineering principles, protection of human health, protection of natural ecosystems, pollution control, water, air, solid wastes. These elements are large in scope, and this scope presents an inherent problem for environmental engineering education and practice. It is difficult to achieve a proper balance between breadth of knowledge and specialty competence.

EVOLUTION OF ENVIRONMENTAL ENGINEERING EDUCATION

Environmental Engineering has evolved as a specialty of larger, more traditional engineering and applied science disciplines. Practitioners have tended to become specialized in a single environmental medium with the greatest majority emphasizing water pollution control as opposed to the air, solid waste or earth science areas. Professional society activities have been spread over many engineering societies and professional associations. The Civil, Chemical, and Mechanical Engineering founder societies (ASCE, AIChE, ASME) each support an environmental division. These are overlain by professional groups such as the Water Pollution Control Federation, Air and Waste Management Association, American Water Works Association, and others. The American Academy of Environmental Engineers is sponsored by twelve professional groups (AWMA, AIChE, APHA, APWA, ASEE, ASCE, ASME, AWWA, AEEP, GRCDA, NSPE, and WPCF) and serves as the lead society in ABET accreditation of environmental engineering programs.

In the evolution of environmental engineering education, the masters degree was generally viewed as the "first degree" in environmental engineering. In 1967, the Second National Conference of Environmental Engineering Education narrowly passed a resolution declaring that, "The master's degree or equivalent education should be the minimum level for entry into essentially all fields of environmental engineering practice."[17] Since then, only a few institutions have developed baccalaureate degrees in environmental engineering. Nevertheless, the Report of the Third Conference on Environmental Engineering Education[4] recognized the advantages of a broad-based baccalaureate degree in environmental engineering to be:

1) Future mobility and flexibility of the graduate
2) Reduced time for the graduate to be productive
3) Pedagogical soundness
4) Production of "doers" rather than managers
5) Excellent preparation for graduate programs
6) Fills an immediate need

The Fourth Conference on Environmental Engineering Education[5] considered the relationship of baccalaureate to graduate environmental engineering education, and again recognized the value of a broad environmental engineering baccalaureate program (including all media) as a foundation for specialization in graduate school. Nevertheless, environmental engineering education has continued to evolve primarily at the graduate level, and, in almost all cases, has developed under the academic guidance of a civil engineering department. A typical M.S. curriculum has been designed to remedy background deficiencies in chemistry and biology, as well as to provide some competence in engineering design and operation.

Although there are about ten universities offering accredited baccalaureate degrees titled as environmental engineering, undergraduate programs have, for the most part, been limited to specialty options within civil and other traditional engineering baccalaureate programs. Turner noted the relative infancy of environmental engineering education at the baccalaureate level and felt that "because of the strength of the civil engineering discipline" a trend toward separate environmental engineering baccalaureate programs was not likely.[18]

In addition, there are about five programs offering ABET accredited baccalaureate degrees in environmental engineering technology. These programs have developed primarily at regional colleges and universities and are particularly suited for educating process operating and laboratory personnel.

There are, however, indications that unprecedented demand for environmental engineers in the 1990s and beyond is causing many universities to increase the curricular presence of environmental engineering at the baccalaureate level. In some cases, this will be manifested by separately titled degree programs, e.g., Bachelor of Science in Environmental Engineering. In other cases, additional emphasis will be placed on options within civil or chemical engineering baccalaureate degree programs. It is also likely that baccalaureate programs in environmental engineering technology will grow significantly.

SUPPLY AND DEMAND IN THE ENVIRONMENTAL ENGINEERING WORK FORCE

Public demand for a clean environment is manifested by strong environmental quality standards and regulations. These regulations drive the environmental market, and the future market will be driven by even more regulations. This market includes not only conventional water and wastewater engineering, air quality, and solid waste management but also "chemicals out of place". The latter segment of the environmental market dwarfs the wastewater treatment plant construction boom of the 1970s. Expenditures in this market segment are forecasted to increase by 22% annually, going from $5.3 billion/year in 1990 to $14.4 billion/year in 1995. At the same time, revenues for environmental consultants will grow from $1.7 billion in 1990 to $4.1 billion in 1995.[19] The total environmental market is currently estimated at about $50 billion/year and growing by 10% to 20% per year. Clearly, the environmental market is the strongest that it has ever been.

Because environmental engineering cuts across the lines of traditional engineering disciplines, it is difficult to obtain good professional supply and demand statistics. Many environmental engineers, for example, are counted as civil or chemical engineers. Nevertheless, information from a variety of sources indicates that there are about 20,000 to 30,000 environmental engineers in practice, and approximately 2,000 to 5,000 new environmental engineers are needed per year.[9] ASCE's Environmental Engineering Division lists 21,400 members, and this amounts to roughly 18% of the ASCE membership. Likewise, AIChE's Environmental Division includes 3,200 members or about 6% of the AIChE membership, and the ASME Environmental Control and Environmental Transportation Divisions include about 12,900 members or about 11% of the ASME membership.

However, the various civil, environmental, chemical and other baccalaureate and graduate engineering programs appear to be producing fewer environmental engineers than are required. Again, the cross-disciplinary and intra-disciplinary phenomena make it difficult to obtain accurate data as many environmental engineering programs actually award degrees in civil engineering.

In the United States there are currently about 200 engineering colleges graduating about 70,000 baccalaureate degrees annually in more than twenty sub-disciplines. Recent data (for 1988) from the Engineering Manpower Commission on the number of degrees granted in various engineering disciplines in the U.S. are shown in Table 1. Nearly 85% of the baccalaureate degrees in engineering are awarded in five major fields. In order of the number of degrees awarded, these are electrical engineering (34.1%), mechanical engineering (21.9%), civil engineering (10.8%), industrial engineering (6.4%), computer engineering (6.0%), and chemical engineering (5.7%).

Only 192 of the 71,367 baccalaureate degrees awarded were titled as environmental engineering. Of the total undergraduate and graduate degree production, only 584 of the 101,382 degrees were identified as environmental engineering. However, as pointed out above, a significant fraction (loosely estimated at 10%) of the baccalaureate degrees identified as civil and as chemical engineering contain a significant environmental component. It must also be recognized that graduate education in civil engineering normally involves specialization in a specialty area, and many civil engineering graduate programs use the "civil" degree designation to denote masters or doctoral degrees which are essentially environmental (or structural, or geotechnical, etc.) engineering programs. Similar phenomena occur in institutions where industrial engineering is a sub-unit or option within mechanical engineering, or where ceramic engineering is a sub-unit of materials engineering.

According to the AEEP graduate program survey, the various environmental engineering graduate degree programs produce approximately 900 graduates per year.[16] Although only a small number of baccalaureate environmental engineering degrees are currently awarded (less than 200/year), this will significantly increase in the future. Baccalaureate civil engineering programs produce about 8800 graduates/year, and it is estimated that at least 10% of these function as environmental engineers. Adding in a significant number of chemical, mechanical, geological and other engineers who function as environmental engineers provides an estimate of 1,000 to 2,000 graduates per year entering the profession.

The data lead to the conclusion that the supply of environmental engineers satisfies less than half of the demand for 2,000 to 5,000 new environmental engineering graduates per year. The remainder of the demand is either not being met or being satisfied by engineers with little knowledge of the environmental field.

ENVIRONMENTAL ENGINEERING COMPETENCE AND SKILL REQUIREMENTS

The expanding environmental engineering market will define the knowledge, competence and skills that professional education in environmental engineering ought to provide. Environmental engineers of the future must be prepared to deal not only with current problems, but they also must be able to adapt to problems of the future. They must be well schooled in fundamental principles of logical analysis, critical thinking and rational design so that they can understand, evaluate and use emerging technologies such as soil bioremediation, vapor extraction and steam stripping. In addition, they should have a sound background not only in the traditional physical sciences but also in biological sciences, earth sciences, and atmospheric sciences so that they can develop integrated, air-water-land approaches to problem solving. Berthouex et al.[8] considered educational needs for dealing with multi-media problems and recommended a list of subjects headed by environmental transport phenomena and fate processes in the environment. Other subjects recommended included: a systems approach to environmental engineering; waste treatment; waste disposal; risk assessment; and societal systems.

Finally, environmental engineers of the future should be able to <u>engineer something</u>. That is, in addition to being able to understand fundamentals, they should be able to apply them to design and operation of an engineered system. The inclusion of meaningful engineering analysis and design into an environmental engineering baccalaureate program is possible only if the scope and complexity of the design exercise is maintained at a suitable level.

The ideal baccalaureate level environmental engineering education of the future should provide:

-a broad background in physical, biological, earth and atmospheric science

-a background in the fundamentals of physical, chemical and biological processes

-an understanding of environmental transport, transformation and fate phenomena

-basic competence in environmental engineering laboratory skills

-some ability to apply methods of modeling and simulation to environmental systems along with some ability to assess risk and estimate cost

-some ability to apply knowledge to the conception, analysis and design of solutions to real world environmental problems

-an appreciation and understanding of ecological relationships

-ability to implement technology based solutions to environmental problems through design, construction, and operation

-adequate skills in oral and written communication

In addition, the environmental engineers of the future must have a new environmental ethic, a new level of environmental consciousness. They must have the ecological wisdom to design, build and operate the works of society with the understanding that humans are part of nature and must live within the ecological and resource limits of the planet.

It must be recognized that many engineers educated in the traditional specialties (structural, electrical, chemical, etc.) will also be required to solve problems of the future. However, the experienced environmental engineer is best equipped to be the leader of the multi-disciplinary team solving complex environmental problems. No other preparation provides the environmental breadth coupled with technological depth.

CURRICULAR ALTERNATIVES FOR EDUCATING ENVIRONMENTAL ENGINEERS

Background Data and Observations

As shown by the data in Table 1, only 584 environmental engineering degrees were awarded by U.S. colleges and universities in 1988. These included 192 B.S., 329 M.S., and 63 Ph.D. degrees. The 584 environmental engineering degrees accounted for only 0.6% of the total engineering degrees awarded in 1988.

In terms of the numbers of degrees awarded at the B.S. level, environmental engineering accounts for only 0.3% of the total annual production in the U.S. The largest six undergraduate degree disciplines are electrical (44.1%), mechanical (21.9%), civil (10.8%), industrial (6.4%), computer (6.0%), and chemical (5.7%). These six undergraduate disciplines account for 95% of the total undergraduate degrees produced annually in the U.S.

The national need for engineering professionals in the environmental field has been filled by individuals with baccalaureate degrees, primarily in civil or chemical engineering. The number of individuals entering the environmental engineering disciplines are small. It should be noted, however, that there are many jobs, both technical and managerial, related to environmental quality control that are performed by scientists or engineers with no specific environmental education. Examples include chemists performing analytical tests and engineers designing electrical controls, motors, pumps, and other equipment.

One career pattern for entry into the profession is for the baccalaureate degree holder in civil or chemical engineering to pursue the M.S. degree in environmental engineering prior to entry into professional practice. Another approach is for the B.S. degree holder to accept employment in an environmental engineering position directly out of college with training then occurring "on the job", perhaps including formal graduate level education on a part-time basis. These common pathways into environmental engineering careers are illustrated in Figure 1.

One important question is whether or not the curricular emphases within the "big six" engineering disciplines -- electrical, mechanical, civil, computer, industrial, and chemical -- provide satisfactory foundations for advanced study or professional practice in environmental engineering. These major undergraduate disciplines are generally lacking in the biological sciences. Of all the scientific disciplines, the biological sciences are probably the most important in water and land quality control and in public health. Also, with the exception of chemical engineering, all of the big six are weak in the basic and applied chemical sciences. Again, the chemical sciences rival the biological sciences in importance (some would argue, exceed in importance) as a foundation for advanced study or practice in environmental engineering. The only basic and applied sciences that are common in the traditional disciplines with the needs of environmental engineering are the physical sciences and mathematics.

The observation just made is rather shocking! Ninety-five percent (the big six) of the B.S. engineers educated in the U.S. are seriously lacking in biosciences and 89% (excluding chemical engineers) are flawed in the chemical sciences, at least in terms of the elemental needs for advanced study or practice in environmental engineering. In contrast to the rather narrow science focus of the traditional disciplines, environmental engineering requires a broad foundation in all of the sciences. The question to be addressed later is whether or not the traditional disciplines offer some strengths, either technical or professional, that offset these obvious weaknesses.

Another important question is whether or not the environmental engineering profession is meeting its obligation to provide sufficient numbers of well trained environmental engineers. It appears that many positions, particularly in regulatory agencies and industry, that should be filled with environmental engineers are being filled with environmental scientists, or even so-called "scientists" with a baccalaureate degree but little or no background education in the environmental area. Given the lack of trained engineers, the industries and agencies turn to what they perceive as "the next best thing" -- biologists or chemists. Many of these positions could be filled with much greater competence with baccalaureate level environmental engineers or environmental engineering technologists.

In the next two sections, advocacy positions are presented for two alternative routes for environmental engineering education. The first section focuses on the advantages of beginning with an environmental engineering baccalaureate program, whereas the second section focuses on the strong features of beginning with a more traditional civil, chemical or other engineering baccalaureate program. It is believed that, in the future, the two routes will co-exist and that separately titled BSEnE degree programs will be in addition to, and not in lieu of, the traditional programs.

As a prelude to the discussion of advantages, it is helpful to list some fundamental observations and realities of the situation. These are:

-The environmental market will continue to demand many engineers and scientists in addition to environmental engineers.

-The market prefers engineers and scientists educated to the MS or PhD level, but these individuals will continue to be in short supply.

-The market will continue to attract many engineers and scientists educated to the baccalaureate level.

-The market demand will be satisfied with people regardless of what the environmental educational establishment does. The demand will be perceived by prospective students, and they will enroll in curricula that they perceive will lead to good jobs. Many will make this choice when entering baccalaureate programs.

Advantages of an Environmental Engineering Baccalaureate

Throughout the history of the engineering profession, the educational establishment has spawned new disciplinary specialties at appropriate times to meet the needs of society. It is obvious that environmental engineering has become a distinct discipline deserving of more emphasis at the baccalaureate level. The questions are: "How much emphasis? How many such baccalaureate programs are needed? And what should the curricula include?" In the Supply and Demand in Environmental Engineering Work Force section, it was estimated that the supply of environmental engineers is satisfying less than half of the demand for 2,000 to 5,000 new environmental engineers per year. The popular press perceives the environmental market to be one of rapid growth and plentiful jobs. At the present time, it is probably not possible to forecast work force needs more precisely than this. Thus, the decision for an individual university or department to institute a baccalaureate program in environmental engineering must be based on a good measure of intuition.

Perhaps the strongest argument in favor of increased environmental engineering undergraduate education is that the great majority (95%) of the B.S. level engineers in the U.S. are being educated in fields (the "big six") that do not provide a good foundation for further development, through education or practice, in the environmental engineering field. Civil engineering undergraduate education offers some advantages relevant to study or practice in environmental engineering. Chemical engineering offers some other advantages (not found in civil engineering). And electrical, computer, mechanical, or industrial engineering each offer certain advantages not found in the other disciplines. The problem is that none is ideal as a basis for future study or practice in environmental engineering.

It can be argued that the current approach to environmental engineering education is producing "mongrels", not "purebreds", for practice in environmental engineering. There is a need to ensure that engineers entering the environmental work force are well grounded in fundamental principles and that they can apply these principles to the solution of multi-media problems. Baccalaureate programs emphasizing the breadth and depth of environmental engineering would be a significant step in the right direction.

Many civil engineering curricula require courses that are of very limited value as a basis for future study or practice in environmental engineering. Examples of these are courses in surveying and transportation. Moreover, these requirements take up space in the curriculum and deny the student sufficient opportunity for study in chemistry and biological science. Although civil engineering curricula typically require extensive course work in mechanics, they often do not require thermodynamics, an area of particular value to environmental engineering. In addition, it is common for CE curricula to offer only one course in environmental engineering. However, CE curricula commonly offer coursework in water resources, including hydrology and hydraulics, and in geotechnical engineering, all of which are substantive and useful courses as a basis for environmental engineering practice.

Chemical engineering offers some advantages over CE as a basis for future study or practice in environmental engineering, but also suffers from some significant deficiencies. For example, chemical engineering curricula are totally lacking in coursework in the hydrology, hydraulics, or geotechnical areas. This is a significant weakness as far as environmental engineering education and practice is concerned. As is the case with civil engineering, chemical engineering is commonly lacking in the biological sciences. Perhaps the greatest strength of chemical engineering is the process orientation of the coursework and the greater emphasis on chemistry.

Each of the other four members of the "big six" offer certain advantages, but mostly disadvantages, as a basis for further study or practice in environmental engineering. Indeed, none of the existing major engineering disciplines provides a satisfactory undergraduate base for further study or practice in environmental engineering.

Another important argument favoring more emphasis on baccalaureate education in environmental engineering is the need to upgrade the quality of the engineer entering advanced study or practice. Because of the significant weaknesses of the major engineering disciplines, it is necessary to provide a great deal of remedial course work at the graduate level. More emphasis on environmental engineering at the baccalaureate level could provide an important supply of high-quality graduates entering environmental engineering graduate programs. The net result could be a significant improvement in the quality of the professional work force in environmental engineering.

The local, regional, and global requirements and demands for a quality environment that is sustainable will require the greatest possible competence in the environmental engineering profession. It follows that it is time for high quality, well-founded baccalaureate environmental engineering degree programs in the United States. Just as the electronics and chemical process industries stimulated the development of BSEE and BSChE programs, so will the environmental market fuel the development of both baccalaureate and graduate environmental engineering programs.

Moreover, degree programs designated as "environmental engineering" will have the visibility necessary to attract environmentally aware and intelligent young people. The public presently perceives of civil engineering as being based on relatively low technology and not strongly related (perhaps even unrelated) to environmental engineering. In general, industry thinks that civil engineering is concerned only with construction, structures, transportation, and municipal public works. The environmental engineering component of civil engineering education does not have high visibility with either the public or the industrial sectors. For example, many job advertisements for environmental engineers specify "degree in environmental engineering, chemical engineering, or related field." Explicit identification of environmental engineering degree programs at the baccalaureate level will help to recruit interested students into the profession.

