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Proceedings

Fifth Conference on Environmental Engineering Education:

Integrated Approaches

Computers

Design and Operation

Edited by
C. Robert Baillod

Sponsored by

AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS

AEEP
Association Of Environmental Engineering Professors

Michigan Technological University
in cooperation with
the Environmental Engineering
Division of ASEE
and Supported by
the National Science Foundation

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CONTENTS

INTRODUCTION AND SUMMARY

C. Robert Baillod P.E.
Conference Chairman

The discovery and regulation of environmental problems have accelerated during the past decade. Because "everything must go somewhere", environmental engineering practitioners are being routinely faced with the necessity of dealing with residual pollutants on a unified, multi-media basis. At the same time, operation of environmental protection facilities has assumed new importance, and significant advances have been made in computer technology and in environmental engineering research. It is essential that environmental engineering education prepare graduates to use these powerful new tools to effectively deal with current and future environmental problems.

In recognition of this need, the Association of Environmental Engineering Professors and the American Academy of Environmental Engineers co-sponsored the Fifth Conference on Environmental Engineering Education. Michigan Technological University hosted the Conference as part of its Centennial Celebration. Financial support was provided by the National Science Foundation, Michigan Technological University, and the Association of Environmental Engineering Professors. The Environmental Engineering Division of the American Society for Engineering Education also cooperated.

This Conference is one in a series that began in 1960.

The First National Conference[1], held in 1960 at Harvard University, was a landmark event that began the drive toward the teaching of unified concepts in environmental engineering and science.

The Second National Conference[2] was held at Northwestern University in 1967, and emphasized the multi-disciplinary characteristics of environmental engineering education.

The Third National Conference[3] convened at Drexel University in 1973. This meeting dealt with issues ranging from technician training to graduate education to continuing education programs.

The Fourth Conference[4], held in 1980 at the University of Toronto, dealt with the issues of excellence, curricular balance, and the relationship between undergraduate and graduate environmental engineering education.

Patterson,[5] and Baillod[6,7] described the relationship of these conferences to the environmental engineering profession and educational system.

The Fifth Conference dealt with Environmental Engineering Education at the advanced undergraduate and graduate levels. Special attention was focused on the Master's Degree level as preparation for research and professional practice. Research is an integral part of both the Environmental Engineering profession and graduate education at the M.S. and Ph.D. levels, and, because of this, research issues were deeply imbedded in the conference fabric.

CONFERENCE PLANNING, ISSUES AND FORMAT

In the fall of 1984, the sponsoring organizations appointed a Conference Planning and Steering Committee. Members were

Representing AEEP
C. Robert Baillod, Ph.D., Chairman. Professor of Civil and Environmental Engineering, Michigan Technological University

E. Robert Baumann, Ph.D., Anson Marston Distinguished Professor in Engineering, Iowa State University

Jon L. Liebman, Ph.D., Professor of Civil Engineering, University of Illinois

Representing AAEE
Paul L. Busch, Ph.D., Vice President Malcolm Pirnie, Inc.

Frederick G. Pohland, Ph.D., Professor of Civil Engineering, Georgia Institute of Technology

Ex-Officio

James L. Patterson, Ph.D., (Chairman of 1980 Conference) Professor of Environmental Engineering, Illinois Institute of Technology

This Committee met at Chicago in November 1984 to establish the issues and format of the Conference. The format was similar to that of previous conferences and was based on a substantial preconference effort by Task Committees to prepare position papers on the major issues. A second meeting, held at Purdue University in May 1985, set the time and place and served to further sharpen and focus the issues. The focal issues and rationale behind their selection were:

1. Integrated, Air, Water, Land Approaches in Environmental Engineering. Many engineers are competent in problem solving in only one medium. While equal competence in all media is neither necessary nor desirable, a multimedia approach to environmental problems requires at least an in-depth awareness of the significance and impact of intermedia transport. The Conference addressed educational needs and curricular design to provide competence in this area.

2. Role of Computers in Environmental Engineering Education and Research. The present is a time of transition and change. The computer literacy of incoming students is improving each year. Environmental engineering instruction and research must exploit this capability without sacrificing the emphasis given to basic engineering principles and problem solving techniques. The Conference addressed both the problem solving and instructional roles of the computer. In a related, but parallel, effort, the AEEP Committee on Computer Software had compiled a Software Manual. The Education Conference provided an ideal opportunity to introduce and illustrate the utility of this manual. Therefore, participants were provided with copies of the manual and program diskettes, and an afternoon session featured a Computer Software Exposition to demonstrate many of the programs contained in the Manual.

3. Role of Design and Operation in Environmental Engineering Education. Some guidelines relative to the design content of curricula exist, but the definition of engineering design is vague. Historically, operation of facilities has received little attention in environmental engineering education. For the most part, this topic has been left to technician and operator training programs. The present complexity of environmental control technology and facilities demands not only an engineering approach to operation, but also research into improved methods of operation. The Conference addressed educational needs and curricular design to improve instruction in this area.

Conference Committee Structure and Position Paper Development

In June 1985, Task Committees of environmental engineering educators and practitioners were formed to prepare position papers on each of the focal issues. The chairmen and co-chairmen of these committees were:

Integrated Air, Water, Land Approaches

P. Mac Berthouex, Ph.D., Chairman
Professor of Civil and Environmental Engineering
University of Wisconsin, Madison

William Thacker, Ph.D., Co-chairman
National Council for Air and Stream Improvement
Kalamazoo, Michigan

Computers in Environmental Engineering Education

John C. Crittenden, Ph.D., Chairman
Professor of Civil Engineering
Michigan Technological University
Houghton, Michigan

J.B. Neethling, Ph.D., Co-chairman
Assistant Professor of Civil Engineering
University of California, Los Angeles

Design and Operation

Davis L. Ford, Ph.D., Chairman
Davis L. Ford & Associates
Austin, Texas

Cal Patterson, Ph.D., Co-chairman
Engineering Science Inc.
Austin, Texas

The complete initial rosters of the Conference Committees are given in Table I. The leadership of these Task Committees prepared initial drafts of the respective position papers for discussion, comment, and revision at a Conference Planning Symposium held August 21-22, 1985 at Michigan Technological University. The revised position papers received additional comment at another Planning and Task Committee meeting held in October 1985. Based on this input, final drafts of the position papers were prepared and distributed to conference registrants and AEEP members during May and June of 1986. Meanwhile, the Conference was announced in various environmental engineering society publications and approximately 6,000 descriptive brochures were mailed.

CONFERENCE PROGRAM

The program centered on the focal issues. Each position paper was summarized and discussed on the first day of the conference. The second day of the Conference began with concurrent forums on each focal issue. The forums featured presentations illustrating educational needs and approaches to the issues. These were followed by Task Committee discussion and writing sessions designed to generate resolutions for presentation at the final plenary session of the Conference. A Computer Software Exposition was held concurrent with the Task Committee sessions. This Exposition consisted of informal microcomputer demonstrations by approximately 20 authors of programs published in the AEEP Software Manual.

The Conference concluded on the morning of the third day with a final plenary session at which the reports and proposed resolutions of the Task Committees were received and presented for approval, modification, or rejection by the Conference. A complete conference program is given in the Appendix. These Proceedings focus on the keynote address, position papers and discussion of Task Committee Resolutions presented to the Final Plenary Session. Presentations given at the concurrent forums on the second day are not included in these Proceedings. However, Abstracts of the Computer presentations and descriptions of the demonstrations at the Software Exposition are given in the Appendix.

SUMMARY

One hundred thirty-five environmental engineering educators and practitioners spent two and one-half days discussing educational needs, problems and solutions related to the Conference issues (see Appendix for list of Conference registrants). In this exercise, the conferees accomplished two things: First, a general consensus was reached regarding some things that ought to be done to improve environmental engineering education; these items are reflected in the resolutions passed at the final plenary session. Second, both the educators and practitioners became more aware of things they could do to improve instruction in the areas of integrated approaches, use of computers, and design and operation.

Some items of consensus were:

Integrated, Air-Water-Land Approaches: Environmental engineering programs should include elements that focus on multimedia problems and incorporate an integrated approach to their solution. Most university programs already include some of these elements, but more attention should be given to this topic. There is a lack of good teaching materials in this area. Consequently, there is a critical need for increased participation by practitioners in the development of practical problems and case studies for use in instruction.

Role of Computers: Agreement was reached concerning desirable computing skills for students entering environmental engineering graduate programs. Consensus was also reached concerning several kinds of computing topics and exercises that should be included in graduate level coursework. The importance of easy access to computers for students and faculty was recognized, and universities were encouraged to establish programs to facilitate the acquisition of personal computers by students. Problems arising from the educational use of proprietary software were recognized, and the use of freeware, shareware, and site licenses was encouraged. Development of software for classroom instruction was recognized as a creative and demanding activity for which credit should be given in career evaluation.

Role of Design and Operation: Environmental engineering programs were encouraged to place increased emphasis on hazardous waste management, the use of computers, operability, maintainability, and process dynamics and control in design courses. Design project courses that integrate regulations, finance, ethics, control systems, risk assessment, safety, and private practice were encouraged. It was further encouraged that these courses be taught by registered professional engineers.

There was general concern over how an increased emphasis on the various topics could be achieved in view of the limited amount of time and credits available in a typical master's degree program. There was also concern over how a baccalaureate environmental engineering program could be designed to include the broad basic science base necessary for environmental engineers as well as the amount of engineering science and design required for accreditation by ABET.[8] This latter concern led to adoption of the overall conference resolution that up to one-fifth year of advanced quantitative physical or natural science courses that have environmental engineering applications can be counted as engineering science in satisfying ABET requirements for basic level accreditation.

ACKNOWLEDGEMENTS

The collective efforts of many individuals and organizations were required to make this Conference successful. Among these were

John Crittenden, Martin Auer, Neil Hutzler, and David Hand of the Michigan Tech Environmental Engineering Faculty.

Ray Decker, Chairman of the Michigan Tech Centennial Celebration.

Eleanor Crittenden and Susan Bucheger of the Michigan Tech Communication and Conference Organizations.

David Carlson and Betty Vickers of the Michigan Tech Academic Computer Services Department.

Stanley LaMuth of the Michigan Tech Instructional Resources Center.

Michigan Tech Environmental Engineering students: James Andreini, Pamela Holingsworth, Vicki Jutila, Larry Krause, James Miller, Jennifer Miller, and Tim Rigg.

Task Committee Chairmen, Co-chairmen and participating members.

Conference Planning and Steering Committee Members.

Edward H. Bryan, Environmental Engineering Program Director, National Science Foundation.

William C. Andersen, Executive Director, American Academy of Environmental Engineers.

Officers and Board of Directors of the Association of Environmental Engineering Professors.

The expert typing and organizational skill of Helen Heinonen is gratefully acknowledged. Judith Taggart of JT&A assisted in editing and publishing these Proceedings.

Table I.—Fifth Conference on Environmental Engineering Education Committee Roster

DESIGN AND OPERATION TASK COMMITTEE

Davis L. Ford**
Davis L. Ford and Associates

James A. Mueller
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Cal Patterson*
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Rudy J. TeKippe
James V. Montgomery Inc.

C. Robert Baillod
Michigan Technological University

Stephen P. Graef
Milwaukee Metropolitan Sewerage Commission

Paul L.Busch
Malcolm Pirnie Inc.

Karl G. Voelkel
Proctor and Gamble

W. W. Eckenfelder Jr.
Vanderbilt University

Paul A. Jennings
Florida Institute of Technology

TASK COMMITTEE ON INTEGRATED, AIR, WATER, LAND APPROACHES IN ENVIRONMENTAL ENGINEERING

P. Mac Berthouex**
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Neil J. Hutzler
Michigan Technological University

William Thacker*
Natl. Council for Air & Stream Improvement

Raymond C. Loehr
University of Texas

Hugh J. Campbell Jr.
E.I. duPont de Nemours Co.

Richard G. Luthy
Carnegie-Mellon University

Larry W. Canter
University of Oklahoma

James J. McKeown
Natl. Council for Air & Stream Improvement

Nicholas L. Clesceri
Rensselaer Polytechnic Institute

Charles O'Melia
Johns Hopkins University

Yoram Cohen
University of California, Los Angeles

Ronald D. Neufeld
University of Pittsburgh

Stacy L. Daniels
Dow Chemical USA

Frederick G. Pohland
Georgia Institute of Technology

Alan W. Elzerman
Clemson University

F. Michael Saunders
Georgia Institute of Technology

David H. Foster
University of Wyoming

George Tchobanoglous
University of California, Davis

N. Bruce Hanes
Tufts University

Douglas A. Wallace
EDI Engineering and Science

TASK COMMITTEE ON COMPUTERS IN ENVIRONMENTAL ENGINEERING EDUCATION AND RESEARCH

John C. Crittenden**
Michigan Tech University

Joseph V. DePinto
Clarkson University

J. B. Neethling*
University of California, Los Angeles

Francis A. DiGiano
University of North Carolina

John F. Andrews
Rice University

Thomas M. Heidtke
Wayne State University

Martin T. Auer
Michigan Technological University

Aaron A. Jennings
University of Toledo

Tom Barnwell
U.S. Environmental Protection Agency

Jon C. Liebman
University of Illinois

Bill Batchelor
Texas A & M University

Paul V. Roberts
Stanford University

Raymond P. Canale
University of Michigan

Bruce E. Rittman
University of Illinois

Steven C. Chapra
Texas A&M University

Michael K. Stenstrom
University of California, Los Angeles

MacKenzie L. Davis
Michigan State University

Walter J. Weber Jr.
University of Michigan

***Chairman*
**Co-chairman*

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A LOOK TO THE FUTURE: ENVIRONMENTAL EDUCATION

Keynote Address

Earnest F. Gloyna, P.E.
Charles A. Sorber, P.E.
The University of Texas at Austin

INTRODUCTION

Engineering education critically needs to be reexamined. Environmental engineering education, in particular, must be given new direction. Few engineering curricula deal effectively with the escalating complications of the modern teaching-learning process. The body of knowledge is growing rapidly and societal expectations concerning health and environmental quality are changing equally rapidly. Unless environmental engineering education changes substantially, there may no longer be a valid basis for a separate degree program in environmental engineering.

We need a new vision for the environmental engineering profession. Historically, sanitary and public health engineers have made great contributions to the wellbeing of mankind. Presently, however, there is a widespread perception that environmental engineers are the technologists and process adaptors of the regulatory process. Now is the time to prepare for the health-related engineering challenges of the 21st century. To do so, we must ask what educational base is required. What educational objectives must be met to sustain academic and professional leadership, not only in the eyes of the professional fraternity, but also by the standards of society at large?

In the past, environmental engineers have responded to obvious pollution problems caused by excessive concentrations of waste from people or industry. Treatment technology is important, but cannot continue to be the dominant driving force for solving environmental problems. The environmental engineers of the future must anticipate potential environmental problems and prevent their reoccurrence, recognize the health effects resulting from environmental insults, apply engineering knowledge across multimedia systems, cooperate with interdisciplinary teams of specialists, and participate in the formulation of public policy.

We educators recognize that the wealth of a nation originates in the classrooms and research laboratories of its universities; yet we must ask ourselves if we are diligently performing the responsibilities entrusted to us. We know that environmental engineering education contributes to a better quality of life, but does the rest of the world recognize this truth? We educators must develop the native intellect of motivated students more effectively, but before we can teach modern fundamentals more effectively, we must modernize our curricula. Also, let us recognize that while college education establishes a foundation for the learning process, the development of knowledge must be a continuum, developed over a lifetime of learning. The knowledge assimilated by an environmental engineer is not applied at a discrete point in time, nor can the knowledge base required be limited in scope.

To develop this breadth of understanding, the environmental engineer must master a broad spectrum of scientific principles, understand what is meant by engineering synthesis and design, and appreciate the fact that risk assessment and risk management mandate participation in formulation of public policy. Only after this knowledge base has been nurtured through carefully tailored degree programs and continuing professional education can those who dare to assume the responsibility of environmental engineering succeed. Interestingly, more than 100 years ago Dr. E.H. Williams, Jr., founder of Tau Beta Pi, remarked that it would be the "whole person" who could influence society philosophically, morally, and ethically; but that in order to do so they would have to broaden their viewpoints beyond the limits of their own technology.[1]

A history of environmental engineering would probably list the giants in the field and their special contributions. However, as we look toward the future, we might borrow a time-honored technique and ask not who the future giants might be, but what will be their contributions? Having established a remarkable record in public health, and more recently in environmental control, environmental engineering is now embarking upon its third mile.

RATIONALE FOR A HEALTHFUL ENVIRONMENT

The sanitary engineering movement, like human history, was based on civilized attempts to control the natural environment through productive labor. Out of magic, mysticism, and trial-and-error evolved the scientific method to control waterborne diseases. Engineers developed predictive treatment processes that represent the essence of disease prevention and public health. The period between 1875 and 1925 marked the beginning of the sanitary engineering profession in America. The difference between traditional civil engineering and the new approach to resolving health-related problems was the fact that sanitary engineers were interested in understanding health effects in order to resolve the problems through engineering.

Sixty years later and within sight of the 21st century, it is now time for environmental engineering educators to address the changes that must be made to ensure effective and continued environmental engineering education. As we anticipate the future, let us heed the words of one of our elder statesmen, Dr. Abel Wolman, who wrote: "History warns us that issues and challenges are never completely resolved. . . . The parasite *giardia* is symbolic of the forgotten fact that all of us live in a 'wormy world' against which the engineer has a continuing battle."[2]

As individuals who are interested in higher education, we should recognize that society rewards those who are appreciated and understood. Interestingly, the public influences the movement of talented people into the professional arena through a system of rewards; however, this same public has little appreciation of the changing complexities of our technological world. Some professionals feel that the rate of change in science and technology is accelerating at such an alarming rate that only a mandatory, lifelong learning process can maintain professional integrity. For example, new technologies such as information processing, biotechnology, exotic materials, intelligent machines, and expert systems are expanding rapidly. Information relevant to better environmental management must be assimilated into the knowledge base of the practicing environmental engineer. But as important as the need for technology may be, the environmental engineer has a continuing responsibility to communicate with the public and to address public policy issues.[3] Surely, a properly informed public will make better decisions relating to environmental quality.

The most difficult challenges for the future environmental engineer will be those that arise from the basic nature of an overpopulated, industrialized society. These include demonstrable health-related problems associated with the protection of groundwater, control of nonpoint source pollution, regulation of toxics, and disposal of hazardous wastes. Growing issues involving multimedia considerations must be addressed. Familiar examples include acid precipitation, residuals management, ocean disposal, water reuse, environmental consequences of biotechnology, and ozone accumulation in the upper atmosphere.

CHANGING CHARACTERISTICS

The engineering profession is undergoing a dramatic change. Let there be a new beginning, but let us also learn from the lessons of the past.[4] We realize that "hard science" and technology alone may not be adequate to meet the environmental challenges of the future. Economic, social, legal, and ethical considerations most assuredly will be involved in making the societal judgments of tomorrow. And no one wishes to repeat any of the regressive trend so common in the evolution of public health practices.

Because of the complexities inherent in global industrialization and population growth, no area of societal adaptation will be harder to predict than the environmental accommodations that will be required. It is probably safe to say that almost anything and everything will happen. In all probability, environmental regulation will be more extensive and the development of new technologies will accelerate. However, if there is a lesson to be learned from history, we may surmise that many older technologies will prevail. It is not likely that there will be a single, best concept for pollution control. Alternative management and treatment systems will proliferate. The problems, remedies, designs, and operations will become more complex. A higher level of education will be needed to satisfy the requirements of design, management, and operations. A broader education will be needed to interact effectively with others involved in the decisionmaking processes.

GLOBAL ENVIRONMENTAL ISSUES

Global environmental issues will profoundly influence the future training of the environmental scientist and engineer.[5] Just as waterborne diseases caused the early civil engineers to turn from bridge building to public health engineering, environmental engineering education must not neglect the sanitation problems of the emerging nations. Environmental degradation, rapid resource depletion, and food shortages associated with unfettered population growth are the larger manifestations of the infrastructure problems in developing societies. Environmental engineers will be asked to address the cause-and-effect relationships concerning resource deterioration and use. Their educational level must be up to the task.