It is also important to consider the external visibility of the degree program to industry. A degree title is an important screening criterion for personnel decisions, and few personnel managers understand the nuances of engineering sub-specialties. It follows that a degree titled as environmental engineering should be of more value for entrance into the environmental engineering work force than a degree in traditional engineering with an environmental option.

Education based on a baccalaureate program in environmental engineering is academically sound. The baccalaureate program will provide the general education and fundamental entry level skills that are so seriously lacking in the major undergraduate engineering disciplines, as discussed previously. This will provide the opportunity for much greater in-depth study in a particular specialty of environmental engineering at the graduate level. Students holding a baccalaureate degree in environmental engineering will be able to begin advanced studies in graduate school without having to take remedial courses. Eventually, environmental engineering baccalaureate degree holders will make up a large share of the students entering environmental engineering graduate programs. This will greatly improve the quality of the research and academic aspects of graduate programs.

Advantages of a Traditional Engineering Baccalaureate Program

Education at the undergraduate level should not be too narrowly specialized. As noted previously, about 95% of the engineering baccalaureate degrees awarded in the U.S. are in six disciplines -- electrical, mechanical, civil, computer, industrial, and chemical engineering. Each of these disciplines is rather broad and establishes a solid base for further professional development through formal education or practice.

A major advantage of baccalaureate degrees in the traditional engineering disciplines is that options for specialization (for example, in environmental engineering) are held off until a greater understanding and intellectual maturity have developed in the student. A student studying in civil engineering and graduating with a B.S. degree has many options for employment or further study and specialization in any one of the major sub-disciplines that offer opportunities for further specialization.

A graduate in civil engineering can begin a career in structural engineering and later decide to move into the environmental field. Such a move is quite feasible and, in fact, happens quite often, especially in view of the current interest and emphasis on the environment. On the other hand, if the student obtains a B.S. degree in a narrow discipline such as environmental engineering, the feasibility of a career change into structural engineering, or any one of the other specialties associated with civil engineering, is not likely.

It can be argued that the baccalaureate degree in engineering should not identify a specialty area -- that specialization should be left to the graduate level. Unfortunately (or fortunately, depending on one's point of view), the current reality is that specialization does occur at the undergraduate level. Industry, graduate schools, and society have come to understand these traditional specialty areas (the "big six"). Environmental engineering may have problems fitting into this traditional framework.

It must also be recognized that specialized engineering education is expensive. Creation of baccalaureate environmental engineering programs will require new courses, additional faculty, and expanded laboratories. Unless financial support is assured, these demands could overload faculty and divert resources from graduate programs. The net effect might be detrimental to environmental engineering education as a whole.

The argument for separately titled environmental engineering baccalaureate programs tends to dwell on words and titles. What is important is the production of competent graduates, regardless of what they are called. A student in a modern civil or chemical engineering baccalaureate curriculum can obtain a program of study nearly equivalent to that provided by an environmental engineering program, especially if specialty options are permitted. Compare, for example, the University of Wisconsin BSCE (intended to be an accredited environmental engineering option) program shown in Table 7 with the BSEnE programs listed. For most intensive purposes, they are equivalent.

Currently, environmental engineering graduate programs draw upon students having baccalaureate degrees in various science and engineering disciplines. Baccalaureate graduates in environmental engineering may not be attracted to graduate programs geared to students with undergraduate backgrounds that are weaker in environmental engineering. Likewise, a graduate program designed for a student with an undergraduate background in environmental engineering might not be attractive to students with other backgrounds.

Although it might be accepted that improving the academic blood lines of the environmental engineer may produce a somewhat better and more competent professional than the current system, this outcome is not certain. Tradeoffs are involved. The gain that is achieved in environmental engineering competence is offset by the losses that arise from a focus on the comparatively small environmental engineering specialty.

Baccalaureate Environmental Engineering Curricula and Programs

From a curricular perspective, environmental engineering derives from many bodies of science, and, thus, requires both diversity and specialization. Undergraduate and graduate curricula should have a breadth of scientific and social courses that serve as a framework for depth. The curriculum should emphasize fundamental physical, chemical and biological sciences, as well as relationships between media and social skills. The curriculum should also be in agreement with ABET general and program criteria applicable to basic level accreditation.

Accreditation Issues

Table 2 summarizes the ABET criteria for basic level engineering accreditation. Addition of the categorical requirements shows that three full years of study are required to satisfy the minimal categorical requirements in mathematics, basic science, engineering science, and engineering design. Most universities have additional requirements for competence in oral and written communication, general education, and other areas which easily fill the fourth year. Under the best of circumstances, squeezing an engineering baccalaureate program into a four year time frame is a tight fit.

Morgan[14] noted that the "tightness" of the ABET categorical requirements presents a formidable disincentive to curricular innovation. He suggested that this disincentive might be removed without compromising ABET's quality assurance function by reducing the categorical requirements by 20%. This would create new "flexible space" in engineering curricula, and this flexibility would be used in different ways by different engineering schools. Some schools would concentrate on specialized applied areas, whereas others would develop new basic areas of engineering science. It seems clear that this flexibility would also facilitate the development and accreditation of high quality baccalaureate environmental engineering programs.

Beyond the general criteria applicable to all engineering programs, ABET lists "program criteria" applicable to degrees in the various engineering specialty areas. The current (1990-91) program criteria for environmental engineering are summarized in Table 3. For purposes of comparison, the program criteria for chemical engineering and civil engineering are summarized in Tables 4 and 5. Comparison of Table 3 with Tables 4 and 5 show some differences and similarities. The criteria for environmental engineering tends to be less specific than those for civil and chemical engineering. Both the civil and the environmental engineering criteria emphasize breadth of topics in professional courses. The chemical engineering criteria specify a list of curricular subjects that must be included.

According to the ABET Fifty-eighth Annual Report[2] it is proposed that the curriculum section of the environmental engineering program criteria for 1992-93 be revised as follows:

-At least <u>two</u> areas of environmental engineering must be provided in the curriculum from among the following: air pollution control engineering; water and wastewater engineering; solid and hazardous wastes engineering; and environmental and occupational health engineering.

-Design courses should emphasize an integrated approach that considers all environmental media in the prevention and control of environmental problems. System and facility operation and maintenance should be stressed in design courses.

-Environmental engineering laboratories must provide a relevant experience in the physical, chemical and biological sciences. This experience should also include applications to processes used in environmental engineering.

In view of the breadth of competence and skill required by the environmental engineer, and in view of ABET's proposed integrated, multi-media emphasis, the proposal to drop the specialty area coverage from the current <u>three</u> to the proposed <u>two</u> is surprising. Environmental breadth ought to be a strength of an environmental engineering baccalaureate program. As a minimum, course work in both water and air ought to be required.

"Integrated Approaches" and "Design and Operation" were focal issues discussed at the 1986 Conference on Environmental Engineering Education.[6] Two of the proposed revisions relate directly to these issues.

It is worthwhile to note that much of the engineering science base needed by environmental engineering baccalaureate programs is taught in advanced chemistry and geoscience courses. These courses are not normally counted as engineering science, and this creates a problem in designing a meaningful four year environmental engineering baccalaureate curriculum in compliance with ABET guidelines (i.e., 1.0 year of engineer science). Chemical engineering also requires an engineering science base taught in advanced chemistry courses. The program criteria for chemical engineering enable a student to obtain an adequate chemical engineering science base by allowing up to one-fourth year of advanced chemistry courses to be counted as engineering science for ABET purposes.

To ensure that an adequate environmental engineering science component is included in basic level curricula, the 1986 Environmental Engineering Education Conference (Baillod, 1986) passed a resolution stating that up to one-fifth year of advanced quantitative physical or natural science courses (e.g., physical chemistry) which have environmental engineering applications can be counted as engineering science in satisfying ABET requirements. This resolution, however, has not yet been recognized in the ABET guidelines for basic level accreditation of environmental engineering programs.

Accreditation of engineering technology programs is governed by a different set of ABET categorical guidelines. Table 6 compares the ABET general curricular content criteria for engineering and engineering technology programs. It is apparent that the engineering technology format offers more flexibility in curricular design than does the engineering format. There is an obvious need for baccalaureate level technologists in the environmental engineering area, and these programs are likely to grow in parallel with the engineering programs.

Typical Environmental Engineering Baccalaureate Curricula

Several need factors and constraints influence the development of university curricula. These are:

Need Factors
- -Societal need for a given specialty competence in work force
- -Demand for graduates with competence in the given specialty
- -Identification of curricular background providing competence
- -Demand of students for admission to curricula

Constraints
- -Availability of faculty and instructional resources
- -Availability of knowledge
- -Availability of good teaching materials

The present situation in environmental engineering is that the need factors have been realized, and curricular developments are limited by the constraints of faculty, knowledge, and resources.

In most cases, environmental engineering curricula at both the graduate and baccalaureate levels have developed in the context of an existing academic structure. New programs and degrees have evolved as specialty areas of faculty strength have developed within traditional engineering departments and curricula. Table 7 compares several baccalaureate curricula which provide for some specialization in environmental engineering. Included are:

-Four existing proposed curricula leading to degrees titled as environmental engineering (Michigan Tech, Rensselaer, U.C. Riverside, Iowa State)

-One program leading to a degree titled as environmental engineering science (Iowa State)

-Three curricula leading to degrees titled as civil engineering but including an environmental engineering concentration or option (Wisconsin, Michigan, Michigan Tech)

-One program leading to a degree titled as chemical engineering but including an environmental engineering concentration (Michigan Tech)

A brief description of each curriculum follows.

Michigan Technological University: Distinct BSEnE and BSCE Degree Programs Administered in the Department of Civil and Environmental Engineering plus a BSChE Program with an Environmental Option

Table 7 shows the Michigan Tech BSEnE curriculum along with the companion BSCE and BSChE environmental option curricula for comparison. The BSEnE curriculum is administered by the Civil and Environmental Engineering Department and coexists with the BSCE (environmental option) curriculum.[13] It should be noted, however, that curricular governance for the BSEnE degree is vested in the environmental engineering faculty. The civil and chemical engineering degree programs each permit the student to elect about 12 credits of environmental engineering science and design courses.

Recent experience indicates that comparable numbers of students follow the BSCE (environmental) and BSEnE curricula. The 1991 senior class, for example, has about 25 BSCE (environmental option) graduates and about 35 BSEnE graduates. About 5 chemical engineering graduates had significant course work in environmental engineering.

Evaluations of the Michigan Tech environmental engineering curriculum by its graduates has been overwhelmingly positive. When an alumni survey asked graduates if they would have rather followed the traditional civil engineering curriculum, only one out of 60 graduates states a preference for the traditional BSCE program.

Finally, the environmental engineering baccalaureate program at Michigan Tech has experienced healthy growth since it was accredited as a separately titled degree in 1986. This growth did not result in a decrease in students following the traditional civil engineering curriculum. Recent enrollment trends for both departmental curricula are shown below (figures include freshmen through seniors):

Year	BSEnE	BSCE
1985	--	407
1986	17	350
1987	32	364
1988	54	395
1989	83	408
1990	137	490
1991 estimated	200	550

Iowa State University: Proposed Baccalaureate Programs in Environmental Engineering and Environmental Engineering Science

Iowa State University[11] has proposed to develop two new baccalaureate degree programs; one in environmental engineering, and one in environmental engineering science. These programs would be initially administered as part of an Engineering Operations curriculum, and would require a significant number of new courses.

The environmental engineering curriculum conforms to ABET categorical requirements for engineering science and engineering design and should be accreditable. A particular strength of this program appears to be the senior level environmental engineering design courses.

The environmental engineering science curriculum emphasizes basic and engineering sciences as a foundation for advanced courses. It also provides for more elective courses. The tradeoff is that the environmental engineering science program does not meet the ABET requirements for engineering design. Nevertheless, this program could have an advantage over the environmental engineering program as a preparation for a research career. The Massachusetts Institute of Technology has recently instituted a baccalaureate degree in environmental engineering science.

University of California at Riverside Curricular Workshop Recommendations

In November 1990, the National Science Foundation sponsored a workshop to develop a baccalaureate environmental engineering curriculum at the University of California Riverside. It is planned that environmental engineering will be one of the focal undergraduate curricula for the new college of engineering at U.C. Riverside. Thus, the U.C. Riverside situation presented an opportunity to take a fresh look at designing an environmental engineering curriculum without the constraints of an existing engineering departmental structure or faculty. The workshop was attended by approximately thirty leading environmental engineering educators and practitioners. At the conclusion of the workshop, a subcommittee recommended the 180 quarter credit curriculum summarized in Table 7.[10]

University of Wisconsin - Madison

Rather than offer two separately titled degree programs, the Department of Civil and Environmental Engineering at the University of Wisconsin - Madison has opted to offer a single baccalaureate degree program in civil engineering. The designated environmental engineering option under this degree (described in Table 7) will satisfy all accreditation requirements for both civil engineering and environmental engineering. The University of Wisconsin intends to submit the BSCE with a designated environmental option for basic level accreditation in both civil engineering and environmental engineering.

University of Michigan - Ann Arbor

Between 1978 and 1984, the University of Michigan Department of Civil and Environmental Engineering administered an ABET accredited baccalaureate degree program in Environmental Sciences Engineering. As part of a college-wide consolidation of degree programs in 1984, this program was folded into the BSCE (environmental and water resources engineering option). Currently, the University of Michigan Department of Civil and Environmental Engineering offers two general options within the BSCE degree, a "wet" option in the area of environmental and water resources, and a "dry" option in structures and materials. Table 7 describes the "wet" University of Michigan curriculum.

Rensselaer Polytechnic Institute

The RPI environmental engineering degree program is described in Table 6. Although the program evolved in affiliation with the chemical engineering department, it is currently affiliated with the Civil and Environmental Engineering Department. The curriculum shows a substantial basic science and chemistry requirement.

Other Programs

Several other universities have developed strong baccalaureate degree programs and options in environmental engineering.

The University of California at Berkeley has recently completed a revision of its BSCE curriculum to allow for more emphasis on environmental engineering. The College of Engineering at Berkeley is also planning a baccalaureate degree program in environmental engineering science.

Pennsylvania State University - Harrisburg offers an ABET accredited baccalaureate degree program in environmental engineering technology. By omitting full courses in some general engineering topics such as electrical circuits and differential equations, this program allows students to specialize in environmental design and remediation at the baccalaureate level.

The Department of Civil, Environmental and Coastal Engineering at Stevens Institute of Technology has developed a baccalaureate environmental engineering curriculum consisting of the fundamentals of chemical engineering coupled with higher level courses from the civil/environmental engineering curriculum.

Comparisons of Baccalaureate Curricula by Degree Title

Table 7 shows some differences and similarities between the various curricula by degree title. Some fundamental differences between the environmental and civil degrees are that:

-The environmental engineering curricula all require more basic science than the curricula titled as civil engineering.

-The environmental engineering programs have a greater environmental engineering and science content than those titled as civil engineering.

-The civil engineering degree programs generally require about 15 credits of structures and other traditional civil engineering subjects. These requirements are at the expense of the basic science and environmental engineering components of the curriculum.

The ABET categorical requirements appear to be satisfied by all but the proposed Iowa State environmental engineering science program. Most programs require some sort of comprehensive design experience. This appears to be particularly strong in the proposed Iowa State environmental engineering curriculum.

Comparisons of the basic science component of the curricula indicates that programs designed in accord with ABET guidelines are not able to include all of the desirable basic science courses. Some curricula provide for a limited number of basic science electives, whereas other curricula specify the specific courses required.

In the engineering science category, it is notable that the U.C. Riverside Workshop recommended 9 quarter credits of environmental transport phenomena in addition to the traditional fluid mechanics and hydrology courses. Other differences between the curricula worth noting are that the Iowa State environmental engineering and Michigan Tech chemical engineering programs do not require dynamics.

Professional Engineering Registration Issues

Several contributors to this position paper expressed concern that, in some states, where professional engineering registration is by specialty area, the specialty categories do not recognize environmental engineering. Thus, the practicing environmental engineer with an environmental engineering baccalaureate degree would have to choose to take the advanced level (P.E.) registration exam in a related field such as civil or chemical engineering.

Although environmental engineering baccalaureate graduates should be well prepared for the Fundamentals of Engineering Examination (E.I.T.), there is currently no advanced level (P.E.) examination in environmental engineering. For an advanced level environmental engineering examination to become available, at least one state must designate environmental engineering as a discipline, and that state will either have to prepare an advanced level examination or will have to request that a national environmental engineering examination be prepared.

Incorporation of Design into Baccalaureate Environmental Engineering Programs

The design content of engineering curricula is a topic which continues to attract significant attention from ABET and engineering educators. It is useful to consider the definition of "design". An applicable dictionary definition of design is:

"... the invention and disposition of the forms, parts, or details of something according to a plan."

ABET defines engineering design as:

"... process of devising a system, component, or process to meet desired needs. ... a decision-making process ... in which basic and engineering sciences are applied to convert resources optimally to meet an objective. ... it includes, objectives, criteria, analysis, synthesis, construction, testing, evaluation, alternatives, economics, esthetics."

Occasionally, some engineers think of design as an activity leading to the development of plans, specifications and construction documents. It is noteworthy that the ABET definition is significantly broad and does not limit design activity in this way.