In all societies, developed and developing, public policy will continue to be formulated by public reactions based on perceived remedies. New technical approaches will be needed to solve these vexing problems, and new insights will be required to assess environmental impacts accurately. The challenge is immense, for we live in a world where a country can deplete its mineral resources, mine its aquifers, cut down its forests, erode its soils, pollute its waters, virtually eliminate its wildlife and fisheries, and yet show that its measured income rises steadily as its assets are depleted.[6]

Pessimists and optimists exhibit great dissension regarding global environmental issues. The pessimists stated their case in two studies produced for President Carter called *Global 2000* and *State of the World Reports*.[7,8] The optimists responded with equal vigor in a study entitled *The Resourceful Earth*.[9]

The point is that the solutions to tough environmental problems do not depend solely on good science and engineering. Questions concerning social consciousness are akin to the problems that faced the public health engineer several decades ago. It is unfortunate that an environmental engineer today may spend a lifetime worrying about the kinetics of a single treatment process without being concerned about health effects. This is a grave situation, indeed.

CRITERIA FOR ENGINEERING EDUCATION

Environmental engineering education must satisfy three criteria:

- Does it provide a foundation for a lifelong educational process?
- Do the formal courses and the research experiences enhance the total body of knowledge?
- Does the study of environmental engineering ultimately contribute to an improved quality of life?

Engineering excellence is cultivated and nurtured by most faculty. However, excellence is a collective state of mind, confirmed first and foremost by oneself and subsequently transformed into an academic ambience in which faculty and students can thrive. The development and maintenance of excellence requires an abundant provision of research support, state-of-the-art facilities, a stimulating work environment, exchange lectureships, freedom from the "the paper chase," fellowships, and staff.

Traditionally, American education has been characterized by diversity and pluralism, and this approach has provided multiple paths to engineering knowledge and skills. Nevertheless, the quest for a more perfect degree program continues to weigh heavily on the minds of faculty and practitioners alike. As usual, a balance must be sought between

- Theoretical and applied subjects;
- Engineering, life sciences, physical sciences, social sciences, and management disciplines; and
- State-of-the-art technical knowledge and basic communication skills.

The traditional concepts of teaching scientific and engineering principles, conducting engineering research, and performing engineering services are, as always, very important. However, we must determine the fundamental principles of environmental engineering per se. Where does the future environmental practitioner obtain sufficient knowledge of the life and social sciences? To date, few if any undergraduate engineering degree programs provide adequate courses in the life sciences. As a matter of fact, an in-depth review of the graduate programs in environmental engineering may reflect the same deficiencies.

A recent National Research Council (NRC) study indicated that changes in engineering education depend on curricular and faculty flexibility. But you and I know that we faculty, as a rule, do not seek change! The NRC study recommended that the faculty make undergraduate level education more efficient through more effective use of computers in the classroom.[10] The study concluded that technological, economic, and social changes will continue to intensify, and these societal transformations will place even greater stress on faculty to modify curricula.

Another NRC study concluded that extensive disciplinary specialization should be postponed until graduate school.[11] Regarding graduate student supply and demand, the NRC concluded that a single, concentrated educational experience is not sufficient for a lifelong career. Furthermore, master's theses have questionable value if they are allowed to degenerate into routine exercises.[12]

The National Institute of Education recommended that "all Bachelor's recipients should have at least two full years of liberal education."[13] However, if the liberal education concepts are to be incorporated effectively into a curriculum for environmental engineering, it will be necessary for the humanities faculty to design courses that appeal to the scientific mind. Herein lies the basis for a pending battle, a turf war for academic teaching credits.

CRITERIA FOR PROFESSIONALISM

An engineering education should provide the basis for a professional career. Four criteria define professionalism:

- An attitude of mind;
- Unique knowledge applicable to the performance of special skills;
- Professional stature, e.g., a level of academic distinction qualifying one for a position of honor and trust; and
- An ability to develop a confidential relationship between client and agent.

COST OF ENGINEERING EDUCATION

Engineering education is expensive. The quality of a program depends on the stature of the faculty, teaching and laboratory facilities, support services, and scholarship of the student body. Ultimately, programmatic improvements in engineering instruction require special funding considerations. Very few faculty, practicing engineers, and even university administrators know what a first-class engineering program should cost. Designers of curricula should be cognizant of direct costs, instructional costs, and indirect costs.

Clearly, advanced-level professional education is expensive. At the University of Texas at Austin, the cost of one additional year of master's level engineering education exceeds that of a four-year, undergraduate level engineering education by a factor of 2 or 3. Similarly, the additional cost of providing doctoral-level education for engineering students surpasses undergraduate engineering education costs by an order of magnitude.[14] Instructional costs represent only about 44 percent and 32 percent, respectively, of the net and gross cost. Net cost is gross cost less the costs of sponsored research, institutional research, and public service.

CURRICULAR BALANCE

Curricular balance is another topic that is easy to discuss but difficult to achieve. This topic was discussed in a position paper at the Fourth Conference on Environmental Education.[15] It was suggested that environmental engineering educators might not be preparing students to meet the challenges of tomorrow. The conferees were told that undergraduate-level students should be taught mathematical, scientific, and engineering principles. Students should be taught to think and to communicate. Are these goals attainable? Unfortunately, overspecialization at the undergraduate level may produce expert technicians instead of thinking engineers.

Increasingly, more authors argue for a greater humanities component. For example, William Kays of Stanford suggests that engineers "have to endure an over-technologized set of courses that starves them of the humanities and awareness of the main forces of society."[16] Broadening the engineering education is an important mechanism for preparing engineers to solve the technical problems of society, for these technical problems almost always include social, ethical, political, and legal considerations. To be successful, an engineer requires a clear understanding of these issues.

In fact, a strong argument can be made for using an undergraduate education as a requirement for entry into an advanced professional degree program. The classical professions have long used this approach; even business executives now consider this the appropriate practice. According to Figure 1, the amount of knowledge introduced into a four-year program has increased severalfold since the turn of the century and within the next few decades probably will increase almost exponentially.[17]

Consider for a moment the three focal issues of this conference:

- Integrated Air, Water, Land Approaches in Environmental Engineering
- Role of Computers in Environmental Engineering Education and Research
- Role of Design and Operation in Environmental Engineering Education

Do most undergraduate curricula deal effectively with these issues? Where are the health, public policy, risk assessment, and risk management components?

At the outset, let us assume that all undergraduate curricula must meet minimum ABET criteria. These criteria include one year of an appropriate combination of mathematics and sciences; one year of engineering sciences; one-half year of engineering design; and one-half year of humanities and social sciences. The engineering science courses are to carry the basic principles learned in the mathematics and science courses toward creative application. The design courses must include devising a system, component, or process through a creative decisionmaking process. Laboratory work is a requirement, also. Other requirements include the development of communication skills; an understanding of ethical, social, and economic issues; and an appreciation of the fine and liberal arts. Programs related specifically to environmental or sanitary engineering must include at least three areas from the following: air pollution control, water quality, solid waste, or environmental health engineering.

A strong argument can probably be made that present civil engineering curricula are less than satisfactory for meeting the broader needs of environmental engineering. The typical civil engineering curriculum lacks several components required for a complete understanding of environmental engineering issues, including

- Organic chemistry
- Microbiology
- Biochemistry
- Environmental Regulations and Policy
- Biology
- Ethics

Clearly, to accommodate these topics in a standard civil, environmental, or other undergraduate engineering curriculum may necessitate deleting some traditional courses.

All engineering practice involves health and environmental considerations. The critical questions might be

- How much environmental engineering should be incorporated into all engineering disciplines?
- Is there a place for an undergraduate degree in environmental engineering?
- What options might an advanced-level environmental engineering degree involve?

Possibly we can agree that all engineering disciplines ought to be sensitive to the impacts of their professional activities on the quality of life and the health of human beings. For some departments this step represents a major departure from the current modus operandi, although students and faculty alike are now inclined to be more environmentally conscious. The question of whether an undergraduate degree can cover the requisites of environmental engineering may generate considerable debate. Such a degree would require a minimum of 123 to 130 semester credits (with 1 semester credit = 1.5 quarter credits). The lack of breadth and depth of such a degree may create problems by limiting employment opportunities for the degree holder. The options appear to indicate that the current undergraduate engineering program must be extended and that the advanced-level programs may need to be modified.

ALTERNATIVE DEGREE PLANS

Education in environmental engineering must involve greater input from basic disciplines as a specialization is developed, particularly if health effects continue to be a dominant environmental concern. The student must achieve a general understanding of the environmental health engineering field as well as competence in an area of specialization. The student must be able to evaluate and solve complex environmental engineering problems, design environmental systems, and provide professional leadership in shaping public policy through an understanding of risk assessment and risk management. Other topics essential to the practice of modern environmental engineering include familiarization with the fields of toxicology and epidemiology. Rarely are these subjects covered by required environmental engineering degree plans. Nevertheless, these basic topics are fundamental for evaluating public policy decisions related to the health effects of hazardous wastes and other current issues.

Alternative engineering degree programs are presented in Figure 2. Three basic plans with two alternatives are developed: B.S. Core, B.S./M.E. or M.S., and Ph.D. or Dr. of Engineering. A lifelong learning and continuing education program completes the requirements for successful employment and public interaction.

1. **Plan A (Baccalaureate Status)**

   A Bachelor of Science degree with an emphasis in some engineering degree-granting program (meets minimum ABET criteria)

   a. B.S. degree with a minimum of 123 semester credit hours (SCH)

   b. A suggested distribution of courses as follows:

Topic	SCH
Mathematics beyond Trigonometry	15
Physical Sciences (Chemistry and Physics)	21
Life Sciences	6
Earth Sciences	3
Humanities/Social Studies	18
English Composition/Technical Communication	6
Engineering Law/Ethics/Public Policy/Economics	6
Engineering Science and Analysis	32
Engineering Design and Synthesis	6
Total	123

2. **Plan B (Baccalaureate and/or Masters Level Status**

   A Bachelor of Science (B.S.) or Master of Engineering (M.E.) degree with emphasis in environmental engineering

   a. A B.S. or M.E. degree in environmental engineering with a minimum of 160 SCH

   b. A distribution of courses would include those listed in Plan A and the following upper division or graduate level courses:

Topic	SCH
Analysis, Design, Report or Thesis Equivalency	6
Humanities	6
Engineering–Controls, Materials, Operations Research, or other appropriate course	6
Public Policy or Management	6
Biotechnology	6
Electives	7
Total	37

   c. The degree actually to be awarded would be either a B.S., M.E., or both. For example,

(1) a Bachelor of Science degree would be awarded with a C grade point average (GPA)

(2) an M.E. degree would be provided if the student presented a B GPA; and finally,

(3) an M.E. degree would be awarded to a student who only had a C GPA but successfully passed the professional engineers exam at some future date.

3. **PLAN C**

   Plan C is identical to Plan B except that students would be enrolled at a university as pre-engineering students for 2 years and then admitted to the College of Engineering for 3 years.

4. **PLAN D (Doctoral Status)**

   A doctoral-level degree with an emphasis in applied sciences and engineering

   a. Doctor of Engineering
      (1) ABET minimum undergraduate requirements
      (2) One minor in science and one minor in engineering closely related to area of specialty
      (3) A substantial contribution to environmental engineering with emphasis in synthesis, analysis, and design

   b. Ph.D.
      (1) ABET minimum undergraduate requirements
      (2) Two minors in science or one minor in science and one minor in a nonrelated engineering discipline
      (3) A substantial contribution to an applied science with some application to engineering.

SUMMARY AND CONCLUSIONS

Let us dream together as we develop a new vision for professional stature. Our goal is to improve the environment, but throughout the educational experiences of the environmental engineer, health considerations must remain paramount. Professional leadership originates in the classroom.

Let us consider whether we are going to prepare educated technicians or innovative professional engineers who have the educational depth and breadth to think. Fundamental education provides the only basis for a lifelong learning process.

Tomorrow's environmental engineers must not be hindered by an inadequate underpinning of the necessary sciences, lest they become a narrowly educated caste of highly skilled specialists tottering ineffectually on the fringes of technology.

Redesigning the environmental engineering curricula must be of great importance to the professional engineer. As we approach the 21st century, a new concept in environmental engineering education must be developed. The environmental engineering student of the future must be able to seek out nontraditional approaches to solving traditional and unforeseen public health and environmental problems. Professors must be more knowledgeable about the problems of the professional practitioner, the manager, the regulator, the decisionmaker, and the public. A multimedia approach in the classroom and laboratory is long overdue.

The basis for engineering curricula is the minimum ABET requirement or 123 semester credit hours, a generally unacceptable four-year degree program. Consideration should be given to recognizing an ABET-accredited master's degree (M.E. or M.S.) as the entry-level professional degree for environmental engineering. Specialization in various environmental engineering areas might best be provided under the Dr. of Engineering degree. Research could encompass design as well as scientific applications to engineering problems. Scientific discovery and selective specialization might best be reserved for the Ph.D. program.

The options for changes in curricula are to add on to the minimum ABET core requirements, resulting in a five-year undergraduate program, or to redesign the educational concept. For example, some educators would argue for a two-year pre-engineering plan followed by a three-year engineering B.S. degree program. Other educational leaders believe that more significant measures need to be taken. The B.S./M.E., 160 SCH concept provides an innovative approach.

There will continue to be a need for the environmental engineering specialist if the educational base is extended. However, a degree will no longer provide a lifetime of tools. Modern high-tech industry clearly has shown that the formal learning process must become a lifelong endeavor. The discovery process in science and the development of modern technological systems will not adjust without a major updating of environmental engineering curricula.

We need not despair, for engineering education as a whole is not seriously flawed; though neither is it monolithic. As a social scientist might say, it has its own infrastructure. Employers of engineers, as a whole, generally agree that undergraduate engineering students are technically better prepared than ever. However, it is apparent that significant gaps in curricula are beginning to appear. Complaints generally concern a lack of communication skills, the inability to cope with public policy issues, lack of management and leadership capabilities, and generally an inadequate appreciation of related disciplines. In specialized disciplines, such as environmental engineering, the breadth and depth of course content is becoming increasingly inadequate. Unless environmental engineers increase their educational scope, the discipline may be relegated to options in other mainline engineering programs.

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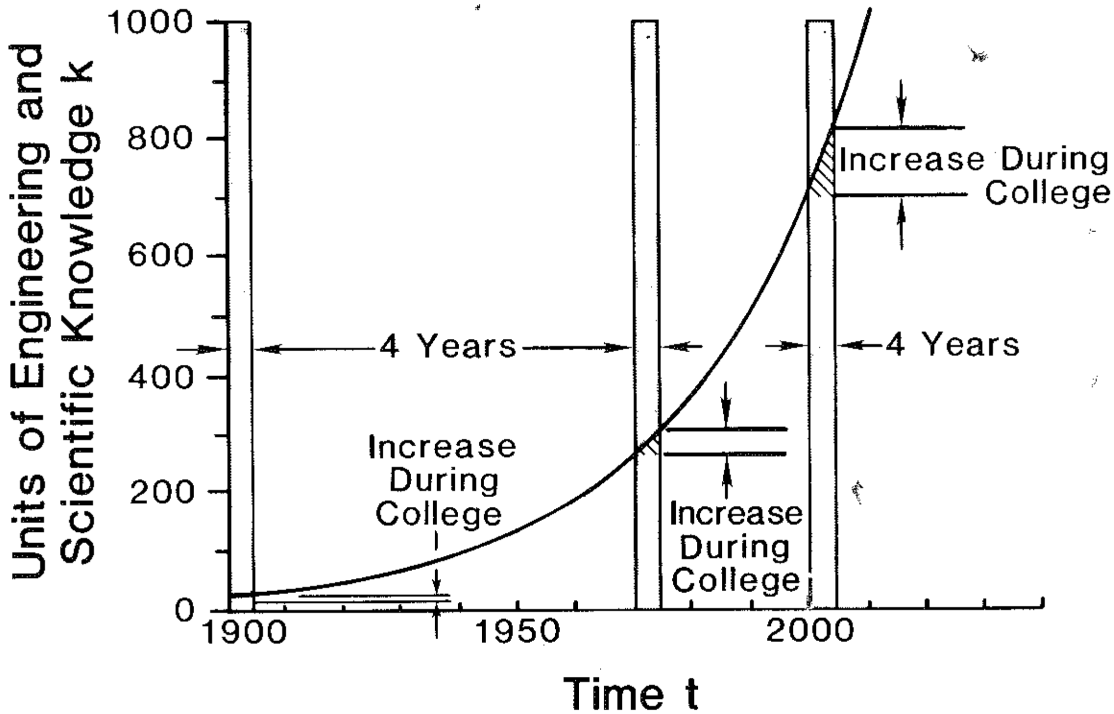

FIGURE 1. Increased Knowledge Base (17)

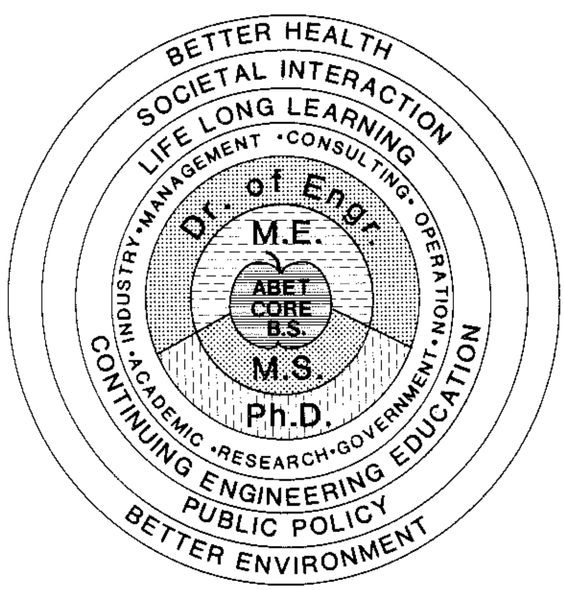

FIGURE 2. Life-Long Learning Contributions

Position Paper

COMPUTERS IN ENVIRONMENTAL ENGINEERING EDUCATION AND RESEARCH

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CONTENTS

INTRODUCTION

The objective of this paper is to address the issues facing environmental engineering educators relative to implementation of computer technology in undergraduate and graduate curricula. This document and the conclusions that will be reached at the conference will assist professors in developing ways in which to include computers in their teaching, and also, approaches to encourage university administrators and federal and state agencies to support activities that incorporate computers in education and research.

This document is not intended as a complete treatise on hardware or software issues, but rather as a presentation of major current issues that environmental engineering educators and practitioners are facing. A discussion and brief overview summary of the current availability of computers, software, and hardware pertinent to the task at hand are included in Appendix A. A number of texts can provide the interested reader with more information on these subjects.

Resources available for engineering calculation have evolved during the past decade from slide-rules and log books to include hand-held calculators and microcomputers. Computer literacy in the current student generation is increasing rapidly as microcomputers become standard tools available to most students. These factors not only open new avenues in engineering education and research, but also change the skills and abilities that the environmental engineering profession expects from new graduates.

A major objective of computer use in environmental engineering education is to expose students to potential applications for use in their professional careers and to practice the skills required for such applications. The principal purpose of involving computing in coursework is for students to overcome their fear of working with computers, to become familiar with at least one operating language, to learn to construct logical algorithms, and to communicate effectively with software engineers. Students should apply skills they have learned from computer science classes in their environmental engineering coursework. The teaching of new computing skills should not be a major objective of computer use in environmental engineering coursework. Some typical computer applications in environmental engineering education are summarized in Table 1, along with the degree of computing skill and the prerequisites associated with each application.

Several major questions which must be addressed in any consideration of computer applications in environmental engineering education and research. How must we modify our courses and assignments to educate students most efficiently? How can we best prepare students for the demands and expectations of the environmental engineering industry? How can we teach students to communicate effectively with software developers? What new research areas should be addressed? How can environmental engineering education derive the maximum benefit from the availability of microcomputers (20-100 floating point operations per second - flops), mainframe computers (1-100 million flops), and super computers (1.2 - 262 billion flops)? These and similar questions underscore the need for this conference to take a leading position that will ensure the smooth advance of the profession into this new age.

Table 1.—Uses for Computers in Education and Research.