The design process includes several levels ranging from conception and formulation of objectives to plan implementation and/or construction. For environmental engineering, these levels can be described as:

CONCEPTUAL DESIGN - This includes:

-environmental investigation and measurements to define objectives

-the development of quantitative environmental transport and process models used to define design objectives and simulate response

-development of flow diagrams, material and energy balances

-development of alternatives and preliminary costs

INTERMEDIATE AND DETAILED DESIGN - This includes:

-application of environmental transport and process models to test whether a design meets an objective

-development of operational and regulatory plans

-facility sizing, site layout, cost estimates, drawings, specifications, bid documents

IMPLEMENTATION AND CONSTRUCTION - This includes:

-implementation of a regulatory or environmental control system

-construction of environmental control facilities

-non-routine operation and improvement of an environmental control system to meet an objective

Relationship Between Research and Design

If research is broadly defined as an activity which brings new knowledge to an individual, there is a clear link between engineering research and engineering design. Good engineering design begins with an information gathering or research phase. Applied engineering research should be given more visibility in baccalaureate environmental engineering programs.

Candidate Subject Areas for Undergraduate Environmental Engineering Design Experiences

Many environmental engineering faculty relate primarily to teaching design oriented courses at the graduate level. It is fundamentally easier to teach design at the graduate level because the student has a better preparation in background material and principles upon which the design is based. At the baccalaureate level, however, there is generally not enough time in the curriculum to provide for adequate preparation and design instruction in all environmental engineering topics (e.g., water, air, land).

ABET is moving toward requiring a comprehensive design experience in curricula. To qualify for this designation, a course must focus on applying knowledge and skills developed in prerequisite courses to a design problem. In a particular sense, this means that a design problem must be well defined and appropriate in scope to a fourth year student. It also means that the curriculum must provide the knowledge and skills required for the design before the final semester or quarter.

Some subject areas which lend themselves to design during the senior year of a baccalaureate environmental engineering program are:

-Water and/or Wastewater Processing: These traditional topics adapt well to design courses. Excellent texts, teaching materials, practical examples, and practitioner resources are generally available. The chief problem at the senior level is that at least one and perhaps two water/wastewater prerequisite courses (introductory course, process engineering course) would be necessary to provide the background knowledge and skills. While this is possible, it begins to take up a lot of room in a crowded curriculum.

-Water Distribution and Wastewater Collection Systems: These topics also have the advantages of good texts, teaching materials, practical examples and practitioner resources. Moreover, a meaningful design course can be taught based on prerequisite courses in fluid mechanics and introductory environmental engineering.

-Environmental Modeling Applied to Design: Here a design course would focus either on surface water, ground water, or air. The objective would be to design an environmental control strategy to attain an environmental quality standard or objective. Some background in modeling principles and skills would be helpful.

-Solid and Residual Wastes: A design course here could focus on one aspect of the problem such as the collection/transportation system, resource recovery/processing system, or a landfill. Analysis and design of a conventional landfill for municipal solid waste is a workable senior level design course.

-Gas Cleaning and Air Emissions Control: This topic shares some advantages and drawbacks of the water/wastewater topic. Some good fundamental texts are available, but practical examples and practitioner input are more difficult to find. Design of a system for control of particulate emissions can serve as a senior project.

RECOMMENDATIONS

A Stronger Presence at the Baccalaureate Level

Environmental engineering should have a stronger presence at the baccalaureate level. Ways of achieving this will depend on the institution and should include:

-Meaningful education of students in all engineering specialty areas in environmental engineering. This should consist of a required introductory course in environmental engineering science coupled with the recognition of environmental engineering components in subsequent specialty area design projects. To facilitate this, environmental engineering faculty should become involved in design projects in other engineering specialties, and other engineering faculty should incorporate more principles of environmental engineering science into their teaching.

-Strengthening of environmental engineering options in traditional engineering degree programs. At many universities, traditional engineering degree programs are highly constrained and do not provide the opportunity for a student to obtain the basic science and engineering science background necessary for a well-founded option or minor in environmental engineering. At other universities curricula are looser, and it is easier for students to follow an environmental engineering option. It is important that ways be found for more engineering students to obtain some competence in environmental engineering topics. ABET requirements for the specialty area and academic politics can pose barriers here.

-Development and improvement of environmental engineering baccalaureate degree programs. This position paper has developed a strong case for the continuation, expansion and improvement of baccalaureate degree programs in environmental engineering. Only a few such programs currently exist. Several additional universities are considering adding environmental engineering baccalaureate programs. It is important that the environmental engineering educational establishment, AEEP, and AAEE support and nurture the development and improvement of these programs.

Improved ABET Basic Level Accreditation Program Criteria for Environmental Engineering

ABET basic level program criteria for the accreditation of baccalaureate environmental engineering programs (see Table 3) are minimal and should be revised to reflect the current situation. The criteria should permit and ensure that graduates are prepared for modern practice in environmental engineering and for life-long learning. Consideration should be given to:

-Recognition of course work in quantitative/applied basic science with environmental engineering application as equivalent to engineering science course work.

-Specification of course work in areas of particular importance, such as: environmental transport phenomena, atmospheric science, or geology.

-Specification of broad guidelines for what constitutes a comprehensive or capstone design course in environmental engineering.

-Retention of the current requirement that instruction in at least three areas of environmental engineering be provided.

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Table 1. U.S. Engineering Degree Production by Discipline for 1988 (data from U.S. Engineering Manpower Commission, Reported by ASCE)

Discipline	Number of Degrees				Percent of Total			
	B.S.	M.S.	Ph.D.	Total	B.S.	M.S.	Ph.D.	Total
Aeronautical	2949	838	150	3937	4.1	3.3	3.3	3.9
Agricultural	362	183	61	606	0.5	0.7	1.3	0.6
Architectural	356	34	0	390	0.5	0.1	0.0	0.4
Biomedical	636	257	70	963	0.9	1.0	1.5	0.9
Ceramic	368	96	24	488	0.5	0.4	0.5	0.4
Chemical	4082	1273	657	6012	5.7	5.0	14.5	6.0
Civil	7714	3025	518	11257	10.8	12.0	11.4	11.3
Computer	4275	2880	262	7417	6.0	11.3	5.7	7.3
Environmental	192	329	63	584	0.3	1.3	1.4	0.6
Electrical	24367	7272	1003	32642	44.1	28.7	22.0	32.4
Engr Science	1378	646	191	2215	1.9	2.5	4.2	2.2
General	1085	516	66	1667	1.5	2.0	1.5	1.6
Industrial	4584	2138	149	6871	6.4	8.4	3.3	6.8
Materials	549	110	20	679	0.8	0.4	0.4	0.6
Mechanical	15610	3753	738	20101	21.9	14.7	16.2	19.9
Mining	404	277	56	737	0.6	1.1	1.2	0.6
Metallurgical	877	621	310	1808	1.2	2.4	6.8	1.7
Nuclear	306	215	102	623	0.4	0.8	2.2	0.6
Petroleum	612	216	38	866	0.9	0.8	0.8	0.8
Systems	474	631	63	1168	0.7	2.5	1.4	1.1
Others	206	123	20	349	0.3	0.5	0.4	0.3
Totals	71367	25435	4561	101382	100	100	100	100

Table 2. Summary of Criteria for General Curricular Content Applicable to Basic (Baccalaureate) Level Engineering Accreditation

Subject	"Years of Full-Time Study"	Semester Credits	Quarter Credits
Mathematics and Basic Science	1.0	32	48
Engineering Science	1.0	32	48
Engineering Design	0.5	16	24
Humanities and Social Sciences	0.5	16	24

Table 3. Summary of ABET Program Criteria Applicable to Baccalaureate Environmental Engineering Programs (1990-91)

Faculty: The majority of the engineering members of the environmental engineering faculty should be registered or should be engineers in training.

Curriculum: At least three areas of environmental engineering must be provided in the curriculum from among the following:

- -air pollution control engineering
- -water quality engineering
- -solid wastes engineering
- -environmental health engineering

Table 4. Summary of ABET Program Criteria Applicable to Baccalaureate Chemical Engineering Programs

Curriculum: Must include one-half year of advanced chemistry (beyond first year elementary chemistry). Up to one-fourth year of advanced chemistry may be counted toward engineering science requirement

Engineering science must include: material and energy balances, thermodynamics, transport phenomena, reaction engineering, continuous and stage-wise separations, process dynamics and control

Must include a "capstone" design course

Computer usage must be integrated throughout the program

Administration: When program is administered outside of an engineering school, qualified faculty guidance and adequate support must be demonstrated.

Table 5. Summary of ABET Program Criteria Applicable to Baccalaureate Civil Engineering Programs

Faculty: At least four faculty assigned to baccalaureate program. At least four specialty areas must be represented. A majority of those eligible should be registered Professional Engineers. A majority of those teaching design courses must be registered Professional Engineers. Faculty shall be involved with the professional development of students.

Curriculum: Minimum of one-half year of civil engineering courses. Minimum of four specialty areas in each student's program. Curriculum must culminate in a major comprehensive design experience; should have practitioner involvement. Laboratory experience should: be integrated, foster creativity, develop communication skills, and develop experimental methods.

Table 6. Comparison of ABET Criteria for General Curricular Content for Baccalaureate Engineering and Engineering Technology Programs

Category	Engineering Semester Credits	Engineering Technology Semester Credits *
Mathematics and Basic Science	32	24
Engineering Science	32	na
Technological Courses	na	48
Engineering Design	16	na
Humanities/Social Sci	16	24
Approximate Total	128	124

Technological courses include technical sciences, technical skills and techniques, and technical design.

Table 7. Comparison of Environmental Engineering Curricula (Semester Credits)

SCHOOL	Mich Tech	R.P.I.	U.C. Riv.	Iowa State	Iowa State	Univ Wis	Univ Mich	Mich Tech	Mich Tech
STATUS	Exist	Exist	Rec	Prop	Prop	Exist	Exist	Exist	Exist
DEGREE	BSEnE	BSEnE	BSEnE	BSEnE	BSEnES	BSCE	BSCE	BSCE	BSChE
TOTAL REQUIRED CR	130.7	134	120	134.5	135.5	131	128	132	130.7
Non Technical & Comm.	28.7	24	24	23.5	24.5	21	24	28.7	24
Engl. Comp.	4		8	6	6		4	4	4
Communication	4			0.5	0.5	5	3	4	1.3
HU/SS/PE	20.7	24	16	17	18	16	17	20.7	18.7
Math & Statistics	17.3	16	18	19	17	18	19	17.3	17.3
Basic Science	27.4	35	28.7	28	52	23	16	19.4	34.7
Chemistry	9.3	16	8	7	18	9	5	6.7	18
Physics	6.7	12	10	10	10	5	8	6.7	6.7
Gen Biol	2.7		5.3	3	3	e	e	e	e
Geology	e		2.7	2	2	e	e	2	e
Microbiology	2.7	4	e	3	3	e	e	e	e
Physical Chem	e	3		3	3	e	e		10
Botany	e		2.7		4	e			
Meteorology	e				3	e	e		
Ecology	e				3	e			
Electives	6	0	0	0	3	9	3	4	
Engineering Science	28	30	25.3	31	18	33	29	33.9	26
Solid Mechanics	8	7	6	6	3	9	11	10	2.7
Thermodynamics	2	3	2	4	e	e	3	2	2.7
Hydrology	2	3	2	2	2	e	e	2	
Fluids, Hyd	3.3	3	2	5	5	6	6	3.3	
Transport Phen	e		6	e	e	e			5.3
Electric Circuits	2.7			e	e	e		2.7	5.3
Surveying		2.7			e	e		e	4.7
CE Soils	e			3	e	4	3	2.7	
Engineering Econ	e			2	2	2		1.3	1
Process Analysis	e	6	2	e	e				2
Comp Sci, Graph	3.3	2	5.3	6	e	9	6	5.2	2
Laboratory		3							1
Material & En Bal	e								4
Electives	4	3		3	6	3	0	0	
Env Eng Science & Des	23.3	23	24	33	24	21	21	12	11.3
Principles	2	6	2			3	3	2	e
Water Quality	3.3		4	6	3	3	e	0.7	e
Air Quality	2.7	3	4	3	3	3	e	e	e
Solid Wastes	2.7	3	2	3	3	3	e	e	e
Laboratory	2	4	4				e	e	e
Env Hlth, Toxicol	1.3		e	3	3	e	e	e	e
Biotechnology	e		e	3	3			e	e
Comprehen. Des.	2	4	e	6	e	3	e	e	e
Geohydrol	e	e	e	e	e	e	e	e	e
Water Chem	1.3	e	e	e	e	e	e	e	e
Ind/Haz Wastes	e	e	e	3	3	e	e	e	e
Elective Cr	6	3	8	6	6	6	18	9.3	11.3

Civil/Chem Engr Req	0	0	0	0	0	15	14	18.7	17.4
Structures		e	e				6	6	8
Contracts		e	e				e	2	
Const Matl's	e	e				3	e	2	
Land Info Sys	e	e				3	e		
Transportation	e	e				3	e	2.7	
Foundations								2.7	
Const, Sched								3.3	
CE (non env) Elec	0	0	0	0	0	0	6		
Plant Design									6.7
Unit Ops Lab									6.7
Kinetics									4
Free Electives	6	6	0	0	0	0	5	2	

THE HAZARDOUS WASTE CURRICULA IN ENVIRONMENTAL ENGINEERING PROGRAMS: IDENTIFICATION OF ISSUES

Position Paper

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INTRODUCTION

The breadth of engineering education has evolved markedly during the last decades. No change has been any greater than that of management of hazardous materials, first as Priority Pollutants were incorporated into industrial and municipal wastewater discharge limitations; subsequently in CERCLA hazardous waste site remediation and RCRA hazardous materials management; now as a significant part of air quality regulations, and increasingly as pollution prevention, waste minimization and resource recovery become objectives in the commercial and manufacturing sectors.

More than in other areas of engineering or in our field in the past, our field has been defined by society's changing priorities, manifested as federal laws and regulations, and often supported by massive federal and state expenditures. We have sometimes led and sometimes followed as hazardous waste issues from mercury to dioxin have advanced from a mg/l to a part per trillion threshold. Hazardous waste remediation and management have come most recently to our agenda, in part, because the volumes of waste were generally small and almost always behind the fences of industry and government and, in part, because environmental laws have been enacted in the sequence that problems have arisen. As a profession, we can claim little credit for guiding public concern or setting the environmental agenda, but we share a considerable responsibility in addressing these important issues.

Our profession, our peers and our students have taken on major responsibilities in each of these activities involving toxic substances, often with a measure of frustration concerning how much we need to know and how little we have learned about key parts of the problems. We have heard demands from our students, from the consulting engineering community and from the regulatory agencies for education in new skills in hazardous waste management and engineering. We have altered our own research activities and made many changes in our courses and curricula. It is an appropriate time to share our experiences, to identify and discuss significant issues, and to try to understand the best approaches to this complex and important topic.

The objective of this paper is to provide an introduction and an overview, to provide some background information and to pose questions that may be developed in the conference presentations and discussions.

CURRENT SITUATION

Hazardous waste curricula proliferated in the 1980s. Luthy and Benjamin[3] surveyed AEEP members, with 47 responding programs, and found about half offering at least one course, with about 10 percent offering a focused curriculum, and the rest incorporating hazardous waste topics in their fundamental environmental engineering courses. Powitz, et al.[5] identified 167 colleges and universities that offer formal courses in the hazardous waste area, including 74 identified as graduate courses in civil and environmental engineering. Wentz et al.[7] found that the number of hazardous waste offerings in a survey of 62 engineering departments had increased six-fold from 1981 to 1988, but only about half of the universities had course offerings. Kummler[4], et al. (1991) identified four masters degree programs in hazardous waste management and 13 others offering graduate level options in hazardous waste engineering or management. There are several additional environmental engineering programs that now offer a substantial degree of specialization in hazardous waste engineering and management; many are trying to address the role of environmental engineers in waste minimization and pollution prevention.

These curricular developments reflect a very strong demand for competent people in the field. Demand in environmental engineering may exceed supply by a factor of two or three at present[3]. Busch[1] cites the need for 22,500 professionals from 1990 to 1995 to meet the hazardous waste clean up needs in the United States. As federal DOE and DOD site remediation activities develop, projected demand for trained professionals reaches astronomical figures. Potential employment in site remediation activities at the Hanford DOE site alone has been projected at 10,000 professionals. On the other hand, it has also been noted the majority of environmental engineering employment is still in traditional areas of water, wastewater and solid waste management and that EPA's assessment of relative risks associated with environmental problems no longer rank hazardous waste site problems at the top of the priority ranking[6].

Professional practice in hazardous waste engineering is dominated by the work of consulting engineering firms, with substantial employment in other industries, with EPA and other regulatory or operating agencies, notably the States and the Departments of Defense and Energy. Especially with consulting firms, but also in other organizations, environmental engineers often have leadership roles in hazardous waste projects. In addressing a project, a wide range of information and skills are usually needed. An environmental engineer may call on basic problem solving skills, on specific application-oriented training, and on the skills of people from several related disciplines. Employers widely recognize their responsibility for providing on-the-job training or continuing education; our main responsibility lies in providing the essential technical skills for engineering analysis and design, as well as the scientific and non-technical breadth to prepare students to work productively with professionals from other disciplines. Our students should understand the broader scientific and social implications of our technological choices. We need to prepare people to work in this new area of the profession; yet we must recognize that most students will have varied careers and may not focus on hazardous wastes for more than a few years.

CURRICULAR CONTENT

Hazardous waste problems are universally viewed as highly interdisciplinary, involving fundamental principles from many fields. "Environmental engineers are significantly involved ... because of their background in environmental sciences, their attention to intermedia processes, and their role in shaping environmental policy for the protection of human health and the environment."[3] They also have a historic role in pollution control and public sector work, either in agencies or with consulting firms, that has provided both the access and the capability to follow hazardous waste problems as they have emerged. The educational challenge is to educate competent professionals, even as the field is emerging and evolving. The skills that may be needed in hazardous waste problems are too numerous for any individual to possess; they are not widely agreed upon, and they are not necessarily the same skills taught in traditional environmental engineering. Furthermore, few environmental engineering educators have significant hazardous waste experience with regulatory agencies or consulting firms.

Perhaps the most common approach to hazardous wastes within our curricula is to develop a course addressing the most salient topics and also to incorporate some modified material into the fundamental environmental engineering courses. Topics in such a course "typically include a historical perspective on legislative and engineering approaches to the issue; extensive coverage of RCRA and CERCLA, their predecessors and amendments; definitions, classifications, and generation rates of hazardous wastes; landfill design and operation, with special emphasis on provisions for leachate and gas control and collection; an overview of pump-and-treat, stabilization, and incineration technologies; and several case studies."[3] Additionally, fate and transport of groundwater contaminants and biodegradation and bioremediation are commonly included. Such courses are intended to familiarize students with hazardous waste engineering; in almost all cases, these courses are open to undergraduate, as well as graduate students. Along with the hazardous waste course, most programs have modified their traditional courses to address the behavior of trace, toxic contaminants in at least some of the unit processes that are used for hazardous wastes. An EPA-funded project, directed by Domenic Grasso at the University of Connecticut, is currently developing materials for such courses, emphasizing processes specific to hazardous waste source control.

A second alternative is to offer a limited number of courses intended to develop competence in specialized areas related to hazardous waste engineering. The best developed of these are in the broad areas of groundwater contamination, often involving courses in subsurface contaminant fate and behavior and groundwater hydrology. Luthy and Benjamin[3] have carefully distinguished between professional training in hydrogeology and environmental engineering, with hydrogeologists having more sophisticated geological training and modeling expertise. Other areas of this kind of moderate specialization include courses in control of hazardous air pollutants, waste minimization, thermal technologies, RCRA-based management issues, and others. The availability of several courses in a program or in closely related departments often constitutes a graduate level option in hazardous wastes.

The third alternative is a graduate degree. The Kummler study[4] identified hazardous waste masters programs at New Jersey Institute of Technology, Tufts, Wayne State, and University of San Francisco and summarized required and elective course topics in each (Table 1). Course topics are more oriented to RCRA-related hazardous waste management than to remediation, and some of the programs are oriented to part-time students, perhaps meeting a continuing education, rather than a graduate education function for many students. It is interesting that two of these programs have arisen at universities with environmental engineering graduate programs, and two have not.

The multidisciplinary nature of hazardous waste management was cited at the beginning of this section. A daunting range of courses and topics can be identified that clearly are relevant. A list has been compiled, inclusive of ones mentioned already, of courses or subjects that have been identified as appropriate for a hazardous waste curriculum (Table 2); it is far from comprehensive. Courses have been found in academic departments, such as Microbiology, Agriculture, Chemistry, Forestry, Geology, Soil Science, Environmental Studies, Law, Economics, Public Affairs, Environmental Health, Toxicology, as well as Chemical, Mechanical and Civil/Environmental Engineering. At many universities the problem is not so much in finding, but in choosing among, appropriate subjects for our graduate students.

A perspective on what should be included in a curricula can be gained from knowing what professionals see as their information and educational needs. Kovalik et al.[2] reported on a survey of EPA employees with RCRA or CERCLA assignments. Technical needs among 40 technology transfer topics were ranked with a high degree of similarity for both groups of employees. Table 3 includes the topics ranked among the ten highest in either group (totalling 12 topics), notably including treatment technologies (6 topics), risk assessment (2 topics), groundwater monitoring and contaminant fate and transport. When the respondents were asked their opinions on technical needs of state agency, EPA contractors, and regulated community personnel, a very similar range of topics was obtained. Though this survey was intended to assess technology transfer, it may be an excellent indicator of the educational needs of young professionals working in hazardous waste management and often educated in environmental engineering. Some topics may be appropriate primarily for continuing education or short courses, the traditional realm of technology transfer, but others can certainly be addressed in graduate curricula.

ISSUE IDENTIFICATION

The first issue is not one of curricula but of capacity. Consultants, agencies, contractors, all have serious needs to find and retain talented, competent people. Expenditures for Superfund site work are very large, and a large component is professional personnel effort. The capacity of our educational system, notably our graduate environmental engineering programs, to recruit talented students and to prepare them to become competent professionals is strained. Many of us are seeing unprecedented student interest in hazardous wastes and in groundwater problems, so the availability of talented people seems assured. However, many programs are at or near capacity for handling students with no prospects for significant expansion. We cannot prepare nearly all the people that are needed, if the expenditure projections are correct. Should we accept all the qualified applicants, or should we limit access to graduate education? What are long term career paths likely to be? Will the site remediation and hazardous waste management expenditures continue? Will hazardous waste professionals be able to change career directions readily, if work in this area decreases?

Of course, the answer to the last question should be affirmative; however, there is the possibility that our curricula will become so specialized that students are hazardous waste engineers, rather than environmental engineers. Just as environmental engineering seems to be diverging from undergraduate civil engineering curricula at some universities, there is some tendency towards defining a new subspecialty, hazardous waste engineering, at the graduate level. The advantages of educating engineers with highly developed skills, strongly focussed on professional practice with hazardous wastes, must be balanced against the loss of breadth in the skills acquired in graduate training and the loss of flexibility in career choices down the line. The pros and cons of such training seem rather analogous to the issues in undertaking baccalaureate environmental engineering degree programs.

Much discussion should focus on what to include in hazardous waste curricula, what to require, and what to suggest as electives. The EPA employee survey suggests that a rather narrow range of topics, fairly closely tied to traditional environmental engineering, is perceived as most needed by young professionals. Some of us have the uneasy feeling that a much broader range of subjects may also be needed for professional work in this multidisciplinary field. These subjects can be approached with different objectives, ranging from familiarization with the subject, to acquisition of technical skills, to development of a comprehensive, fundamental understanding. Especially as we identify subject material that is traditionally taught in other disciplines, such as molecular biology, toxicology or environmental law, we will encounter problems in finding courses at the correct level -- or, perhaps, students at the correct level. A traditional solution in environmental engineering has been to bring the subject within our courses, notably with aquatic chemistry, microbiology, and reactor analysis. This approach may be appropriate for some of the subjects, but certainly not for all. We may wish to require more background of students entering our graduate programs, or devote more of the graduate programs to fundamental science and engineering outside of our departments.

There are many approaches to assimilating new material into curricula. Incremental knowledge can result in incremental changes in courses, but larger changes result in new courses, new degrees, even in new disciplines. Hazardous waste practice involves attention to toxic compounds, often at low concentrations, and the development of remediation techniques that are often highly problem- and site-specific. Much of the curricular development can be characterized as the incremental adaptation of existing courses to considering behavior of these novel contaminants, supplemented with a case study approach to illustrate investigations and engineering solutions. With a developing technology, such as bioremediation, this process can impact several existing courses and result in several new ones. For example, bioremediation requires knowledge of the trace organic contaminants, of the range of microbial degradation options, biodegradation kinetics, groundwater flow and contaminant transport, in situ and reactor treatment systems -- topics that impinge on several existing courses, that involve fundamentals going well beyond traditional topics, and ones that can be addressed in new courses, and at levels ranging from familiarization to detailed mechanistic understanding. There probably are better and poorer ways for us to proceed with bioremediation material, and with the several other subject areas, and we can profitably exchange our ideas.

Finally, as hazardous waste curricula emerge, we will have to make many decisions about subject matter and courses to leave out of our students' courses of study. There are few of us who regret that Imhoff tanks and rodent control have fallen by the wayside, but many of us will be very uncomfortable seeing students graduate without such subjects as aquatic biology, physical hydrology, or water resources systems. The skills acquired addressing hazardous wastes will be mirrored by other skills that are omitted. The choices involved should be made carefully with clear thinking about the effects on individual careers and on the environmental engineering profession.

Environmental engineering historically began with the sanitary revolution and direct concern for public health, and the most notable accomplishments of our profession still arguably are the reduction of communicable diseases. In many ways, the entry of hazardous wastes matters so forcibly into our profession is a return to our roots in public health. The restructuring of curriculum to prepare our students for professional careers in this new old area is an opportunity and a challenge for us at this conference.

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Table 1. Required (R) and Elective (E) Courses for Four Master's Degree Offerings in Hazardous Waste (Kummler, et al.)4

Course USF	NJIT	Tufts		Wayne
Introduction/overview of hazardous waste	E	R	R	E
Environmental/hazardous waste law	R	E	R	R
Environmental chemical science or fate and transport of environmental contaminants	R	R	E	E
Health effects, risk assessment and/or toxicology	R	R	R	R
Laboratory or internship	R		R	
Risk management and public policy		R	R	E
Environmental economics/business management		R		R
Groundwater		E	R	
Probability, statistics, data analysis		E	R	
Biochemistry, biomedical sciences	R		E	
Industrial safety, chemical process safety		E	R	
Waste treatment engineering (biological, chemical, physical)	E	E	R	R
Transportation, emergency response, spill response			R	
Waste minimization recycling		E	R	
Capstone course or thesis	R	R	E	R

Table 2. Selected Courses for Hazardous Waste Management and Engineering

Analysis of toxic chemicals

Environmental, aquatic, or wildlife toxicology

Environmental law

Environmental microbiology, bioremediation fundamentals

Geotechnical aspects, containment, stabilization, and drainage

Groundwater contaminant fate and transport

Groundwater hydrology

Groundwater monitoring

Hazardous air pollutants

Innovative remediation technologies

Natural resource economics

Radioactive waste management

Risk analysis and assessment

Risk management and public policy

Solid waste management

Toxic spills, emergency response

Waste minimization, pollution prevention

Table 3. Highest Ranked Technical Needs for EPA CERCLA and RCRA Staff (Kovalick, Town and Peters, 1990).

Establishing risk-based cleanup levels for various contaminants and site conditions.

Fate and transport of contaminants in the subsurface (e.g., facilitated transport, methods for measuring contaminant mobility, non-aqueous phase liquids).

General technical information on the performance, limits, safety, and cost of hazardous waste treatment technologies.

Ground-water monitoring for site inspection and for evaluating the effectiveness of treatment.

Use and effectiveness of *biological treatment* process (biodegradation or bioremediation).

Use and effectiveness of *physical treatment* processes (e.g., soil washing, vacuum extraction).

Use and effectiveness of *chemical treatment* processes.

Use and effectiveness of *stabilization/solidification.*

Use and effectiveness of *thermal destruction* (incineration, oxidation).

Risk assessment information: risk levels for RCRA waste (e.g., incinerator ash, contaminated soil).

Selecting and applying release and flow control, and source control technologies for RCRA corrective action.

Applicability of RCRA Treatment Standards to Superfund.

FUTURE CONCERNS IN ENVIRONMENTAL ENGINEERING GRADUATE EDUCATION

Position Paper

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INTRODUCTION

In many respects environmental engineering graduate education is entering a new era. As noted in the AEEP Conference on Fundamental Research Directions in Environmental Engineering (Luthy and Small[18]), we now address a wider range of environmental processes than ever before, over a wider range of spatial and temporal scales, and with a wider range of disciplinary skills. The need to solve environmental problems is being intensified by ever-increasing public awareness and concern for environmental issues, and the various regulatory requirements and policy agenda that continually broaden their scope and complexity. Many recent events, such as the Exxon Valdez oil spill, the oil fires and spills in Kuwait, the global climate debate, etc., have given environmental engineering and science greater challenges than ever before. The modern environmental engineer is confronted by challenging problems which cut across various disciplinary bounds. As a consequence, the profession is becoming increasingly multidisciplinary with the need to use and integrate talents and perspectives from a wide range of fields.

THE AGENDA FOR THIS CONFERENCE

With these issues in mind, the Committee on Future Concerns in Environmental Engineering Graduate Education has identified five themes for discussion at this conference: (1) Graduate education for versatility and perspective; (2) Programmatic issues on research and graduate education; (3) Relations between the environmental industry and graduate education; (4) A philosophy of graduate education; and (5) Environmental engineering and society. The basis for selection of these topics is as follows.

Educational processes must prepare students for careers that may span more than 40 years, and thus graduate education must be flexible and endow the student with abilities to address both present and future challenges. For example, in this century we have seen a continuing evolution in the types of problems that environmental engineers must address: pathogen control, protection of receiving waters, energy and environment issues, hazardous wastes, low-level contaminants and risk, and problems of regional and global scale. Tomorrow's environmental challenges will be no less diverse than those of today. Thus, graduate education must strike a balance between breadth and depth of specialization. It must also introduce students to the limits of knowledge as well as the ambiguities in real world problem solving. The education process must prepare students to be innovative and to be able to solve unstructured problems; students must acquire the tools and abilities for a lifelong learning experience. How we may do all this within an MS program is a perplexing problem. The answer may require greater involvement with the undergraduate curriculum.

Several programmatic issues impact the process of graduate education. These issues include the advantages and limitations of thesis versus non-thesis MS programs. Moreover, because of the widespread interest in environmental engineering, the challenge remains to accommodate students who enter the field from non-engineering disciplines. Accreditation of graduate programs is controversial and requires discussion. Although desired by some, most graduate programs are not interested in accreditation. We need to find ways to take advantage of growing interest in environmental engineering to recruit more minority graduate students.

Practitioners may assist the graduate education process by serving on visiting committees, providing seminars, and serving as adjunct faculty. Practitioners provide important perspectives on the value of research, and they can point to new advances in design methodologies, emerging technologies, and novel approaches for solution of modern environmental problems. Given the positive roles that practitioners may play in the graduate education process, their level of involvement should be increased.

The environmental industry (e.g., manufacturers, contractors, etc.) does not usually provide the general level of programmatic financial support as that provided by industry in the chemical engineering and electrical/computer engineering fields. The reasons for this lack of industrial support need to be explored; greater support would help solve manpower requirements in the environmental professions. Stronger links with the environmental industry may provide a means for dealing with the tension between scarcity of resources and the need for a diverse mixture of environmental engineering programs with adequate strength in graduate research programs, including development and sustaining the capabilities of faculty members throughout their careers.

We need to help students understand more of the possible leadership roles that they may assume. Environmental engineers and scientists need to become more involved in emerging social and political issues revolving around their field. Because of their training and experience, environmental engineers should undertake a participatory role in helping to structure and articulate rational environmental policy. Students should learn more of their place in a complex society in which the engineer/scientist may help the profession by working at the interface between policy and technology.

CONNECTION TO PAST CONFERENCES

The Committee on Future Concerns in Graduate Education has developed an agenda that is less concerned with specific curricular matters, but rather focussed towards broad issues of educational goals and processes. In this regard it is worthwhile to reflect on certain themes at past AEEP environmental engineering education conferences, in order to establish a context for the agenda for the current conference.

The Third (1973) and the Fourth (1980) Conferences on Environmental Engineering Education recognized that the environmental engineer is concerned with the ... " (1) protection of human populations from the effects of adverse environmental factors; (2) protection of the environment, both local and global, from the potentially deleterious effects of human activities; and (3) improvement of environmental quality for man's health and well-being." The view taken at the Fourth Conference was that these responsibilities carry an implied need for diversity and excellence. Because of the size of most programs, the argument was taken for encouraging a diversity of programs, each examining its own strengths in light of societal needs and striving to provide the highest quality of education possible. Programs should not be encouraged to look alike, but rather should define their own unique qualities and to build strength around this uniqueness. Curriculum content is not the determining factor in achieving excellence.

A lesson from the past is that graduates must be prepared for change. As it is not possible to predict with certainty what skills will be needed in the future, students must be educated in the fundamental fields so that they will be equipped to deal with change. This requires training in the sciences as well as engineering; and it requires development of communication skills. These traits may be fostered by faculty with diverse abilities, and by faculty who appreciate this diversity. The educational atmosphere should include a mix of natural sciences and engineering, and combine engineering with the humanities and social sciences. All of these issues are still relevant today.

GRADUATE EDUCATION FOR VERSATILITY AND PERSPECTIVE

The Problem

Robert M. White, President of the National Academy of Engineering, has noted that activities that are central to raising standards of living throughout the world (energy production and use, industrial development, and the production of food) are those that endanger the habitability of the planet. Stumm and Morgan have stated this fact in more general terms. There is "a basic property, a constitutive property of all organisms including humans: Conditions of life preservation are unavoidably interrelated with conditions of life endangerment. This constitutive element is particularly evident with humans in their conflict between exploitation of natural resources and protection of the environment."[23] Environmental engineering contributes to the identification of these conflicts and is the discipline that solves environmental problems by appropriate application of engineering science and technology.

The scope of environmental problems has grown substantially in the past decade and will continue to expand in the future. Environmental engineering education and practice should grow and develop to solve these problems. We can no longer be a water-focused profession; air, land, and water each require substantial effort and concern. We can no longer base our environmental science and technology only on fluid mechanics and chemistry; law and regulation, risk analysis and risk assessment, and the tools of modern molecular biology are examples of areas that also require study and application. In the past, the education of environmental engineers has been largely accomplished at the masters level, and frequently with a one year program. This simply will not serve us in the future if we are to meet our responsibilities to society. Change is coming and we can direct it or be constrained and perhaps eliminated by it.

The Masters Degree

The masters degree has served, and continues to serve, as the principal entry level into environmental engineering, whether the path to be followed after earning this degree is into private practice, government, or additional education. Because of this diversity in professional objectives and also because of differences among the chemical, civil, mechanical, and other engineering undergraduate programs that prepare students for graduate study in environmental engineering, masters programs differ greatly in goals, content, length, and thesis requirements. Nevertheless, many are water-focused, science-oriented, and can be completed in two semesters of study. Over time, programs have evolved that include both water quantity and water quality, both water supply and wastewater treatment, both human health and environmental protection, and that also provide a significant base in environmental science. And all of this in nine months!

The diversity has been accomplished with some costs. A sizable fraction of a one-year masters program is used to introduce engineers to environmental science. Necessary emphasis in aquatic chemistry, environmental microbiology, environmental fluid mechanics and other similar subjects involves instruction that is at the level of upper level undergraduate courses. Stated another way, our faculty teach and our graduate students take courses in their masters education that are largely introductory. Civil engineers lack chemistry, chemical engineers lack hydrology, and no engineers know biology.