USE	COMPUTER SKILLS REQUIRED*	COURSEWORK SKILLS REQUIRED	REQUIRED PREREQ. OF M.S. GRADUATES
Demonstration Software, e.g. Real Time Simulation with Auto Execution	0	None	Yes
Word Processing	1	None	Yes
Communication between Computer Systems	2	None	Yes
Spreadsheet	2	None	Yes
Data Base Management	2	None	Perhaps
Roots of Nonlinear Equations	2	Numerical Methods	Yes
Solutions to Simultaneous Linear and Non-linear Equations	2	Numerical Methods	Yes
Interpolation	2	Numerical Methods	Yes
Matrix Operations	2	Numerical Methods	Yes
Solutions to Ordinary Differential Equations	3	Numerical Methods	Yes
Graphics Display	2	None	Yes
Data Acquisition	2	Perhaps Statistics	Yes
Statistical Analysis	3	Statistics, Mathematics	Yes
Control Laboratory Equipment	3	Control Theory	Perhaps
Programming (Problem Solving) that Involves Simple Logical Flow	3	Programming Numerical Methods	Yes
Programming (Problem Solving that Involves Many Subparts that Include both Arithematic and Logical Connections)	4	Numerical Methods	Perhaps
Advanced Modeling-Research	4	Numerical Methods	Perhaps
Modeling - Water Resource Management	4	Numerical Methods	Yes
Programming (Process Design and Natural System Transport)	4	Application Dependent	No
Process simulation	4	Numerical Methods	No
Software Development for Complex Problems	4	Experts Only, Not Usually Performed by Engineers	No

**Evaluation scale:*
0 = None *3 = Substantial*
1 = Little *4 = Expert*
2 = Some

COMPUTERS IN EDUCATION
Introduction

There are degrees of skill in using computers, but the development of such expertise is, in some cases, more appropriately done in professional practice. The mainframe computer is clearly a tool that is used widely in practice but for which great expertise is not necessary for students *as students*. Although students are taught to write programs, they are not required to use that ability every day. Personal computers are rapidly changing the role of the computer in practice, and this change makes a great difference in the kind of educational experiences that must be provided. Microcomputers have the potential to become truly "personal" and indispensable for day-to-day engineering activities. Thus, frequent use and knowledge of the microcomputer should be expected from and taught to students.

In addition to having students develop simple programs, several points may be illustrated using computers in coursework. Students can conduct sensitivity analyses with complex models to understand the importance of model parameters or phenomena on the process. Experiments that yield the most important information can also be designed. This can be often demonstrated only with computers because some problems are too complex or tedious to solve by hand. The students could be exposed to general purpose software that can help them solve complex problems. For example, they may use programs that solve sets of simultaneous linear and nonlinear equations, sets of nonlinear ordinary differential equations, general optimization and parameter estimation programs, and statistical packages (for example, programs included in the International Mathematics and Science Library).

One important consequence of having students use computers to solve problems is that any student who can program a computer to solve a problem has a good grasp of the problem. This answers critics who claim that writing programs is mostly a computer science exercise and should not be used extensively in coursework.

Availability of Computers

Computers must be readily available to students and faculty. They are an educational resource and, similar to a campus library, should be freely available without restrictions or limitations. Distinction should be made between the availability of mainframe and microcomputers, and the needs of undergraduate versus graduate students. Graduate students solving complex problems will need access to mainframe computers; however, many complex problems which have been solved on mainframe computers can now be solved on microcomputers. In contrast, undergraduates can solve most of their problems on microcomputers. Accordingly, this paper will focus on microcomputers.

To make the microcomputer truly personal, it must be readily accessible to students at a convenient place and at convenient times. It is not sufficient to provide a handful of microcomputers and let students wait in line to use them. The power of the computer in these applications is severely limited unless the user can have access for fairly long periods of time, free of pressures that would interfere with creative thought. The purchase of a microcomputer should therefore be encouraged.

THE CLARKSON EXPERIENCE

This philosophy is embodied in the Clarkson University personal computer program, which (beginning in Fall 1983) issues a microcomputer to *every* incoming freshman. The first personal computer issued to students was a Zenith Data Systems Z-100, with both 8-bit (8085) and 16-bit (8088) Intel microprocessors, a separate 12-inch green phosphor monitor, a single 320K dual-sided 5.25 inch disk drive, and 192K RAM. Software issued with the system included two operating systems (CP/M-85 and Z-DOS, ver.1), Z-BASIC (with graphics), FORTRAN and Pascal compilers, an electronic spreadsheet (Multiplan), and a word processor (Galahad, a Clarkson software product). This entire package was given to each student for only a $200 surcharge per semester on his tuition. Upon graduation each student would then own his own personal computer, having paid $1600 for what at the time was a computer and software package worth well over $4000. Any graduate student or undergraduate enrolled in Clarkson prior to initiation of the program can purchase the system for the same total price of $1600.

The program has kept pace with the rapid hardware and software advances in the microcomputer industry. This fall (1986) incoming freshman will be issued an IBM AT-compatible Zenith Z-241-81, which is equipped with a 32-bit 80286 processor, two disk drives (one 320K and one 1.2 M byte drive), a hard disk drive controller board, 512K RAM (expandable to 3072K), and a whole complement of software that includes MS-DOS (ver. 3), high level languages (Z-BASIC, FORTRAN, Pascal), Multiplan, Galahad, TERMITE (a complete communications/terminal emulation program), and "toolbox" disks that contain many utilities, graphics, and general and special purpose programs written at Clarkson. In spite of the greatly increased capabilities of this system, the cost of this package to the students has not changed.

By this fall (1986) there will be in the neighborhood of 4,000 personal computers on campus, all of which have the potential (either via hardware or a phone modem) to communicate with any of Clarkson's four host computers, or with each other through a developing network and electronic mail system.

In recognition of the importance of faculty for incorporating personal computers into the curriculum, each faculty member is given his own microcomputer and encouraged in a number of ways to incorporate its use into his courses. This has been a key factor in the success of the Clarkson personal computer program.

Microcomputers Versus Mainframe Computers

Computer resources have increased dramatically with the introduction of microcomputers. Micros have brought the price of computers within the range of many individuals, brought the users closer to the machine itself, and increased the computer literacy of the population. It appears that the microcomputer is now capable of many of the tasks that have been executed by mainframe computers and microcomputers have many advantages over mainframe computers.

Microcomputers are used for a variety of applications: word processing, spreadsheet, numerical methods, data base management, accounting, operating laboratory equipment such as gas chromatographs or atomic absorption analyzers, data acquisition, graphics, data analysis, special purpose programs, communication, and programming for specific applications. Microcomputers are limited in their application by the available memory, the capacity and speed of the storage device (disk, tape), and the speed of the processor. These factors are rapidly changing. For example, in 1983 the average microcomputer had 16-64 K byte memory; currently (1986) microcomputers typically have 128-1024 Kbyte memory – a tenfold increase. In addition, the number of flops have increased from 20,000 to 90,000 and with parallel processing in microcomputers 10 - 100 million flops have been reported (see the March, 1986 Byte Magazine).

Mainframe computers are used extensively for programs that use large data sets, codes requiring high speed calculations, and programs using established special subroutines. In addition, mainframe computers are also used for word processing, data analysis, simulations, graphics, and data base management. However, more and more general and special purpose routines are becoming available for use on microcomputers without significant loss of power and generality.

Microcomputers have significant advantages for education: namely, availability and flexibility. As a result, they are less intimidating. Moreover, the user has personal control over the computer and direct access. Failure of one computer does not leave everyone stranded.

The speed and power of microcomputers should not be underrated. For example, Crittenden *et al*[1] down-loaded a mainframe FORTRAN 77 program that solved two and six simultaneous nonlinear partial differential equations (PDEs) to an IBM PC. These equations describe fixed bed adsorption of single and three solutes. The IBM PC was configured with 640 K of memory and a 8087 coprocessor. Using the method of orthogonal collocation, the PDEs were converted into 64 and 88 simultaneous ordinary differential equations (ODEs) for the single and three adsorbates, respectively. These ODEs were solved with the method of Gear which is in the IMSL package using Professional FORTRAN. The execution times were only 11 and 35 minutes, respectively. These execution times could be further reduced by economizing the codes (e.g., by storing output during execution and eliminating if statements). Also, the run time may be reduced by a factor of 3 with the new 80287 coprocessors. However, larger problems that require more storage run more efficiently on the main frame and super computers.

Green Bay has been modeled[2] as a system of 19 nonlinear differential equations with highly time variable coefficients. A complete algal growing season can be simulated in about 1 minute of computer time, using the Runga Kutta method on a standard IBM PC with a standard coprocessor. The Microsoft BASIC compiler was used to convert the code into machine language.

Scheffe *et al*[3] have developed an Acid Lake Reacidification Model (ALaRM) to predict the temporal profile of a lake's chemistry following neutralization with a calcite material. The model solves a system of 21 nonlinear differential equations using a fourth-order Runge-Kutta method with a time step of 0.5 days. After each time step a Newton-Raphson solution of a proton balance is solved in each of two water-column segments for the new pH. This program, without any attempt to make it more efficient, runs a full year's prediction on a Z-100 with an 8087 math coprocessor in less than 10 minutes.

A Monte Carlo technique has been applied to evaluate different methods of estimating annual tributary phosphorus loads from a limited data set[4]. The FORTRAN program semi-randomly (with considerable logic testing on the selection) selects 12 flow and concentration values from a data set of 365 pairs and performs 9 different load calculation algorithms. Using the Z-100 with an 8087 coprocessor, the program will repeat this process 1,000 times (used for bias determination of each load estimation method) in about 1.5 hours. Neither of these programs has been written to optimize run time.

Computer Programming Assignments

The objective of programming assignments in courses is to increase the computer literacy of the students and their ability to solve problems logically. The programming assignments should help the student appreciate the engineering principles and stimulate the student's interest in the environmental problem under consideration without dominating the exercise. Programming skills should be taught in the computer science classroom, and applications in the engineering classroom.

Since programming can be a very time-consuming endeavor, assignments should be designed with care. Many graduate students are average to poor programmers, and because they are often unfamiliar with the hardware and new operating systems, too much unproductive time may be spent on a program. One can also expect that as students become more computer literate, and as computer assignments are given more routinely, their increased programming skills will reduce the time required for programming.

The question is, therefore, what level of experience should the student have. The possible student exercises could include writing both short and long programs or modifying existing programs to suit a special need.

Writing short programs requires less time and skill. The student need not develop a well-planned and comprehensive program, but rather a functional program able to solve the given problem. Examples of short programs can include analyzing a set of aeration data to determine the mass transfer coefficient, writing a program to solve a simple differential equation numerically, or simulating a Streeter Phelps dissolved oxygen sag curve. (These problems can be solved using spreadsheets as well.) The input and output of the program are simple and the students spend most of their time developing the algorithm. The danger of this approach is that it may foster bad programming habits and poor program design. For example, students may not learn how to solve the problem in a compartmental or modular way.