An important solution to these past constraints has been the 1.5 to 2-year master program in which students learn introductory environmental science, study environmental engineering including design, prepare a substantial masters report, essay, or thesis, and may even have the opportunity to study additional areas such as air pollution, epidemiology, or systems analysis. A 1.5 to 2-year masters program in environmental engineering can serve present requirements for versatility and perspective and can probably be adapted to meet future needs over the next several years. But it faces severe and perhaps fatal resource requirements, both financial and human.

Today's students receive their undergraduate engineering degrees after four years of difficult study, and also after four years of debt accumulation. As they graduate they have opportunities for challenging positions at reasonable salaries. It is difficult for them to decide to forgo these opportunities, accumulate more debt, enter a new field, and choose to study for the entry level eduction to environmental engineering, i.e., the masters degree. One to two years of postponed employment and additional debt is a severe burden, too severe to be expected for these undergraduates. Some financial support must be provided if the masters degree, either one or two years in length, is to continue to provide society with the environmental engineers who are needed for environmental management and protection.

Universities, whether state or private, do not provide financial or human resources to support graduate education fully in any field, and environmental engineering is no exception. To focus their educational efforts on graduate education, faculty in environmental engineering must obtain substantial support for themselves and for their students from outside sources, usually from research grants and contracts from government and industry. This problem is more difficult and more important for environmental engineering than for other fields, because entry into the field requires graduate education and because masters students taking courses that are in large part introductory are not well prepared to do productive research. The result can be inadequate education and poor research. The problem is not in the talents of the students and the faculty; the problem is in the resources available to both students and faculty, particularly for the entry level masters degree.

How can present difficulties be resolved and future changes accommodated as they arise? How can we teach more needed science, provide sufficient focus on engineering design, consider all media (air, land, and water), and instill perspectives on protecting human health and the environment? As stated earlier, how can we educate environmental engineers to identify conflicts between resource utilization and environmental protection and then solve them in a world of exponential economic growth? Answers are neither obvious nor easy. A five year program for all engineering fields, educationally and professionally desirable, is not feasible. Our present one year masters programs are not adequate for future demands and are expensive. Our 1.5 to 2-year masters programs require even more financial and human resources that are in very short supply.

Undergraduate Education

Undergraduate education in environmental engineering is coming, although probably not in the conventional sense and perhaps not taught by environmental engineers. In time, and hopefully in a short time, the undergraduate education of all engineers will involve concepts and applications of environmental engineering. As Friedlander has written:

> "Environmental engineering should routinely incorporate environmental constraints into the design procedures of existing engineering disciplines, and environmental consequences of technology and the basis of regulatory standards should be part of the engineering curriculum. In plant design, there must be a growing emphasis on waste reduction rather than end-of-pipe treatment and disposal. However, waste reduction needs a fundamental engineering research base which is still under development and merits high priority. Finally systematic improvements in consumer product design are required, especially

for items dispersed through society."[12]

Environmental engineering will be taught to undergraduate chemical, mechanical, electrical, civil, biomedical, and other engineers, and this instruction will most probably be given by faculty in these other engineering disciplines. Since the teaching of environmental engineering will not be limited to faculty in environmental engineering, the practice of environmental engineering may no longer be reserved to those who have graduate education in this field.

It is time to look very hard at undergraduate education in environmental engineering. The introduction of environmental engineering in all undergraduate engineering disciplines will have very beneficial effects in the prevention of and the solutions to environmental problems. The development of students with these abilities will allow our graduate programs to change in order to meet the new demands that face them. But education in environmental engineering as a normal component of an undergraduate education in any engineering discipline will leave important areas unaddressed. How will the capacity of the environment to assimilate wastes be addressed and the health of the environment sustained? According to Lee[16], pressure for change in technological systems stems more properly from concerns about the capacity of the environment as a receptacle for wastes than from its bounty of resources. Depletion of resources is rarely a driving force for resource substitution, while environmental protection is properly emerging as an important force in this direction. Can society's needs for environmental management and protection be met by environmental engineers with one year of graduate education, however well prepared the students may be in other disciplines and however effective the curriculum for this year might be? The answer to this question may very well be found to be affirmative, but it probably has not yet been sufficiently considered at this time. Undergraduate education with a major or emphasis in environmental engineering, a difficult and perhaps risky undertaking, should be and is being considered as a response to future challenges and opportunities in this field.

The Doctorate

Doctoral education is typically research-based and lengthy. Many graduates enter academic life, and effective doctoral education is necessary for the maintenance of teaching and research programs in environmental engineering. Increasingly, doctoral graduates are joining private consulting firms and government. Both students and faculty involved in doctoral education and research are typically funded by research grants from governmental agencies and, less frequently, by industrial sources. Principal problems at present are funding and the length of time required. These problems are not independent, since students without adequate funding will seek other employment while pursuing their degrees, thereby lengthening the time required to complete their studies. Among other important factors in the length of time required are the expanding science base needed to conduct useful research and the diverse educational pathways by which students reach doctoral programs, resulting in needs for additional course work and laboratory experience.

The Ph.D. degree involves research as its essential component, so that the coupling of the need for research funding with the development of doctoral programs is inappropriate. Funding is always a problem, but the time and effort now required to obtain it by faculty members are much too excessive; the result is frustrating for faculty and inefficient for society.

CONCLUSIONS

-Education for versatility and perspective requires new science, new technology, new management strategies, and consideration of all environmental media. We can either expand the scope of our graduate programs to meet society's needs or we can maintain our present water-focused programs. If we choose the first path, we have the possibility of contributing to the identification of new environmental problems and the development of technological and managerial solutions to them. If we choose the second path, we can attempt to maintain our present position but will face substantial competition from other disciplines including other engineering fields.

-Graduates of present undergraduate engineering programs are not prepared to undertake graduate programs in environmental engineering, with the result that a significant fraction of course work at the masters level is presently in introductory environmental science.

-Considerations of changes in graduate education in environmental engineering should be coupled with considerations of developments in the undergraduate education of all engineers. The possibility that aspects of environmental engineering will become parts of the undergraduate education of all engineers provides possibilities and opportunities for changes in graduate environmental engineering programs.

-The possible formation of new undergraduate curricula for majors and minors in environmental engineering, and the further development of existing undergraduate environmental engineering programs, also open avenues for change in graduate programs. Such changes in the undergraduate education of engineers can enable graduate programs in environmental engineering to expand in scope and in depth, in versatility and in perspective, in order to manage technologic and economic growth and to meet environmental demands resulting from raising living standards throughout the world.

-Whether or not we expand our scope and effort in environmental engineering education at the graduate and/or undergraduate levels, funding for masters study is urgently needed for the benefit of the students, the profession, and society.

PROGRAMMATIC ISSUES ON RESEARCH AND GRADUATE EDUCATION

An important programmatic concern is the range of appropriate backgrounds for graduate study, and makeup course requirements for non-engineers. Another important concern is the recruitment of minority graduate students. We need to develop a graduate student population that is more representative of the ethnic composition of this country.

Background and Preparation for Graduate Study

The traditional undergraduate background for graduate study in environmental engineering has been civil engineering due to the historical association of civil engineers with engineering in the public sector. A number of factors are changing the pipeline to graduate study. In recent years student interest in civil engineering has been low, and the quality of students admitted into undergraduate civil engineering programs on average is not as high as in other engineering disciplines like electrical engineering or computer science. Given the rise in public concerns and employment opportunities, many individuals with backgrounds in other engineering disciplines are now interested in graduate study in environmental engineering. This broad base of educational backgrounds provides an excellent opportunity for the profession to advance and have the trained engineers needed to accomplish some of the mandates placed on environmental engineers by society.

While there is some commonality in undergraduate engineering curricula, the various engineering disciplines provide somewhat different levels of preparation for graduate study in environmental engineering. For example, chemical engineers are best prepared in chemistry and transport phenomena; mechanical engineers have preparation in fluid mechanics and thermodynamics; and civil engineers have studied hydrology, water resources engineering, or geology, and are also likely to have taken one or two introductory environmental engineering courses. Despite the need to tailor individual masters programs for students from varied engineering backgrounds, the general belief is that good graduate students from any appropriate engineering field pose no special programmatic difficulties.

In the future, we may see many more students applying for graduate school having earned an option or minor in environmental engineering. If such programs require relevant engineering courses outside a student's home department, the individual will be much better prepared for graduate studies in environmental engineering.

Unlike the situation with undergraduates from engineering disciplines, there is no clear consensus on how to best handle incoming graduate students who have baccalaureates in the sciences. The debate usually focuses on the number and extent of makeup course requirements for science majors. Some of the issues are:

-Should makeup courses for an M.S. in environmental engineering be restricted to a subset that provides exposure to engineering concepts and methodologies, and prerequisites for graduate environmental engineering courses?

-Is there justification for specifying different makeup course requirements if an individual with preparation in science desires to pursue a Ph.D. in environmental engineering versus an M.S.?

-To what extent should graduate environmental engineering education be concerned with the need for engineering registration for baccalaureate science majors? Should substantial makeup courses be required in order to satisfy ABET undergraduate accreditation criteria?

Students with an undergraduate major in the sciences may be expected to have completed 1.5 to 2 years of mathematics, one year of calculus-based physics and one year of chemistry. Additional course work preparation to provide an introduction to engineering methodologies and to satisfy certain prerequisites for environmental engineering courses may include the following: a course in differential equations, a course in fluid mechanics, a course in scientific computing, an introductory environmental engineering course, and two to four other non-environmental engineering courses such as dynamics, soil mechanics, hydrology, kinetics and reactor theory, and transport processes.

The actual courses required for non-engineers depends on program emphasis and university requirements. Some universities will not allow a student to receive a masters degree in civil engineering unless the student has completed all courses required for the undergraduate program in civil engineering. Others are more flexible, but all are driven by an attempt to preserve some strict disciplinary boundaries while providing for a background permitting professional registration in civil engineering. Requiring a complete undergraduate program in civil engineering is not an efficient use of resources and would tend to divert good students with scientific backgrounds from the field. On the other hand, no graduate student pursuing a master of science program in environmental engineering should be able to graduate without a broader exposure to engineering. Scientific training is essential, but professional practice requires the ability of integration, approximation or modeling, and analysis that only comes from exposure to engineering courses. That minimum exposure to engineering through preparatory course requirements for non-engineers can be set only by individual universities as they balance out their focus, goals, and available resources.

International Student Enrollment

Another issue of concern in the graduate education of engineers in general, including environmental engineers, is the proportion of international students in graduate programs. As interest in science and engineering has declined in the United States, graduate programs have maintained their enrollments and research programs by increasing the number of international students. For the most part, the international students may have comparable or better academic preparation than domestic students, and may be more interested in Ph.D. study. The training of international students has been a great resource for helping to satisfy personnel requirements, both foreign and domestic. However, for the public universities, there have been various attempts to lower international student enrollments through quotas and increasing nonresident tuition. Environmental engineering is needed worldwide, and as yet there has not been the exclusion of domestic students from graduate study in favor of international students. Our objective should be not to unduly restrict international student enrollment, but to seek broad representation from various countries.

Minority Enrollment

The United States has made significant progress toward the goal of full participation for minority citizens, who are defined for purposes of this discussion to include African Americans, Hispanic Americans, and Native Americans. Despite such progress, we must discover new ways to achieve equitable participation of minority citizens in engineering education, particularly environmental engineering. Today we face two major crises in the environmental industry that not only require new approaches, but also rededication to the goals embodied in the national effort to increase minorities in engineering. First, there are insufficient human resources to meet the environmental challenges of today and the future. Second, there is an erosion of the base of the scientific and technical work force on which the nation has traditionally relied.

By the year 2000, one-third of all school-age children will be minorities[24] and between 1985 and 2000, it is predicted that minority workers will make up one-third of the net additions to the U.S. labor force.[7] In addition, a recent report of the American Association of Engineering Societies shows that the number of American, non-minority white males has declined since 1982 for both enrollment in engineering programs and bachelor degrees awarded in engineering.[8] However, the same report shows an increase for minority population groups in both enrollment and degrees awarded.

As leaders in the environmental profession, we must develop ways to attract and educate the minority population to help meet the environmental challenges of today and tomorrow. A continuum of action items has been proposed by others to increase the involvement of minorities in the environmental work force. For example, the U.S. EPA has recommended several remedial actions, which include pre-K to 12 educational programs, higher-education incentives and assistance programs, and training of current minority employees.[25] Although it may be difficult for us as a small group to have a significant impact in all of the recommendations proposed by the EPA, we can work with organizations such as the ASCE, WPCF, AWWA, and others, as participants in such endeavors.

One area where we can make a significant impact, however, is in undergraduate and graduate education. At the undergraduate level, we must raise the public awareness of the vitality and attractiveness of the environmental profession. High school students and undergraduates are constantly searching for an exciting, well-paying profession that is in demand. The Washington Post[15] recently cited civil engineering and environmental management as one of four fast-track fields. By participating in science fairs, providing undergraduate research experiences during the summer, operating workshops for middle and high school teachers, and designing and teaching campus-wide courses on environmental issues, we will be able to spread the word about the excellent opportunities in our profession.

In 1990 twelve schools produced more than 30% of all minority graduates.[8] Four of these were historically black institutions, and four served significant Hispanic populations. The remaining four were traditional engineering schools that had developed programs for recruitment and retention for minorities. The message is two-fold. First, we must set up linkages with producers of minority students. A likely result is the opportunity to market environmental engineering and our programs to an audience of minority students. Second, we must investigate the enhancement (or development) of current recruitment and retention efforts for minorities on campus. From this effort, we may realize a larger pool of students for our graduate programs.

Howard Adams, Executive Director of the National Consortium for Graduate Degrees for Minorities in Engineering, Inc. (GEM), provides four recommendations for minority recruitment and retention at the graduate level[1]:

1. Intensify efforts to identify and recruit capable full-time minority students in engineering;

2. Restructure the admissions process to include a wider range of criteria for assessing the quality of each applicant;

3. Make adequate financial resources available to support minority students in graduate programs; and

4. Create an environment conducive to developing the full academic potential of minority graduate students and sensitize faculty to their needs.

Finally, we need to encourage the environmental industry to become more supportive of programs that inspire minorities to pursue graduate degrees. GEM awarded 226 M.S. engineering fellowships to minority students in 1991. Few students with an interest in environmental engineering were selected because of the more than 65 employer members of GEM not one is a supplier of environmental services. One of our goals must be to encourage (in fact, demand) that the top-tier firms in our industry join GEM or similar programs. No magic solutions exist to recruit and retain minority environmental engineering students. All of us need to make a personal effort in this direction since so much is at stake for national competitiveness and productivity. Fuller minority participation in our environmental programs will benefit the individual and our programs, the environmental community, and the nation.

Graduate Programs

Some schools have course-work-only programs that can be completed in one academic year. Other programs require a project by the student that provides an exposure to synthesis on a larger problem. There are schools that require a masters thesis, which with course work could take an average of about 1.5 calendar years or more to complete. The previous section of the position paper pointed to problems with both types of masters programs. Those comments notwithstanding, some arguments in favor of a course-work-only program are that: 1) professional practice requires a broad exposure to physical, chemical, and biological principles applied to environmental engineering, and there is no time left for projects or a thesis; 2) the professional engineer needs exposure to engineering principles rather than research methods; and 3) meaningful masters theses are difficult to devise and accomplish in a limited time. The arguments in favor of a masters thesis include: 1) a sense of accomplishment by the student in a sustained effort resulting in a unique contribution; 2) working individually with a faculty member on an open-ended problem; 3) accomplishing research over a shorter period of time that would not normally be undertaken by a Ph.D. student; and 4) taking a project from synthesis to completion, including a significant writing component. It is important to note that a masters thesis in conjunction with a research project often provides the means for supporting a student through an M.S. program. It would be interesting to hear the advantages and disadvantages of a thesis from the perspective of government, industry, and consulting that have employed such students. In either case, a master of science program should not exceed two years in length, because such excessive time indicates either an inappropriate topic, or a lack of guidance by the faculty advisor.

An alternative degree, the master of engineering, is available at some universities. Generally, this degree has a technical focus, with nontechnical breadth courses such as business, policy, or planning, and some engineering project having a more professional orientation compared to a master of science thesis. Unfortunately, this degree has not been acknowledged by the environmental engineering profession in commanding a salary higher than a master of science degree, and some universities have used this degree as a consolation prize for those students that do not pass preliminary examinations for Ph.D. study.

Ph.D. programs are individually designed for each student because of the need for a unique product. The ability of universities to meet the need for the future researchers and teachers is constrained by a number of university-wide issues related to research supervision, the length of time in graduate study, and exposure to teaching. Most importantly, university faculty should set a good example in teaching, research, and professional involvement. In 1990, the Council of Graduate Schools published a brochure titled "Research Student and Supervision, An Approach to Good Supervisory Practice" that presents the need for a framework to move the research student through the various steps in the graduate program including courses, examinations, dissertation topic selection, and completion of the dissertation. A similar document, "Institutional Policies to Improve Doctoral Education, A Policy Statement of the

Association of American Universities and the Association of Graduate Schools in the Association of American Universities"[4] specifically addresses the decline in enrollments and the increasing time required for the completion of degrees. The main problem identified nationwide is the increasing time required for completing Ph.D. programs. The causes of this increase is manyfold, including increasing course requirements, long periods of time devoted to studying for examinations, working as teaching assistants for longer than three years, working as a research assistant on a project unrelated to the thesis, and prolonged study because of the student's value to the faculty member's research. While the post-baccalaureate time to the Ph.D. degree in engineering fields is less than in the humanities, average times that exceed five to six years are being viewed with concern.