In a modular design, the problem is broken up into smaller pieces which often later become subroutines. The programmer can check each routine for errors and then combine them. Once they are combined they can be checked for logical linking errors. Many students try to write the complete program all at once; this must be discouraged.

Writing long programs requires the most programming skills and is the most time consuming. Examples would include solving a mass balance problem for a wastewater treatment plant, or analyzing a pipe network. These problems are suitable for semester or multiple quarter courses where sufficient time is available to write and run the program. Students should be exposed to this at least once either in their research or coursework in order for them to understand modular construction so they can communicate with software developers.

Modifying existing programs for a special application may require the least time from the student, but probably the most time from the instructor. The student must have sufficient knowledge to read the program and understand its logic. An example of this approach is to provide the input and output routines while requiring the student to write the calculation algorithm. This approach can be used for short and long programs. One problem is that each programmer has his/her own style of writing and it might be more time consuming to understand the code logic than simply writing a separate one. However, most programs usually contain only a few lines that represent the solution algorithm of the problem; if the student is expected to develop this program component, he/she will be spending most of the time on solving the problem.

Another alternative is to increase the use of the spreadsheet for some computer assignments. This has the advantage of utilizing the power of the microcomputer for problem solving without requiring new programming skills. Spreadsheets are particularly useful for sensitivity analyses and design computations. More and more consulting firms are using spreadsheets extensively. For example, spreadsheet programs have been developed to design air strippers and to simulate oxygen depletion. Therefore, it is important that spreadsheets be integrated aggressively into the undergraduate and graduate curriculum. Spreadsheets can be used in association with practically every environmental engineering course. Easy to use spreadsheets such as FRAMEWORK and ENGINCOMP are available to students from McGraw Hill for less than $25. (See Table A-14.)

One important aspect of the personal computer should be mentioned. If this machine is truly personal, that is, if it belongs to the student, then the possibility arises of using it (and its associated disks) for storage of information that can be used later, either in one's academic career (as, for example, in a later course) or in one's professional career. Information can include not only data, but, perhaps more importantly, programs and templates for solving specific problems. That is, once the student has, as an assignment, set up a spreadsheet to do a critical path analysis, he or she has the template for that spreadsheet on a floppy disk that can be reloaded at a later time. Similarly, the set of equations that the student feeds to a simultaneous equation solver to analyze the carbonate equilibrium system of a water sample can be retained for use in later courses or in professional life. The motivation to do it right, document it, and correct it (when grading uncovers an error) is much stronger than when the work merely goes into a set of notes which will either gather dust or be discarded at the end of the course. Instructors can, in fact, encourage this attitude by pointing out that students can build "tool kits" of software for later professional use, and even by coordinating problems using the same data and the same methods from one course to another.

Numerical Methods

Many problems encountered in environmental engineering practice are complex and require numerical solutions; numerical methods are a common research tool. The use of numerical methods has thus become routine in the environmental engineering profession, and student training and experience with such methods must be included in all undergraduate and graduate programs. This assertion is based on the expectation that computer methods will continue to replace other techniques in engineering practice.

Programs such as NUMERICOMP (EnginComp Software, Inc.) can be used for illustrating Gaussian elimination, linear regression, numerical integration, and other numerical analyses. It is important to recognize that students must have had a course in numerical analysis before they can take advantage of general purpose software that utilizes numerical methods. Without this prerequisite, the ability to understand error messages or data requirements is severely limited. It is professionally irresponsible for engineers to use computer programs without knowing the limitations of the computational techniques involved.

At Clarkson, the students are taught FORTRAN and BASIC programming in a two-course sequence in the freshman year. These courses also introduce the students to word processing, electronic spreadsheets, and computer graphics. In addition, they begin to learn some basic numerical methods and to develop a library of routines for the application of these methods, since their homework problems require writing such routines. Beyond the normal three-semester calculus and semester differential equations series, the students need take only one more math elective. They could take a numerical analysis course for this elective, but most do not elect to do so. Any more advanced numerical methods that the students learn are taught in individual upper level courses as the instructor deems necessary.

Special Purpose Programs

Special purpose software programs are designed to solve unique engineering problems. Examples include estuary, stream, or lake water quality models, modeling the activated sludge process in terms of the influent flowrate and concentration, organic loading or sludge age, illustrating the effect of changing the empty bed contact time, or hydraulic loading on the fixed-bed adsorber life. Such programs are essential where time constraints prevent a student from developing his own program. They allow the student to study the phenomenon without being burdened by programming.

The most obvious application of a simulation model is to perform a sensitivity analysis on the different process variables (organic or hydraulic loadings, different temperatures, kinetic coefficients, etc.). Another application is to develop control strategies based on model performance and simulation runs. The student can perform several simulation runs to evaluate the optimum control strategy for reducing energy or chemical costs. With a reasonable amount of effort, students can use simulation models to improve and evaluate alternative designs.

Computer simulations should be used to improve the student's understanding of engineering principles and not to turn a process into a "black box." Computer programs provide a means to improve understanding by reducing brute force computational efforts and allowing more time and energy for actual problem analysis; they should not replace development of the student's capacity to solve the problem. Accordingly, hand calculations must always be assigned to illustrate the solution technique. (This may mean that assignment would have to be simplified for one case.)

Data Analysis

Computers can be used to eliminate time-consuming number crunching, while facilitating a detailed and complete analysis of the data. Several software packages are available for statistical data analysis. Alternatively, the student may use a computer model for parameter evaluation or model verification by comparing predictions to experimental data. These approaches can be illustrated in laboratory classes where students collect experimental data and then analyze it using existing computer programs. Again, students should include a sample calculation to show their understanding of the governing engineering principles involved. However, one danger in using statistics to evaluate model parameters, which has not received adequate attention, is nonlinear regression and the examination of model appropriateness. These are common problems that students will face during their research; coursework that emphasizes these points should be taken.

However, this can be illustrated in data-intensive courses for which the underlying principles are known. For example, at Clarkson, in the sophomore year, the CEEs are required to take a "surveying" course, which has evolved into not so much a surveying course as a data analysis course. Hydrology is another course in which statistical analyses are appropriate.

Computers in the Laboratory

Computerized control, data acquisition, and data analysis can increase the productivity and accuracy of laboratory experiments. Microcomputers are well suited for use in the laboratory. Setting up a microcomputer to access data from an instrument can be time consuming, but the end result is worthwhile. Data acquisition can be a very important research tool, although its application in teaching is limited to laboratory classes as a demonstration of existing procedures. Students should not be expected to develop software for this purpose. Trained professionals typically develop such software.

Computer control of experimental protocol in the laboratory can introduce its use in larger-scale applications.

Visual Aids

Computers are very effective as visual aids for demonstrations. Not only is the computer a dynamic tool, but material demonstrated by computer is typically available for subsequent repeat demonstration and study.

Computers can be used directly for in-class teaching demonstrations if all students in the classroom have access to a terminal. The computers can also be used in a manner similar to an overhead or slide projector while offering many additional features and greater flexibility. The demonstration is not only dynamic and visually appealing, but students can also practice the exercise outside classroom hours. Students may execute identical programs simultaneously as the instructor provides instructions on its use and application. This approach has been used successfully at a number of schools.

A single microcomputer may be used for classroom demonstration if the computer is equipped with a video projector. Two examples are the high-resolution color monitor and a video projector. Video projectors will project a clear image ranging from 50" x 50" to 10' x 10' on a screen. They have been used for classroom instruction, university seminars, presentation of papers at professional meetings, and research workshops. When working with small groups of students or clients/sponsors, a color monitor can be used directly.

Instructors can use computers to prepare and update handouts, overheads, and slides for classes and presentations.

Computer Communications

The advent of microcomputers and associated communications hardware has tremendously increased the use of electronic communication and networking in all technical and information fields, including environmental engineering. The professional environmental engineer who does not have access to a microcomputer equipped with a modem for communications and access to a network (such as BITNET or TYMENET) is at a great disadvantage. Communications and networking can be used for such benefits as rapid data transfer between consultant and client or between investigators on a multi-institutional project; electronic mail or bulletin systems; access to large water quality or other information data bases (see Table A-9) for research or consulting purposes; access to large host computers or supercomputers through an intelligent terminal that permits interactive use of these systems and output retrieval without leaving one's desk.

In general, communications and network applications should be taught in courses and every undergraduate should be introduced to this tool. Efforts should be made by universities to give students access to a network. At the very least, students should have access to a microcomputer tied to the campus mainframe.

Clarkson University, for example, is developing a total campus network so that any student or faculty member can, via his own personal computer, communicate with any other member of the campus network. Although this network is not totally completed, several capabilities already exist. Students and faculty who have either a hardwire connection or a modem can access any of four campus host computers via a communications/terminal emulation program and thereby use their personal computer as any one of nine terminal modes, including a Tek4010 graphics mode. A campus-wide electronic mail and network bulletin system also operates through one of the host computers, and students and faculty may access BITNET, an international communications network. With these facilities in place, no undergraduate should leave Clarkson without some experience in computer communications.

Software Development for Education

Few resources are currently available to sponsor software development for educational purposes. This responsibility is left to the individual instructor. The software manual prepared by the Association of Environmental Engineering Professors (AEEP) (1986) is a valuable resource to all environmental engineering professors.

Publishers and professional societies can help universities share experiences by encouraging articles for publication in their journals. It is anticipated that book publishers will increase the number of texts that reference and discuss computer programs. Recently introduced journals include *Microsoftware for Engineers*, Lighthouse Publications (Mission Viejo, CA), *Software Abstracts for Engineers*, CITIS (New York - provides international engineering data bases). A new journal entitled *Environmental Software* is planned for the beginning of 1986.

Software Analysis

The number of commercially available computer programs is expected to increase greatly over the next several years. Engineers must possess the skills to evaluate packaged programs with respect to their speed and accuracy. It is professionally irresponsible for an engineer to use a special purpose software program without verifying its accuracy and limitations. In addition, students need to be taught how to check programs that they have developed. Educators must prepare students to evaluate and compare software, test its accuracy, and determine the limitations of its application.