Ph.D. graduates in environmental engineering desiring careers in academia have tended to go directly into tenure track positions at universities without a postdoctoral period. The competitive nature of universities for tenure and research funding provides incentives for postdoctoral study. A year or two as a postdoctoral fellow could substantially improve a candidate's breadth of research experience and preparation for the startup problems of new assistant professors. The engineering field in general has not emphasized postdoctoral study because of occasional shortages in faculty candidates, the lure of professorships, and the financial opportunities available in industry. It is very difficult to fund postdoctoral positions that are competitive with industry in spite of the long-term advantages of such a position. With increasing student fees on campuses, and the recharge of those fees to contracts and grants, a time could come when faculty would prefer to hire postdoctoral researchers rather than Ph.D. students. This practice would have significant consequences on the rate of production of Ph.D. students.

RELATIONS BETWEEN THE ENVIRONMENTAL INDUSTRY AND GRADUATE EDUCATION

One critical goal of all environmental engineering programs is to prepare students to become functional professionals, endowed with the important attributes of leadership and innovation. How this goal is approached, by consensus of faculty, students (perhaps) and administrators, or collectively with active inputs from extramural elements of the industry (e.g., manufacturers, contractors, consultants, etc.), determines the relative success or failure of such an initiative. The core of a productive relationship between academia and the practicing profession builds on mutuality of respect, perception of needs, adequacy of product, post-graduate responsibility for continuing education in either sector, and dynamic feedback to reasoned program development.

Perhaps it is time to review the state of the relations between academia and the environmental industry, and examine whether a sufficient communication exists between the two. In approaching this subject, it soon becomes clear that there are many diverse opinions concerning the effectiveness of environmental engineering education as it affects the practicing profession and vice versa. To some, the academicians tend to take a rather myopic view, often avoiding interaction, decrying the overall lack of financial support, and wondering why their sphere of influence is often so restricted. Similarly, the practitioners are sometimes characterized as prone to be apathetic, awaiting recompense for the more tangible output of their "real world" focus, too busy to be engulfed in activities considered of lesser priority and requiring involvement of a continuum, and yet wondering why the "other side" has not routinely sought their advice and counsel.

A difference of opinion may exist between employers and educators regarding the extent to which graduate education should prepare students in engineering practice. Environmental engineering faculty often represent a mixture of disciplines, often with limited practicing experience, and often with a propensity for focus on science rather than engineering. Indeed, many engineering professors see themselves as engineering-science teachers and researchers, consciously or unconsciously dispatching the necessary linkage of such science and the practice of engineering to others. Without a sufficient balance between engineering and science, the students may emerge more representative of the latter. Such individuals may require more on-the-job training when first employed, leading some employers to reflect dissatisfaction with the preparation and worth of these graduates. On the other hand, faculty view the purpose of education as providing fundamental intellectual tools for life-long professional growth, rather than providing job-specific skills that reflect the practice of engineering.

Some employers are concerned that nonengineers may use the opportunity of graduate study in environmental engineering to take a "short cut" to an engineering degree. The associated pressure for broader admissions to graduate engineering programs is significant, since one of the major attractions for the vast array of nonengineering students is the access to a more financially and perhaps professionally rewarding career, and most programs are seeking methods to ensure student populations deemed necessary to support and sustain stability. Emerging coincident with this trend is a continued evolution of engineering technology programs, often considered by engineering faculty to be too shallow and devoid of theory to produce engineering professionals. Such programs, however, have a certain appeal to the marketplace, not only because of favorable salary differential, but because such students may focus more on engineering practice. The difference in substance between such environmental engineering and environmental engineering technology programs is the concern of ABET accreditation procedures at the baccalaureate level. Inasmuch as only a few graduate environmental engineering programs have been offered to be accredited, it has been suggested that a re-examination of the relative merits of ABET accreditation of environmental engineering programs at the graduate level may benefit the alliance between such programs and the practicing profession. However, graduate programs are wary of accreditation. The experience at the undergraduate level is that accreditation involves a huge effort for little benefit. Accreditation is also viewed as stifling diversity.[20] This, and other concerns resulting from accreditation of undergraduate programs, are seen as major obstacles to widespread interest for accrediting graduate environmental engineering programs.

Closer relationships between environmental engineering educators and environmental industry will benefit both parties. It is acknowledged that practitioners do assist in providing occasional seminars, establishing unique but relatively infrequent support relationships, and serving as student co-advisors or adjunct faculty. However, these initiatives are limited, scattered, and generally without clearly defined motives or a nurturing of such opportunities on a continuum. Similarly, industrial, consulting, regulatory, and other private and public sector activities should be called upon to provide opportunities for educators to observe and participate in professional practice outside of the academic realm. Such associations may lead to a mutuality of respect and desire for more active and productive support of environmental engineering education.

The key to success in developing stronger relationships entails understanding of intramural and extramural resources by educators and practitioners alike. Although many approaches are possible, some specific examples of how relationships may be enhanced include:

-Providing assistance with student recruitment.

-Participation and exchange between educators and practitioners in hosted seminar series.

-Targeted financial support from environmental engineering practice for research in areas of mutual interest, which may include support of professional societies research foundations.

-Sponsored student symposia.

-Program-based co-op/intern opportunities or special assignments within the practicing profession.

-Service on advisory boards for departments, programs or research centers.

The AEEP has recognized a need for a more productive partnership between academia and the practicing profession, and some elements of such collaboration have already been established. Certainly, the development of the AEEP Distinguished Lecturer and the AAEE Kappe Lecturer series, and the AEEP-industry sponsored awards programs are notable in this regard. It is incumbent upon all contributing academic and industry professionals to embrace the principles embodied in these and other established initiatives, and to encourage a more responsible approach to educator-practitioner influences on graduate environmental engineering education.

A PHILOSOPHY OF GRADUATE EDUCATION

The role of an educator is to be both intellectually challenging to and personally supportive of students. Those of us teaching engineering at the graduate level tend to focus on the intellectual challenge part of our role, but may rarely focus on the support that students reasonably expect us to provide. Further, it seems likely that we may generalize too much from our own individual experiences in the educational system, forgetting that many of our students, including graduate students, are different from us in important ways. The purpose of this section of the position paper is to investigate a few areas of psychological and developmental theory, i.e., to listen to voices of people who have generalized in those fields, and attempt to apply them to a philosophy of graduate education in environmental engineering. Two areas are investigated: a theory of cognitive development, and some aspects of women's psychological development that are likely pertinent to education of all of our students. These thoughts might make us re-evaluate the intellectual challenges and personal supports we provide our graduate students.

Personal and Cognitive Development

Graduate students differ from undergraduate students in several important ways. Our teaching at the graduate level (both in the classroom and through research done mutually with graduate students) should recognize and take advantage of these differences. A principal difference is in the level of cognitive development; recognizing the stage of development in students can help us identify appropriately different goals in teaching at different levels.

Perry[21] developed a widely-accepted theory of cognitive development apropos of students in higher education. As he perceived it, people tend to progress through fours stages of cognitive development that he termed dualism, multiplicity, relativism, and commitment within relativism. These categories reflect how an individual views the world, changing from a simplistic view to a more complex pluralistic one. Each is described briefly below. This synopsis is based largely on that of Barna and Haws.[5]

A student in the dualistic stage views the world in simple dichotomous terms (right and wrong, good and bad), depends heavily on teachers or other authorities to provide answers, and has little ability to analyze and synthesize material. The perceived role of a teacher is to impart knowledge; the role of a student is to learn answers and receive information. Many students enter college in this mode.

A student in the multiplicity stage acknowledges multiple perspectives. As students move through this stage, they first think that the lack of a single answer ("the truth") is only a temporary condition because the authorities have not yet found the answer. Later, they see diversity and lack of an answer as legitimate. The perceived role of the teacher is to teach the student the process for finding the answer. Students begin to feel more responsible for learning, but still see themselves as recipients of information from the teacher. Students in this stage are likely to question evaluation procedures, and use quantity of work as a defense mechanism to overcome their confusion and their inability to make judgments about possible routes to take.

In the relativistic stage, the student shifts from primarily turning outward for answers to taking responsibility for one's learning. The student in this stage no longer seeks truth, but sees knowledge as relative and contextual. Such a student finds freedom in diversity and is able to identify and analyze alternatives, but is likely to resist making choices among those options. The teacher is perceived as a valuable resource in exploring diversity, primarily because he or she is more advanced in groping. The student in this stage enjoys open discussion, recognizes that much remains to be learned, wants variety, and likes to play with ideas, but does not like to make choices and narrow alternatives.

In the final stage, commitment within relativism, the student recognizes legitimate diversity in approaches to knowledge but is also willing to make choices and live with the consequences of those choices. The student has a high internal locus of control, recognizes his or her own strength, can handle paradox and complexity, and is able to integrate. The teacher is perceived as one who challenges the student to take risks and seek new knowledge.

How does this theory apply to graduate education in environmental engineering? An explicit answer(s) is not obvious, but a few thoughts emerge. First, this development process is difficult to reconcile with some of the mythology (if not foundation) of science. To a first approximation, science prides itself on the pursuit of the TRUTH, a dualistic view. Advanced science and engineering recognizes diversity and ultimately commitment within that diversity, but that approach is likely to come later to students in science and engineering than those in the liberal arts and social sciences. Second, different students (and faculty) are at different points of development in this process. Research shows that undergraduates tend to enter college at the late stage of dualism or early stage of multiplicity; graduate students tend to enter their programs at multiplistic and relativistic levels. The choosing of a dissertation topic and the writing of a research proposal perhaps represent the ultimate move from relativism to commitment within relativism; the theory elucidates why students often hover at the edge of that commitment for a long time. If we accept (a) this framework of development and (b) a philosophy that the faculty role is to provide both intellectual challenge and personal support, then recognizing the levels of different students and providing different types and amounts of challenge and support seem necessary.

For undergraduates, it is appropriate to define the upper limits of knowledge or understanding that students are expected to attain. Indicating that there are both deeper levels of knowledge and limits to anyone's understanding of many subjects is good, but expecting undergraduates to be able to explore these areas without more guidance is unrealistic. Conversely, in graduate teaching, it seems most appropriate to explore those deeper levels of knowledge to show that the field is without limits, in the sense that there is always more to know, and has severe limits, in the sense that there are dead ends and ambiguities in our current state of knowledge.

The above approach is general to all learning, but can be applied to graduate engineering education in concern with two beliefs about engineering. First, an understanding of theory is the key to good engineering practice. Second, engineers are expected to make judgments. These ideas mean that graduate engineering students need to learn to think, to be creative, and to make decisions within the context of ambiguities in engineering problems, i.e., graduate engineering education should strive to bring students to commitment within relativism. Training graduate students to emulate today's practice is of minimal value and reflects a dualistic view; educating them to understand today's practice and be able to create tomorrow's practice is of great value and reflects a more advanced stage of cognitive development. The following lists some specific ways in which we can apply these concepts to help graduate students to progress in cognitive development and self-learning.

-Provide variety of viewpoints/perspectives; encourage students to analyze and synthesize diverse perspectives.

-Draw different perspectives out of students for complex ideas and ask the class to make judgments about which they believe.

-Give assignments that require students to make judgments and justify them; grading should reflect the student's ability to argue for his/her position and not simply the professor's judgment about what is "right".

-Reduce the "energy barrier" between students and faculty; know your students and let them know you.

-Allow students flexibility in accomplishing assignments.

Theory of Women's Psychological Development and Opportunities for Environmental Engineering

The percentage of women entering environmental engineering is generally higher than it has been in the past and also generally higher than that percentage in other fields of engineering. Most of us think of these trends as positive for our field; however, to take advantage of these positive trends and continue them into the future is likely to take significant effort in understanding and using developments in the psychology of women.

An advance in understanding such issues came from a theory of psychological development set forth by Carol Gilligan in her book, In A Different Voice. The book notes that, predominantly, men and women develop and learn in different patterns. We might think of this as overlapping curves on a spectrum reflecting ways of thinking, acting, speaking, etc., with these curves having recognizably different means for men and women. In what follows, the terms "male" and "female" or "men" and "women" are used to note these differences, but it is recognized both that the differences do not follow gender lines in every case and that each of us, regardless of gender, has some of the tendencies of both.

Perhaps the key difference between the male tendency and the female tendency is expressed in two words: separation and connection. Males tend to develop by, think about, and be rewarded for separation; females tend to develop by and think about making connections. These differences in approach to learning and to decision-making are generally unrecognized in all of society, but, especially in male-dominated fields like engineering.

Opportunities to observe ourselves and others on the spectrum of separation and connection abound in our daily professional lives. For example, in a discussion of a paper or certain experimental results, one student might propose a certain interpretation. Two other students, one male and one female, might have very similar thoughts in response, but their stated responses might sound quite different. The male would tend to state that he disagreed with the first student's interpretation and ignore areas of agreement; he might revel in the disagreement, the intellectual competition, the separation. The female would tend to state what she agreed with in the first student's interpretation and be more tentative in stating the disagreement; she would try to connect herself with the first student. We might ask ourselves how we respond to and reward these two students who had virtually identical thoughts.

Desjardins has considered the implications of Gilligan's "Different Voice" for higher education. Of particular interest is her assault on the theory of assimilation; she argues that trying to increase the numbers of women in non-traditional fields without changing the ground rules for success is bound to failure. To require women to become "autonomous, separate, and competitive" is a male approach and far less desirable than recognizing the value of connection and caring that characterizes the female approach.[10] Harris et al. have addressed directly the issues of educating women in science and engineering. They suggest that changes in pedagogy from a traditional hierarchical, competitive style to a nonhierarchical, egalitarian one can have a profound effect on all students, but the change is particularly important for women. Classroom teaching, assignments, and research advising that are interactive and cooperative are surely better for everyone, but will make a more dramatic change in the satisfaction of women than men with respect to the educational process.[14] The following gives several suggestions on how we may construct a learning environment conducive to the improvement in the education of women graduate students.

-Notice whether the "feminine" or "masculine" style of a student's comment, question, or response affects your own perception of its importance.

-Consider, if women students are experiencing difficulties, that it is a problem in the program rather than in the women.

-Ask women and men qualitatively similar questions -- ask students of both sexes critical as well as factual questions.

-Allow students to experience a sense of "connectedness" with you as the professor/research advisor. Try to create a sense of "belonging" within the entire graduate program and among the research group.

-Give students a high level of feedback on their work, being as positive and encouraging as possible.

Additional discussion on ways to create a learning environment that best fosters the intellectual growth of both men and women students is provided in a report by the Association of American Colleges.[3]

The environmental engineering field probably attracts more women than any other branch of engineering. The reason is related directly to the perception that it is a field that can make a difference in society; in essence, it is perceived as a field that is caring and connected to society. Even part of its scientific basis, ecology, is the study of connectedness. A challenge that faces us more than most fields is to gear our education, at least in style and perhaps ultimately in content, to the education of women. We must be leaders in learning how best to educate women in engineering. Because the overwhelming majority of professors are men, we cannot sit idly by and hope that the few women professors will be able to create the environment in our programs that maximizes women's learning.

CONCLUSION

This section of the position paper started with the thesis that the role of an educator is to be both intellectually challenging and personally supportive of students. Recognizing that different students are at different stages in cognitive and personal development and have different learning styles is an important backdrop for what we can accomplish in our graduate programs. Creating an environment in our graduate environmental engineering programs that is more supportive of students than the typical situation today will aid the education we provide. Students will be more productive during their tenure in our programs, become better engineers in practice, and probably be more likely to recommend our programs to others. We as faculty will also benefit by such changes in several ways, including, perhaps ironically, the ability to be more intellectually challenging. While these changes are likely to have a more dramatic effect on women than men in our programs, all will be aided. The point here is not to propose the replacement of a male paradigm with a female one, but to suggest that a fully human one will recognize aspects of both paradigms and create a better environment for the education of all students.

THE CITIZEN ENGINEER

The first canon of the ASCE code of ethics states, "Engineers should hold paramount the safety, health, and welfare of the public in the performance of their professional duties".[2] We reason herein that this ideal requires more than the competent completion of assignments. Modern society needs "citizen engineers" who ask questions, pursue inquiries, and participate in discourse beyond their assignments and contract obligations. We are concerned that, unless deliberate steps are taken, education might not adequately prepare such citizen engineers.

We must be aware that the roles of environmental engineers have changed over the last half century. At one time environmental engineers were intimately involved with directing public policy and influencing regulations for the protection of the environment and human health, and with the implementation and management of facilities in response to these regulations. Today environmental engineers are largely reacting to laws and regulations; our role in directing environmental policy is substantially diminished. For example, many of us have seen millions of dollars being spent on Superfund cleanup projects with little tangible benefit. What has gone wrong? There is no simple answer. In some respects we may have lost the initiative to speak out on what is "right" and "good". We may be abrogating a professional obligation by seeking refuge under the perception that if it is law it must be ethical and right. If we wish to solve problems as complex as the Superfund mess, we must educate environmental engineers to understand that they have responsibilities as citizens. These responsibilities are especially important in environmental engineering because of the close link with protection of public welfare.

An example of the type of moral dilemma that environmental engineers may find is provided by a retrospective analysis of the process of preparing environmental impact statements. This study had the lengthy but descriptive title, "An Examination of the Moral Dilemmas of University Scientists Participating in the Preparation of Environmental Impact Statements." This "Dilemmas Study" found that professors, including engineers, became involved in funded assessment studies as a means to support research and the training of graduate students. The "Dilemmas Study" involved a content analysis of the available documents from three projects, a line-by-line comparison of the original study documents and the final environmental impact statement of one project, and interviews with professors and graduate students who had participated in the work of the three case studies. The conclusions of this study contained the following disturbing assessment.