Problems and Pitfalls in Using Computers in Education

- Merely running computer programs to solve engineering problems cannot replace the need for each student to develop a fundamental understanding of the key engineering principles and techniques involved.
- An environmental engineering class should not be designed as a computer science class. Computer problems can be very time consuming; without care in preparation, an environmental engineering assignment can become a computer programming exercise.
- Students learn different programming languages and operating systems as undergraduates. This problem is not very serious, since a new system is easily learned once one operating system has been mastered.
- Incompatibility of different microcomputers at schools and at home may at first be perceived as an obstacle in assigning problems or relying on data contained on a diskette. This problem actually represents an excellent opportunity to learn the much needed skill of transferring files and data among systems.

COMPUTERS IN RESEARCH: A NEW GENERATION OF USES

Computers as Research Tools

Computers are used extensively in environmental engineering research for modeling. Many environmental engineering problems can be analyzed by mathematical models. These models have been used to design and evaluate experiments. By performing sensitivity analyses, the most important phenomena or process variables can be identified. Once the model has been shown to predict natural and/or engineered system behavior, it can be used to predict behavior for conditions other than those for which the model was verified. The proper use of models can reduce the time and resources devoted to experimentation and data collection. Furthermore, the increased use of computer models should signal decreasing reliance on empirical rule-of-thumb methods and more use of scientific methods.

Computers can be a useful tool in the laboratory to facilitate data acquisition, statistical analysis of data, computerized bibliographic searches, and manipulation of the data output. These applications have been implemented to some degree by many researchers. Much more can be done to automate experimental methods and data reduction. Researchers must be encouraged to share their experiences through publication in professional journals. One example of this is the Annual Conference on Microcomputers in Civil Engineering sponsored by the University of Central Florida and the Florida Section of the American Society of Civil Engineers (ASCE).

Emerging Computer Technologies

New computer technologies are emerging that will have major impacts on environmental engineering. It is neither expected nor desirable that all environmental engineering programs become involved with all of these areas. However, it is important that the environmental engineering profession be involved in the development of these technologies.

The most exciting computer technology on the horizon is that of artificial intelligence. This area includes expert systems, pre- and post-processing of data, and interfaces between data acquisition and control algorithms. Each of these holds great interest for environmental engineering. Expert systems could be used to site hazardous waste disposal facilities or plan remedial actions at abandoned sites. Pre-processing of data could be used to optimize sampling grids for water quality monitoring or to help choose optimal spacing of grid points in simulation models. Automatic control of treatment facilities could be improved by intelligent interfaces between data acquisition systems and control algorithms.

Some expert systems seem well-adapted to use rules based on engineering judgement rather than first principles. As a result, some environmental engineering disciplines should take a lead in developing expert systems based on rules rather than principles. Obviously, super computers will play a significant role in solving complex problems that include more realistic mechanisms. Accordingly, we must continue to examine the utility of super computers. For example, they have been used to solve complex fluid mechanics and fixed-bed adsorption problems.

DISCUSSION

This section identifies four broad areas for discussion and consideration, to guide our thoughts toward some logical and realistic conclusions during the conference.

Issues Related to Undergraduate Students

The importance of integrating computing throughout the entire engineering curricula must be stressed. We cannot convince students of the importance of computing skills to engineering practice if computers are not used widely during their engineering education. Apart from teaching the theory and fundamental methods, students should be exposed to packaged programs as well as the experience of writing their own programs.

Students must recognize that the programs they write in their course work will probably take longer to perform than hand calculations, but this activity has longer-term goals. That is, once they are proficient, in circumstances where numerous and complex calculations are required, good computing skills will save time.

Learning (1) to program, (2) to use application programs, (3) to apply numerical methods, and (4) to communicate with software developers are all important topics in undergraduate engineering education. Between 3 and 6 semester hours should be devoted to these topics, and be distributed roughly as follows: 25 percent for programming, 25 percent for application program, and 50 percent for numerical methods. Accordingly, we recommend that a numerical methods course be included in all environmental engineering curricula.

The choice of programming language is not as important as teaching good programming habits. Students should be taught how to write structured programs with a high degree of documentation and modularity. Modularity refers to building small programming elements and assembling them into a larger program. The advantage of this method is that each element is easier to check for logical accuracy. Although the choice of programming language is not critical, BASIC has some advantages for educational use that should be considered. It is the language that most freshman will have used in high school. (The use of BASIC in high school curricula will probably change because the SAT and Advanced Placement exams use PASCAL.) Hence, BASIC is the language that can be used to bring them most rapidly to the point where they can easily use it to solve engineering problems.

BASIC also is closely related to FORTRAN, so it would be relatively easy for a student who knows BASIC to learn FORTRAN and have access to the wide variety of existing engineering programs written in FORTRAN. The major disadvantages of BASIC (as found on most microcomputers) are the lack of structured and global variables, thus encouraging sloppy logic and code, and the variety of dialects. Another limitation of BASIC is that most versions cannot accommodate programs that require more than 64K to store the program listing, or that require more than 64K to store the program variables.

All undergraduate students should be required to develop skills in the use of a word processor and spreadsheet during their first year. The ability to use computer graphics and data base management programs is desirable, but not necessarily essential. A good way to accomplish these goals is to teach students how to use integrated packages.

The major hardware issues at the undergraduate level relate to the decision to use personal computers or larger computers, and the degree of access to computers available to all students (see *The Clarkson Experience*, described earlier, for a workable solution.) It is easier to teach computing skills with microcomputers than with networks of larger computers and terminals. Microcomputers provide an environment for learning that gives rapid feedback to the student and does so in a way that is less intimidating than larger systems. Since most computer work done by undergraduate students is limited by input and output functions rather than computation, the advantage in computational speed held by larger computers is not important. Another major advantage of microcomputers is that they give a student experience with all facets of computing – input, output, programming, data storage, and operating systems. It is too easy for students using larger computers to take a "black box" approach to some of these functions and avoid learning how the computer functions.

Issues Related to Graduate Students

Computing is a basic skill that should be expected of all engineering graduate students. All students should be expected to be skilled in the use of a high-level programming language (BASIC or FORTRAN), word processing, and spreadsheet programs. Students should also be familiar with numerical methods to solve these problems: simple matrix inversion, nonlinear simultaneous equations, ordinary differential equations, interpolation, and roots of nonlinear equations. Students without those basic skills should be required to develop them.

All graduate students in environmental engineering programs should be required to apply basic computing skills regularly in their graduate education. For example, students could be required to use a spreadsheet or data base management program to store and manipulate laboratory data or they could be assigned a term project in which they are required to write a program that describes the fate of a substance in a natural system or engineered process. In this assignment, they could be required to use a numerical integrator or nonlinear equation solver. Those computing skills that are important to the efficient practice of engineering must be reinforced.

A variety of computing experiences should be available to all students, even though most will not use them all. Some examples are simulations (water quality and process), environmental application programs (e.g., CAPDET, SWMM), environmental data bases (e.g., STORET), computer-aided design (e.g., ASPEN), computer-aided data acquisition, and computer control.

Software Development and Evaluation

Many public domain and commercial software programs are available for use in the environmental engineering profession. Consequently, it is important for students to be able to evaluate computer output for errors and examine computer code for logical errors.

Educators must supplement and modify the programs for environmental engineering education. Many programs are available through books, book companies, and the AEEP Software Manual, which professors can incorporate in their courses. Federal and state agencies as well as universities should be encouraged to support research and other projects that will contribute to educational programs, including those that establish methods and criteria for software evaluation. Universities should support professors by sponsoring teaching and research assistants to advance the incorporation of microcomputers in environmental engineering education.

One technique that has been useful for the development of software for both teaching and professional practice is the preparation of software for professional practice. Universities have supported this activity from the sale of such software.

"Teaching Old Dogs New Tricks"

How do we encourage faculty who didn't grow up with microcomputers to use them in teaching? Academics should by the nature of their profession, be able to learn microcomputing skills very easily. Even though the computer age can be overwhelming, one can easily bring microcomputers into play in some capacity. For example, at the very least, homework assignments can be designed that would encourage students to use microcomputers to explore the question more fully for more credit.

To resolve this, each faculty member must have a microcomputer. If a faculty member has little or no skill, the computer should have a user-friendly operating system such as a mouse in the MacIntosh computer. The faculty member must feel confident that he/she will be productive immediately. This will encourage faculty to learn and grow into higher levels of computing. In addition, it is important for faculty to have easy access to professional help both for software and hardware problems. Faculty development workshops are an excellent way to encourage the acquisition of computing skills.

CONCLUSIONS AND RESOLUTIONS

It is important to integrate computers in all aspects of the environmental engineering curricula. Computers have been used for many years in environmental engineering education without making them an integral part of the educational experience. The availability of microcomputers is now opening new opportunities to environmental engineering education to make computers truly personal. The following conclusions and resolutions are proposed:

1. It is recommended that students entering graduate environmental engineering programs be able to do the following:
   a. Prepare simple programs in a high-level language.
   b. Use word processor and spreadsheet programs.
   c. Understand the limitations, strengths and weaknesses of major numerical methods.

2. Graduate curricula in environmental engineering should emphasize basic understanding of processes and mechanisms and the mathematical expression of these principles through models. Graduating M. S. students should be able to implement these models on a computer. In addition, the students must recognize the limitations of the model computations. To spend more time on the formulation and interpretation of the problem, students should also be exposed to commercially available programs that reduce the computational and solution effort.

3. Easy access to computers is important. Accordingly, students should be encouraged to buy their own computer and Universities should establish programs to facilitate their acquisition. To facilitate the implementation of computing into coursework, universities should provide personal computers to all engineering faculty.

4. AEEP should establish a standing committee on Computer Software. The charge of the committee would be to encourage development and distribution of computer applications in environmental engineering. Specific objectives of the committee would be to continue to update the computer software manual, to actively solicit the support of professional organizations through seminars and workshops, and to encourage state and federal agencies to fund the development of computer software.

5. University administrators should provide support for the development and integration of computers into the curriculum, namely, teaching assistantships, release time, summer support, hardware, and purchase of commercial software. Developing software for classroom instruction should be recognized as a creative and demanding activity, for which credit should be given in career evaluation.

6. To avoid legal and ethical problems that may arise with the educational use of proprietary software, faculty should make sure students are aware of copy restrictions and the consequences of violating them. Classroom assignments should incorporate available freeware and shareware, where feasible; otherwise, universities should seek site licensing agreements that allow students to acquire proprietary software at an affordable cost.

7. To provide a variety of educational opportunities, graduate curricula in environmental engineering programs should include exercises in advanced computing applications such as simulation, process control, data acquisition, and data base use.