> "Seemingly, they upheld the ideal of scientific values and moral responsibilities, but largely perceived themselves as contract laborers who held to these values only insofar as was possible within terms of their contracts. If society expects that scientific [engineering] participation ensures high standards, it is liable to be disappointed." (page 103)

What went wrong? One answer is the tendency of organizations to distort or omit information, particularly information unfavorable to the organization.[6] While one may not find individual fraud or falsification, systemic distortions nevertheless occur. Ethically, the whole is less than the sum of its parts. The "Dilemmas Study" found evidence of such systemic distortions because individuals confined their concerns to the immediate demands of their assignments:

> "Research that has a negative effect on the project is challenged, contracted to another group of scientists, or explained away -- on the other hand, favorable research is subject to no such scrutiny and in several instances purely speculative discussions are introduced that have no positive conclusions based on no hint of evidence." (pp. 36-37)

> "... few of the originating scientists [engineers] were aware of the disposition of their research, beyond the point at which they submitted their reports. Primary values seemed to be placed on meeting the contractual obligations, fulfilled by one's report, as opposed to the larger societal obligation ..." (page 100)

There is a lesson here. Systemic distortions do no require individuals to lie and deliberately falsify information, behaviors widely recognized to be ethically unacceptable. Instead, systemic distortions arise from those more acceptable "functionary behaviors" that lead individuals to focus their entire attention upon the demands of their immediate assignments, devoting little effort to broader and independent inquiry and discourse. Through our actions, we must teach students that something more is required than "functionary behavior." But what? President Dwight D. Eisenhower (1961) answered such a question in the following way.

> "I know nothing here that is possible, or useful, except the performance of the duties of responsible citizenship. It is only a citizenry, an alert and informed citizenry which can keep these abuses from coming about." (Eisenhower).[11]

We ourselves must act out and prepare students to fulfill the responsibilities of "citizen engineers", people who are technically competent and also willing and able to pursue independently questions and inquiries for "justice and the common good" (a phrase from James Madison). "Citizen engineers" are needed to sustain the free discourse essential for "the safety, health, and welfare of the public" (from the ASCE Code of Ethics).[2] We cannot turn over such responsibilities to the organizations that financially support us. Without practicing the free inquiry and discourse of the citizen, a technically competent engineer too easily becomes an organizational functionary, a danger we and our students both face. How must we better act out the educational responsibilities of "citizen engineers"? The following are a few suggestions.

a. Students must be regularly exposed to independent and interdisciplinary discourse, so that broad issues and policies can be critically examined in spite of the lack of organizational support.

b. Environmental engineering education, while preparing professional specialists, must also prepare engineers in all specialty fields to better understand and address as citizens those environmental problems (e.g., global climate change) that extend beyond the domain of any specialized field.

c. Environmental engineers should challenge other fields to better prepare students to address broad environmental problems (e.g., we should press for environmental awareness across the curriculum).

d. We should seek to restore graduate traineeships so that some of our brightest and most creative students could afford to attend graduate school and pursue inquiries that are not limited or directed by the demands of funding agencies.

e. We should study organization failures, publish results, present examples in our courses, and discuss ways that engineers might reduce such problems.

f. Students should be introduced to the many ways that they might act as responsible citizen engineers (commenting on environmental impact statements, speaking at public hearings, writing discussions of papers or book reviews, etc.).

Of course, to do all of this without sacrificing technical discipline is a challenge that no individual could meet. Nevertheless, as a community, drawing upon the abilities of many individuals, environmental engineering educators can meet such challenges so long as we ourselves are not dominated by functionary behaviors.

SUMMARY

The following are suggested as principal issues for discussion:

1. How should undergraduate engineering curricula be modified to better prepare students for graduate study in environmental engineering?

2. How should we promote distributed environmental engineering education across various engineering disciplines and departments?

3. How should limited financial resources be best utilized for support of M.S. level education?

4. Should graduate environmental engineering education be modified in style, and perhaps in content, to address the educational needs of women?

5. What are the best opportunities in graduate environmental engineering education to take advantage of advances in understanding cognitive development?

6. What should be the makeup course requirements for baccalaureate science majors desiring a graduate degree in environmental engineering?

7. Why are minority enrollments so low? How may we exploit the growing interest in environmental engineering to recruit more graduate minority students?

8. What are the advantages and disadvantages of seeking ABET accreditation for M.S. programs in environmental engineering?

9. How may closer professional and financial ties be established between the environmental industry and academia?

10. How can we better prepare students for leadership roles at the interface between environmental public policy and technology?

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ENVIRONMENTAL ENGINEERING EDUCATION IN THE YEAR 2000
OBSERVATIONS OF THE CONFERENCE

Summary Address - Academic Perspective

Walter J. Weber, Jr.
The University of Michigan
Ann Arbor, MI

The twelve resolutions forged this morning from the deliberations of the past few days represent a concise and reasonable summary for this Conference. They are thoughtful and substantive, and should serve us well as a base upon which to structure efforts to meet the many and significant challenges facing educational programs in environmental sciences and engineering in the years ahead.

The few observations I would make by way of addition to the resolutions go in part to the process of the Conference, and in part to amplification of certain issues discussed and debated enroute to the resolutions.

The process has been satisfying. The points and counterpoints on specific issues were made enthusiastically and convincingly. The gradual development of a focus on what should comprise specific resolutions and their major elements was thoughtful. Lastly, the "word-smithery" of this morning's plenary session was nothing short of Oxfordian.

While the resolutions may be the best summary of the Conference in "bottom-line" terms, it is seldom possible in any summary to completely capture the undercurrent of debate upon which resolutions are built. This is, I think, particularly the case for the first of the twelve.

That resolution is a comprehensive one which, among other things calls for support of efforts to develop baccalaureate degree programs in environmental engineering. While the records of this conference will reflect consensus on support for a baccalaureate degree, I perceive a distinct lack of consensus on what should comprise a curriculum for such a degree. This was reflected in the floor discussions, and in the ancillary recommendations that a "blue ribbon" AEEP/AAEE committee be appointed to consider and advise on the issue.

I must admit to some concern about an unqualified statement of support for a separate baccalaureate degree program, particularly in the absence of any meaningful characterization of content. My concern is that different programs at this level may have remarkably different foci, depending upon the particular leanings and inclinations of the faculty and administration who puts them together. Some may view the proposal to support baccalaureate degree programs as a mandate for specialization, for development of programs which train "short-order cooks" in the details of popular recipes. Others, including me, will see it as an opportunity to broaden and generalize; to develop "chefs" having the ability to create recipes to meet the different and changing tastes of different palates.

In my opening comments to this Conference, I suggested a "mom and apple pie" needs position for environmental engineering education. I also argued the need for basing the education of environmental engineers and scientists on physical truths. If specialization in this field is to have substance and endurance, then we must develop more fully the foundations upon which that specialization is ultimately built. In my perspective, the most meaningful implementation of the first resolution would be a baccalaureate program which broadens and reinforces those foundations, one which better prepares an individual to undertake a comprehensive program of professional development at the post baccalaureate level. In this context, I strongly endorse the fifth resolution, that --- "the Masters degree should continue to be considered as the minimum level of professional education in environmental engineering."

It has been a stimulating and productive conference. I salute the profession for its willingness to confront itself in critical self-examination, and this group of its representatives for their collegial manner in the face of evident disagreements on particular issues. That we are able to so vigorously debate the future of the profession, and then seek, and generally find, consensus on major issues is a good measure of its robust health.

I congratulate the conference and its participants for the evident progress made in setting objectives and defining means that will enable us to continue the growth and maturation of education in environmental engineering and science. I commend the Conference Steering Committee for its wise choices in selection of position groups, and those position groups for their outstanding work in developing their respective papers. Lastly, I applaud our hosts, the Western Region HSRC, and Ken Williamson and his faculty, students, and staff, for exceptionally efficient and hospitable arrangements.

ENVIRONMENTAL ENGINEERING EDUCATION IN THE YEAR 2000 - OBSERVATIONS OF THE CONFERENCE

Summary Address - Practitioner Perspective

H. G. Schwartz, Jr.
Sverdrup Corporation

As you recall, when I started, I admonished you about keeping diversity in your thinking. Having sat through the last four hours, I need not have been concerned about that. This has really been a great pleasure for me to join you. You are an extraordinary group. It's been fun and exciting to be here and be a part of it.

I did have a few comments to make and I'll go through them in the order you presented your findings.

On the undergraduate program, I think I share Walt's concerns. Frankly, I was surprised at the amount of interest in the undergraduate baccalaureate degree in environmental engineering. As I recall, there was some 20 schools yesterday afternoon that indicated that they were considering, and 8 or 9 that were definitely proceeding with such a program. I have somewhat ambivalent feelings. On the one hand, I think it is great to see that interest at the baccalaureate level, but I've got some serious reservations, and I have said them earlier. I am concerned that there is not enough time or content in these programs to really develop an environmental engineer. I do agree that it is perhaps a more useful degree for someone like myself in the consulting business than the straight civil engineering degree. I would say it was better suited, perhaps, to go to graduate school. But I want to make it perfectly clear, while it's a useful degree, I think it is much less marketable, in my kind of business at least, than a master's degree. I consider the master's degree to be the entry level degree for environmental engineers who want to practice in the theoretical and process oriented portions of our business. I think those firms that are even more environmental oriented than mine would echo that, and I have heard them say they will only take master's degree. I caution you not to mislead your students as someone said earlier. Do not go so far afield with this idea that you don't have a home any longer, that you don't have advocates sitting out there. Civil engineers still are advocating environmental engineering as a part of their total base of responsibilities.

A related concern, I thought, was in the graduate session. On the philosophy of education that was brought up, and this idea of dualism and multiplicity, relativism, and commitment: and if you take that approach, you look at an undergraduate program where you have students who were moving from dualism to multiplicity, who are not really ready, perhaps, and as able to move as a graduate student who is presumably farther along in that maturation process (i.e., graduate students may be better prepared to undertake the broad spectrum of concerns we have in environmental engineering).

I support your position on ABET at the undergraduate level fully.

On hazardous waste, I like the reference to the management skills. I think we had a great example of management skills in your conference chairman, Ken Williamson. He kind of takes a little bit of a laissez-faire approach to management, you may think, but think of what he accomplished here in the way of logistics, for example. If I am right, on Friday night we had dinner at the Woods', Saturday was dinner at the Williamsons, breakfast Sunday at the Woods', dinner Sunday was a barbecue, lunch Monday was outside, dinner was at the Forum, and today I do not know where we are having lunch, but it all came off without a hitch. I think that is remarkable. But I think these questions of management issues ... you cannot cover them all in course work. I think there are some that you can incorporate in your programs. You spoke to those. We simply do not have the room in the curriculum to have a lot of management courses. I would make one observation: since lawyers are practicing engineering, it is about time engineers started learning something about law and practice law.

I concur with the conclusion that hazardous waste is a legitimate and important part of environmental engineering. I hope we will keep it as a part of environmental engineering. It does require the application of some difference science and engineering fundamentals, and I encourage you to incorporate those in your programs. From a practitioners point of view, it is one of the major driving forces in our business.

On graduate education, I was gratified to see continually the focus on science and engineering fundamentals. I strongly believe in them. I concur with the concept of a master's degree as the first professional degree. I like Paul Roberts' comment about comparing it to pre-law or pre-med. It is a pre-engineering degree at the bachelor's level, and it is important at that level to advise and guide the students in preparing for a graduate degree in environmental engineering.

I also agree very strongly that an engineering degree should be restricted to those who have some level of engineering competence, albeit the ABET recommendation that you made. Again, I would repeat that better and more science makes a better environmental engineer, but all science does not make an engineer. I guess I should comment. For some of you who seem to be uncomfortable with that ABET recommendation, I almost had the sense that the concern was more that we were going to lose students that we had attracted in and I do not think that is the proper rationale for deciding whether or not to support that.

I strongly support the traineeship idea. I went through, many of you went through, on that program. I might also say that, I made a note to myself, that you might consider more strongly marketing your programs to your former graduates and companies and perhaps garner some more financial support. I have to think, but other than a general solicitation from three universities I went to, I do not believe any of the programs has ever tried to solicit me to support the environmental engineering programs that I came out of. My support may not have been large, but I suspect that I and others would respond to that.

I was a little surprised there was virtually no discussion on strengthening the environmental exposure throughout the university campus. There was some discussion about it within the engineering school. But shouldn't the environmental engineering faculty be the leaders on campus? What better place to do it than to be the spokesman on campus trying to bring environmental concerns into other disciplines, not just engineering?

I was delighted to listen to Dr. Sanford and Dr. Johnson on the subject of minorities and women. On a somewhat smaller scale, I now have more empathy since I am the token practitioner at this conference. And I say that because I think that it is a problem that we clearly face with women and minorities, and I had a little sense of that at this conference. It is surprising to walk into this room, frankly, on the first day and see less than 10% of the makeup of this group is minorities and women.

Practitioner involvement: I would encourage you to seek more involvement of forums like this, and I am not trying to blame the organizers for not having more involved. On the contrary, I and the Academy are probably to blame for not having more people here. I think you are going to have to reach out to get us here. Your problems, your concerns, we need to know about. Sometimes you think they are obvious. They are obvious to you, but we are busy with our problems and they are not obvious to us, and I think you are going to have to reach out to encourage our involvement. If you were to look at this program, for example, the normal practitioner might not be terribly interested in just looking at this whole program and wanting to attend. He would say, "It is just for professors." So, I am encouraging you not to be too insular in your exchange and dialogue. I would make a couple of specific suggestions about practitioner involvement. I made a couple of them the other day, especially the idea of some type of post-doctoral fellowship in practice for those who want to have a long term career in academics. The practitioner in residence concept and another one that occurred to me the other day is: what about a lecture series offered by AEP to companies wherein a professor might make a lecture tour on a subject that might be of interest? I think you might get a surprisingly strong response to that.

And finally, on ABET accreditation, I know that continues to be a concern, particularly at the graduate level. I want to keep emphasizing the importance of accreditation at both the bachelor's and master's level. I think its purpose is to establish an acceptable norm, an acceptable level of quality, a minimum, if you will, a floor. It is not intended to constrain higher levels of achievements, higher levels of quality, and it should not be allowed to do that. I am afraid sometimes ABET gets too constrictive. But in spite of your frustrations, I hope that all of you stay the course and work to solve the problems from within the system.

Just by way of closing, you keep us on the cutting edge, you provide us the products we need, the students, the research. I think I speak for all the practitioners in that we want to work with you, we want to understand your problems because they are our problems, and to help you solve them. So, I hope we have other opportunities to exchange our thoughts.

ENGINEERING EDUCATION IN THE YEAR 2000
ACHIEVING CULTURAL DIVERSITY

Banquet Address

Stephanie Sanford
Director, Affirmative Action
Oregon State University

Good Evening. On behalf of President John Byrne I would like to welcome you to OSU and express how honored we are to serve as the location of the Sixth Conference on Environmental Engineering Education. The nasty comments from some our own faculty about our football team, notwithstanding, I hope that those of you who are visitors have experienced the extent to which Oregonians are proud of the beauty of the natural environment here and our reputation as a leader among the states on environmental issues.

It is truly exciting to be involved in a conference where the participants are about the business of actually carving out a new area. Given this context, it is extremely gratifying to know that the conference committee chose "Achieving Diversity" as an issue to be addressed at this gathering.

Attending this conference has been a real eye-opener for me. Among my associates, the engineering discipline consistently is held up as the quintessential example of the traditional male-dominated field, engaged in either blatant racism and sexism or invidious and ever-present insensitivity and lack of awareness when it comes to understanding women and people of color. Engineering is the white-male club, women and people of color need not apply.

This is a perception. I have found that practically everyone I've talked to here is involved in some effort to encourage the participation of African Americans, Hispanic Americans, Native Americans, women and other underrepresented groups. Some are involved in programs to improve the retention of women students, some have developed scholarships to support students of color, others are struggling with questions about how to encourage students from underrepresented groups to pursue graduate degrees. Among this group of conferees the question, "Should we seek diversity?" has been answered with a resounding "yes".

Nevertheless, and although it isn't obviously the best after-dinner entertainment, I'd like to focus on the negative perception of engineering, the discipline as the epitome of the white-male exclusive club. In doing so, I believe that I am elaborating on one of the major points Walt Weber identified in his discussion of the academic perspective on environmental engineering education in the year 2000; i.e., to communicate the knowledge of the discipline to those who have no command of it, and, on the other hand, to learn to speak their language as well. I realize that this may not be what

Professor Weber had in mind, specifically, but I really think that what I have to share with you fits with his charge.

The field of engineering, along with many other disciplines in higher education, continues to experience dramatic underrepresentation of women and people of color, especially African Americans, Hispanic Americans, and Native Americans. At every point in the educational and career pipeline women and people of color drop out of the process in disproportionate numbers when compared to white men. While total enrollment at the undergraduate level is 54% female and 16% African American, Native American, and Hispanic American combined, of the bachelors degrees awarded in engineering, 15% go to women and 6% go to African Americans, Native Americans, and Hispanic Americans combined. At the doctorate level in engineering, 9% of degrees awarded go to women, less than 2% go to African Americans, Native Americans, and Hispanic Americans. Nationally, women are 3% of the engineering professorate; less than 1% are African American, Hispanic American, and Native American.

When dealing with the issue of diversity, it is very important to recognize that there have been advances and that positive trends exist. The field of environmental engineering holds particular promise for turning the low numbers around. The problems addressed by environmental engineers capture the interest and imagination of more women and students of color than other specialties do. As the conference position paper "Future Concerns in Environmental Engineering Graduate Education" points out, environmental engineering is perceived as "a field that is caring and connected to society", a perspective that meshes well with the tendency of women to develop by and think about making connections; a tendency also identified among African American, Hispanic American, and Native American high school students in their attitudes toward career goals.

People do make it through the entire pipeline; most of you probably have 2 or 3 women on the faculty, possibly an African American, in rare circumstances someone of Hispanic American descent. Many colleges offer substantial financial aid packages, although there aren't enough of these, to students of color since a disproportionately large number of the very brightest African American and Hispanic American students simply can't afford to go to college otherwise. Most colleges take the pipeline conceptualization very seriously and have implemented pre-college, and now more commonly, pre-high school programs aimed at introducing young people to the idea of being an engineer and what sort of preparation that requires.

The challenges to recruitment at this point in the pipeline are "awesome" -- and I don't use that word as an expression of adolescent vernacular! At the age at which future engineers need to be developing at least competent math and science skills, the importance of peers to one's identity and the desire to conform to the norms of peer culture are particularly strong influences. Girls who, in general, outperform boys in math up to this point, lose ground as they get older and, by high school, score lower than boys on math achievement tests. Some of this is due to peer pressure. At a time when social and sexual interests among peers prevail, girls do not want to compete with boys. High school girls studying science describe themselves as less feminine, less attractive, and less popular. On the other hand, we also know that adults who fill very important roles as parents, counselors, and friends, are frequently the people who discourage young students from pursuing engineering - traditional sex role stereotyping is alive and well.

As fascinating and challenging as questions of socialization, peer culture, and sex role stereotyping are, I think that too many faculty and administrators have latched on to these concepts as a way of avoiding the difficult and painful work of examining one's own actions for evidence of exclusion, stereotyping and discrimination.

One reason there is a tendency to look elsewhere for explanations for continuing underrepresentation is that the barriers to equal participation have changed. Many of the overt barriers that existed 25 years ago have been removed. Not all ... but many. As a reminder of the roots of my profession I keep a copy of a letter in my desk written in 1953 by the then-dean of the College of Veterinary Medicine to a woman applicant for admission as a student. In the letter, the dean explains that the university has barely enough spaces for the men who apply and that he would advise her to consider biology if she's really interested in this sort of stuff. We don't write it out like that any more but the barriers still exist -- they're just more subtle, more difficult to articulate, often inadvertent, easy to deny.

The fact is, for many women students and students of color in engineering and other predominantly white, male fields, the classroom climate remains what we call "chilly". The experience of being "the only one" of color or the only woman is not an unusual phenomenon and it's a natural reaction to experience feelings of being an outsider. These feelings are strongly reinforced when the teacher or instructor behaves in ways that underscore differences: when there are comments or jokes based on gender or race stereotypes, when an instructor acts surprised at your ability or willingness to contribute or, on the other hand, when others act as if you are invisible. Women and students of color report that they are either expected to represent and speak for their entire race or gender, or expectations are so low that they are ignored or treated in a patronizing fashion. African American students, in particular, talk about the frequency with which faculty openly express surprise, sometimes in front of the entire class, that they are able to understand concepts or solve problems.

Let me give you one specific example to illustrate how this plays out for the student. One woman student recently complained to me that the professor in one of her engineering classes described his expectations for the final exam in this way: it should be like a woman's skirt; long enough to cover the subject but short enough to be interesting. The student was surprised at what she considered to be a lack of professionalism in emphasizing the role of women as sex objects. She told this to the professor after class, and he responded by suggesting that she needed to develop a sense of humor and not take things so seriously. She talked to the two other women in the class, and while they agreed that they were embarrassed by the comment, they were afraid to say anything because of possible negative repercussions.

In understanding the experience of women and people of color in engineering, the analogy of the "membership club" is useful. Few women and people of color have been or currently are members. The informal networking that is the main method of recruiting people into the club doesn't operate to include women and people of color -- these networks are largely segregated based on race/ethnicity, gender, and class. The rules for being a member are mostly unwritten and new members must rely on the current members to share the rules that exist. New members have high visibility; both their successes and their mistakes are noticeable and noted. Success is often attributed to "beginners' luck"; failure, on the other hand, is treated as evidence that this person really doesn't have what it takes to be a member of the club.

I like the "membership club" analogy because it rather easily offers some ideas for what faculty can do to create a welcoming environment for women and people of color. Identify and tap into other informal networks; ask those women and people of color who are members of the club to tell you how to have access to other networks. Share the rules. The process of articulating them will be a fascinating exercise that will benefit all of the "members": how is performance recognized and acknowledged; who gets consulted on which projects; how are people compensated; with whom, how and when do people socialize; who gets copies of communications; when do you compete and when do you cooperate? The most well-intentioned faculty and administrators may not share the rules because they assume everyone knows them. Women and people of color are more likely to have moved through the pipeline without the benefit of a mentor, that person who has the role of passing on the rites and rituals of the organizational culture.

There is an aspect of membership that has a profound affect on underrepresented faculty in particular; and it is a direct consequence of programs like affirmative action that work to do away with underrepresentation. Social psychologists, Pettigrew and Martin, identify it as one of three factors that create a situation of "triple jeopardy" for women and people of color in predominantly white organizations: the solo and token rules that people from underrepresented groups walk into when they join the organization.

Because that person very likely may be the "only one" in the department or the building or the college, he or she may work solo most of the time. On top of that, the chances that many of their colleagues may view them as the "affirmative action candidate", here only by virtue of affirmative action, and, by definition, less qualified, are quite high. We have plenty of research to show that people act based on this stereotype. In a system that highly values collegiality, this false stereotype can make it extremely difficult for the woman or person of color to experience success.

There are ways to address this problem without doing away with affirmative action programs; they go back to sharing the rules. Educate faculty and students about how hiring decisions are made, about the fact that race and gender only influence hiring decisions when there is a "manifest statistical imbalance" and, then, only within a pool of equally qualified applicants. Share the reasons why this person was the best fit for the department at this particular time.

A final word about the "club". Even though women and people of color are joining, the officers -- those in leadership positions -- continue to be drawn from the traditional membership. This is true in so many organizations that "breaking the glass ceiling" -- dealing with the fact that women and people of color can rise to only a certain level in the organization -- has been identified as a priority for civil rights groups nationally. AEEP and AAEE could accomplish something very important at this conference by making a commitment to groom and invite women and people of color to assume leadership roles at the highest levels of the organization. Unless people see that they can rise to the top, they will leave the organization, taking their talents elsewhere.

Finally, I would like to refer to one of the points made in the original report produced by the Hudson Institute: Workforce 2000, Work and Workers for the 21st Century. The report underscores the dramatic shifts in the composition of the U.S. population and workforce; the fact that by the year 2000 85% of new entrants to the workforce will be women or people of color. 61% of women aged 16-64 will hold jobs, as compared to 43% in 1970 and 51% in 1980. The report concludes that these demographic changes will require significant changes in organizations that have assumed a predominantly male workforce supported by spouses who remain in the home and have the major responsibility for childcare.

This pattern simply does not exist in many arenas and women and men are experiencing the stresses of trying to operate with rules that soon may be obsolete. In academia, these stresses establish barriers for women. For example, many departments treat pregnancy leave as a special gift that, ultimately, must be earned or returned, rather than an aspect of human experience that should drive the system. Also, academia has been slow to respond to the increasing number of dual career couples -- partners who are committed not only to each other but also to full-time professional careers. The extent to which universities are responsive to the needs of dual career couples tends to affect women more often than men since women in academia are more likely to have a partner who is also in academia. When faced with the question of whether or not to find a position for a spouse or partner, many search committees finally pull out their affirmative action policies and procedures and argue that things have to be done by the book.

To conclude, what I am suggesting is that, while the difficulties experienced by women and people of color can often be linked to the fact that people aren't sharing the rules, an essential step toward achieving diversity will be to change the rules that work to establish barriers to equal participation and inclusion.

RESOLUTIONS RELATING TO THE DEVELOPMENT OF BACCALAUREATE ENVIRONMENTAL ENGINEERING PROGRAMS AND DEGREES AS AMENDED AND BROUGHT TO VOTE

1. **Stronger Presence of Environmental Engineering at Baccalaureate Level.**

Environmental engineering should have a stronger presence at the baccalaureate level. Ways of achieving this will depend on the institution and may include:

> Strengthening of environmental engineering options in traditional engineering degree programs. Some traditional engineering degree programs are highly constrained and may not provide the opportunity for a student to obtain the basic science and engineering science background necessary for a well-founded option or minor in environmental engineering. It is important that ways be found for more engineering students to obtain some competence in environmental engineering topics.
>
> Development and improvement of environmental engineering baccalaureate degree programs. A strong case has been developed for the continuation, expansion, and improvement of baccalaureate degree programs in environmental engineering. Only a few such programs exist. Several additional universities are considering adding environmental engineering baccalaureate programs. It is important that the environmental engineering profession, AEEP, AAEE, and ASEE support and nurture the development and improvement of these programs.

2. **Revision of ABET Basic Level Accreditation Program Criteria for Environmental Engineering.**

In future revisions of ABET basic level program criteria for accreditation of baccalaureate environmental engineering programs, consideration should be given to:

> Allowing up to one-fourth of an academic year of advanced (beyond the first year) quantitative/applied basic science to be counted toward the engineering science requirement provided that such course work demonstrates an application theory that qualifies it as environmental engineering science.

3. **Revision of ABET Basic Level Accreditation Program Criteria for Civil Engineering.**

In future revisions of ABET basic level program criteria for accreditation of baccalaureate civil engineering programs, consideration should be given to:

> Allowing up to one-fourth of an academic year of advanced (beyond the first year) quantitative/applied basic science to be counted toward the engineering science requirement provided that such course work demonstrates an application of theory that qualifies it as environmental engineering science.

4. **Guidelines for ABET Environmental Engineering Visitors.**

AEEP and AAEE should jointly develop basic level guidelines for ABET visitors in environmental engineering. Issues to be addressed in these guidelines include:

> Ways to ensure that environmental engineering curricula include appropriate coverage of multimedia (air, water, land) phenomena.
>
> A broad interpretation of what constitutes environmental engineering design courses that emphasize an integrated (air, water, land) approach.

5. **Participation in AEEP by Community College Faculty.**

The AEEP board of directors should explore membership of community college (two-year) faculty in AEEP.

6. **Role of Masters Degree in Environmental Engineering Education.**

The masters degree continue to be considered as the minimum level of professional education in environmental engineering.

RESOLUTIONS RELATING TO THE FUTURE CONCERNS IN ENVIRONMENTAL ENGINEERING GRADUATE EDUCATION
AS AMENDED AND BROUGHT TO VOTE

1. **Role of Traditional Undergraduate Engineering Education.**

The diversity of academic backgrounds among students seeking graduate training in Environmental Engineering programs is one strength of those programs, and such diversity should be encouraged. A corollary is that, even if such students undertake essentially identical course work at the graduate level, there remain important generalizable distinctions among them. One distinction is between those who have the training associated with traditional undergraduate engineering curricula and those who do not. We believe this distinction should be reflected in the degree designation. Therefore, the conference recommends that the completion of all ABET requirements for basic accreditation be required of students seeking degrees designated as engineering degrees. All undergraduate and graduate course work should be considered in determining whether a student's program of studies fulfills this requirement. Students who do not meet this requirement should be granted degrees without the engineering designation. Efforts should be made to explain the distinction to students and potential employers.

2. **Recruitment of Minority Students.**

Be it resolved that all faculty intensify their efforts to increase enrollment of women and minority students in their environmental programs.

3. **Creation of Environment to Support Minority Students.**

While recognizing the need to support all students, be it resolved that we encourage the development of an environment conductive to the full academic potential of minority, women, and disabled students, including financial support, a personally supportive environment and participation in all program aspects.

4. **Federal Support for Environmental Engineering Education.**

In view of the projected demand for graduate-level environmental engineers and the desire to have our brightest and most creative students attend graduate school and pursue inquiries that are not constrained by the demands of funding agencies, AAEE, ASEE, and AEEP should seek federally-supported graduate traineeships, fellowships, and scholarships.

RESOLUTIONS RELATING TO HAZARDOUS WASTE TOPICS IN ENVIRONMENTAL ENGINEERING CURRICULA
AS AMENDED AND BROUGHT TO VOTE

1. **Hazardous Wastes as a Component of Environmental Engineering.**

Hazardous wastes in the context of environmental engineering education should be defined broadly, rather than narrowly, as materials that are harmful, hazardous, toxic, infectious, and radioactive. Hazardous waste management is an integral component of an environmental engineering graduate program. Environmental engineering education should prepare students in the science and engineering of environmental contaminant reduction and control, including management of hazardous substances.

In the terms of the Drexel Conference definition of environmental engineering, hazardous waste management in an environmental engineering MS program properly is a specialty area encompassed within the recognized fields of professional practice.

2. **Changes in Environmental Engineering Curriculum.**

Hazardous waste issues require changes in course work. Education dealing with hazardous, toxic, and concentrated wastes and associated control technologies requires scientific and engineering fundamentals that are broader than those for traditional environmental engineering. The development of representative course content, outlines and materials for biological, chemical and physical principles should be developed by an AEEP task force or committee.

3. **Level of Education Required for Hazardous Waste Practice.**

Hazardous waste practice should be based on MS level preparation. Practice in hazardous wastes, perhaps more than in traditional environmental engineering areas, should require a masters degree as a first professional degree.

CONFERENCE PROGRAM AND SCHEDULE

SUNDAY, August 18, 1991

1:00 pm — Opening and Welcome
Kenneth J. Williamson, Conference Co-Chair, Oregon State University

1:15 pm — History of Environmental Engineering Conferences
Perry L. McCarty, Stanford University

1:30 pm — Keynote Addresses
"Environmental Engineering Education in the Year 2000 - What is Needed?"

Academic Perspective
Walter J. Weber, Jr., The University of Michigan

Practitioner Perspective
H. Gerald Schwartz, Jr., Vice President, Sverdrup Corporation

Public Perspective
Dennis Hayes, Founder of Earth Day 1970 & 1990, Green Seal, Palo Alto, CA

Open Discussion
Keynote Speakers Panel

4:00 pm — Social Hour
Sponsored by CH2M Hill

5:00 pm — Barbecue

MONDAY, August 19, 1991

9:00 am — Position Paper Summaries

Development of Baccalaureate Environmental Engineering Programs and Degrees
C. Robert Baillod, Michigan Technological University
William C. Boyle, University of Wisconsin-Madison

Inclusion of Hazardous Waste Topics in Curricula including Innovative Technologies
John Ferguson, University of Washington

Future Concerns in Environmental Engineering Graduate Education
Richard G. Luthy, Carnegie Mellon University

12:00 noon — Luncheon

1:00 pm Concurrent Forums on Focal Issues

Development of Baccalaureate Environmental Engineering Programs and Degrees

Current situation, requirements for competence and demand for graduates, advantages and disadvantages of various approaches, accreditation issues, and curricular alternatives

C. Robert Baillod, Michigan Technological University
William C. Boyle, University of Wisconsin-Madison
Richard Dague, Iowa State University
Robin Autenrieth, Texas A&M University
George Tchobanoglous, University of California-Davis

Inclusion of Hazardous Waste Topics in Curricula including Innovative Technologies

"The One Course in Hazardous Wastes"
F. Michael Saunders, Georgia Tech University

"The Expanded Hazardous Waste Curriculum"
Thomas M. Keinath, Clemson University

"Hazardous Waste Education for the Consulting Engineering Profession"
Greg Peterson, Director of Technology Transfer, CH2M Hill

"Education to Promote the Use of Innovative Technologies"
Walter Kovalick, Jr., Director, Technology Innovation Office, EPA

Future Concerns in Graduate Environmental Engineering Education

"Philosophy of Graduate Education"
Desmond F. Lawler, University of Texas at Austin

"Graduate Education for Versatility and Perspective"
Charles R. O'Melia, Johns Hopkins University

"Programmatic Issues on Research and Graduate Education"
James R. Hunt, University of California-Berkeley

"Relations Between Practitioners and Graduate Education"
Fred G. Pohland, University of Pittsburgh

"Environmental Engineering and Society"
David A. Bella, Oregon State University

4:00 pm Development of Refined Position Statements

5:00 pm Tour of OSU Wave Basin Research Facility

6:00 pm	Banquet & Keynote Address "Engineering Education in the Year 2000 - Achieving Cultural Diversity" *Stephanie Sanford, Director of Affirmative Action, Oregon State University*
8:00 pm	Dessert, Social and Poster Sessions *Sponsored by CH2M Hill*

TUESDAY, August 20

8:00 am	Plenary Session: Presentation of Work Group Reports and Refined Position Statements
10:00 am	Plenary Session: Discussion and Vote on Resolutions
11:30 am	Summary Addresses "Environmental Engineering Education in the Year 2000 - Summary Observations of the Conference"

Academic Perspective
Walter J. Weber, Jr., The University of Michigan

Practitioner Perspective
H. Gerald Schwartz, Jr., Vice President, Sverdrup Corporation

General Perspective and Summary
Kenneth J. Williamson, Conference Co-Chair, Oregon State University

12:30 pm	Conference Wrapup and Adjournment

POSTER PRESENTATIONS

1. "The Role of Environmental Engineering Technology in Undergraduate Environmental Engineering Education -- Case Study, Penn State, Harrisburg." R. Scott, Huebner.

2. Untitled. Dave Bella, Oregon State.

3. "Development of an Undergraduate Environmental Engineering Curriculum Under Multiple Constraints." David A. Vaccari, Stevens Institute of Technology.

4. "Frontiers in Education at California State University at Sacramento." Leonard W. Hom.

5. "Educational Program -- Environmental Restoration and Waste Management." M. Guven Yalcintas, Oak Ridge National Lab.

6. "What Does an Engineer Do ... Perceptions of Girls." Carol Diggleman, Milwaukee School of Engineering.

7. "ASDC: A PC-Based Program for Air Stripper Design and Cost." David A. Dzombak, Carnegie Mellon University.

8. Untitled. William P. Mason, RPI.

9. "Environmental Engineering at Cal Poly." R. Lang, H.C. Cota, and S.A. Vigil.

10. "Team Taught Undergraduate Design Project -- Design of Wastewater Treatment Facilities." Jim Morgali, University of the Pacific.

11. "Curriculum Comparison & Curriculum Alternatives." Robin Autenrieth, Texas A&M.

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