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Appendix A

CURRENT SITUATION

INTRODUCTION

This Appendix summarizes the current status of computer resources in the United States. This is not a complete review of all the hardware and software issues, but merely a summary as it pertains to educational issues. The interested reader should consult books published on this topic. Computer technology is rapidly changing and when the ink dries on this paper, the information on it may be outdated! However, this summary will provide some useful background information.

Hardware and software issues will be discussed. Hardware refers to the equipment needed for computing while software refer to the programs that drive special applications.

Software can be divided into two major categories:

1. General purpose software provides a utility to the user. The specific use of the utility is determined by the user. This category includes word processing programs, spreadsheet programs, mathematical packages, numerical methods, graphics, data base programs, and compilers for programming languages such as FORTRAN, Pascal, or BASIC.
2. Special purpose or "black box" software is designed for a specific purpose, such as an activated sludge simulation or a pipe network analysis program.

Table A-1.–Current Microcomputer Models

MANUFACTURER	MODEL	BASIC MEMORY (Kb)	EXPANDED MEMORY (kb)
IBM	PC	256	640
-	XT	256	640
-	AT	512	3072 (*)
Apple	McIntosh	128	512 (*)
-	Lisa	128	512
Tandy/Radio Shack	Tandy 1000	128	640
-	Tandy 1200	256	640
-	Tandy 2000	128	768
Commodore	128	128	512
American Research Corp.	ARC	640	
AT&T	PC 6300	640	
Compaq	Deskpro	128	640
-	Compaq 286	x	30,000
Epson	OX-16	256	512
Kaypro Corp	Kaypro 286i	512	640
Leading Edge	Model D	256	
Televideo Systems	pm/16	256	
-	Tele-pc plus	256	640
Zenith Data Systems	Z-100	128	768
-	Z-150pc	320	640
-	Z-241-81	512	3072

(*) 10 Mbyte now being developed

OPERATING SYSTEMS

An operating system is a program that allows the user to communicate with the computer – direct input and output, manipulate storage devices, and so forth. Several different operating systems are currently in common use. Table A-2 lists some of the most common operating systems used on microcomputers and Table A-3 those associated with mainframe computers.

Table A-2.–Operating Systems for Microcomputers

NAME	DISTRIBUTOR/ MANUFACTURER
Apple DOS	Apple
MS - DOS	Microsoft Corp.
Xenix	Microsoft Corp.
PC DOS	IBM
VM/PC	IBM
UNIX	AT&T
CP/M	Digital Research
CCP/M	Digital Research

Note: PC Buyers Guide, Fall 1985, lists more than 60 operating systems.

Operating systems, in general, restrict portability, i.e., a computer running under Apple DOS will not be able to read disks created under IBM PC DOS. Software exists, however, to allow communications between microcomputers operating on different systems.

EXPECTED NEED IN INDUSTRY

The use of computers in the environmental engineering industry is expected to increase rapidly. The M.S. graduate will be expected to be familiar with computers. Typical uses may include:

- Word processing and report writing
- Spreadsheets
- Numerical methods
- Statistical data analysis
- Design drafting - graphics
- Operation and control of processes in the field
- Operation and control of equipment in laboratory
- Technical calculations
- Use of computer simulations to demonstrate processes to clients, in court, or at meetings.

THE NEED FOR COMPUTER PROGRAMMING

There is little doubt that all environmental engineers should have some programming skills. The question is how much programming expertise is required. Should the student be trained to write long programs to solve complex problems, write short programs to increase his/her programming skills, or only modify existing programs for special purposes?

Undergraduate engineering curricula commonly require a programming course. Most graduate students are capable of drawing from their early undergraduate programming courses to write elementary, short programs. The student's programming skills can be improved greatly by computer programming assignments.

Another issue is to determine the most suitable programming language. Engineers have traditionally used FORTRAN for its speed and mathematical capabilities. As shown in Table A-4, other programming languages have become popular since microcomputers have become so prevalent.

Table A-3.–Operating Systems for Mainframe Computers

NAME	DISTRIBUTOR	USE
VMS	Digital Equipment Corp.	VAX
UNIX	ATT	VAX
CMS	IBM	IBM 370 Series (308X, 309X, 43XX)
MVS/SP/JES3	IBM	IBM 370 Series (308X, 309X, 43XX)

While a "standard version" exists for most programming languages, few commercial compilers actually follow the standard format. Commercial compilers usually relax the strict rules of the standard language. Programs written according to the standard version will therefore often be compatible with most compilers, while a program written for one specific compiler will not necessarily be compatible with another compiler.

Most microcomputers come with a version of the BASIC programming language. This has increased the popularity of BASIC among microcomputer users. Newer versions, such as BETTER-BASIC or PROFESSIONAL-BASIC, include extensive scientific and engineering functions. The execution times of compiled BASIC programs are comparable to many FORTRAN programs. BASIC is the easiest language for graphics output. Documentation for BASIC is readily available. Books have been written for many applications, and special books for graphics are available. The major disadvantages of BASIC (as found on most microcomputers) are the lack of structured and global variables, thus encouraging sloppy logic and code, and the variety of dialects for different microcomputers. Another limitation of BASIC is that most versions cannot accommodate programs that require more than 64K to store the program listing or variables.

FORTRAN, an acronym for FORmula TRANslation, still remains the favorite programming language of many engineers and scientists. Since its development in 1954, it has evolved as the most powerful scientific programming language with tremendous resources in terms of established and familiar subroutines and libraries. Mathematical and scientific libraries (Table A-5) are available for almost any commonly encountered problem, such as solving partial differential equations, solving sets of equations, statistical analysis, and many more. These libraries are commonly available for mainframe computers but also can often be purchased for microcomputers. Library routines are fairly straightforward to use, but the user must have detailed knowledge of the routine. If a consultant or experienced user is not available to answer questions, a new user needs to be a fairly skillful programmer or be prepared to spend some time learning the routine.

Table A-4.—Commonly Used Programming Languages for Engineers Use

NAME	COMMENT
FORTRAN	Most commonly used language for scientists and engineers. Available on most mainframe computers. Many resources. (Compiler)
Pascal	A favorite language of application programmers. Pascal has fewer available scientific mathematical subroutines and libraries. Especially suited for manipulating strings and for writing user friendly programs, and for writing structured programs. (Interpreter and Compiler)
BASIC	Available on most microcomputers, easy to learn, and powerful for graphics and running operating system commands. Compilers for scientific and engineering purposes are available. (Interpreter and Compiler)
FORTH	A new language, designed for control applications such as robotics. Not extensively used for calculations.
C	Designed for use with the UNIX operating system. Use for general applications, such as data base or system commands. Limited use in calculations. (Compiler)
APL	A programming language. Very user friendly and designed for individuals with little or no programming and numerical methods background. (Interpreter)

The current standard FORTRAN is known as FORTRAN 77. As shown in Table A-6, many different FORTRAN compilers are commercially available for both mainframe and microcomputers. Few versions require strict FORTRAN 77 code. Special programs are available for microcomputer graphics. FORTRAN demands strict conformation to the programming rules. FORTRAN can manipulate character strings to some degree. Many books on FORTRAN are available, with the only complication selecting the most appropriate book for your needs! Books on special applications, such as graphic routines, are more rare.

Table A-5.–Libraries Available for FORTRAN

NAME	APPLICATIONS
IMSL(*)	Analysis of Experimental Design Data
-	Basic Statistics
-	Categorized Data Analysis
-	Differential Equations, Quadrature, Differentiation
-	Eigenanalysis
-	Forecasting
-	Generation and Testing of Random Numbers
-	Goodness of Fit
-	Interpolation
-	Linear Algebraic Equations
-	Mathematical and Statistical Special Functions
-	Nonparametric Statistics
-	Observation Structure
-	Regression Analysis
-	Sampling
-	Utility Functions
-	Vector and Matrix Arithmetic
-	Zeros and Extrema
SSP–Scientific Subroutine Package	Numerical differentation Interpolation, approximation, and smoothing of tabulated functions Roots and extrema of functions
-	Systems of ordinary differential equations
-	Data screening and analysis
-	Elementary statistics
-	Correlation and regression analysis
-	Analysis of variance
-	Discriminant analysis
-	Principal components analysis
-	Nonparametric statistics

(*) Also available for microcomputers.

Pascal, named after the 17th century mathematician Blaise Pascal, was developed in 1970 by Dr. Niklaus Wirth in Switzerland. It is a favorite programming language of microcomputer application programmers and software developers. The biggest advantage of Pascal is its structured format, which encourages logic. Its power to manipulate character strings and its flexible and forgiving programming format make it very easy to write user-friendly programs. (Although BASIC is more forgiving.) UCSD (University of California, San Diego) Pascal is the most popular version of Pascal, while Turbo Pascal (Borland International) is a very popular and inexpensive Pascal compiler for microcomputers. Turbo Pascal executes extremely fast and includes graphic routines for the IBM PC, but generates quite large source code programs. Major advantages of Pascal are recursion, good graphics, and its excellent portability. Many books are available on scientific Pascal applications.

The C programming language was developed by Dennis Ritchie of Bell Laboratories to be used under the UNIX operating system. Today it is used widely. C is relatively simple, and provides limited functions for input and output. It is also limited in its ability to manipulate data.

Other programming languages, such as APL, ALGOL, COBOL, FORTH, LISP, and PL/1 are also available.

GENERAL PURPOSE SOFTWARE

Definition

General purpose software refers to programs that do not require formal programming, but the application of the program is determined by the user. Examples include word processors, spreadsheets, numerical methods, statistical packages, and graphics packages.

Word Processors

Word processing has become a household phenomena. The first application for many new microcomputer users is often word processing. This is an area where the environmental engineering educator can encourage computer usage by demanding typed reports! Many different programs are available, varying in their degree of sophistication, versatility, and price ($50-$600). Some word processors also allow one to edit "non-document" or data files and program listings.

Spreadsheets

A spreadsheet is an electronic sheet filled with "cells" that the user can define for his special purpose. The user can put either strings, numbers, or expressions into a cell. Expressions can refer to other cells to perform calculations. Spreadsheets are easy to design and use. The user designs the sheets the same way he would do the calculation on paper. Repeated multiple recalculations are performed by simply changing the contents of a cell. Spreadsheets are used almost exclusively on microcomputers.

Table A-6.–FORTRAN Compilers Available

NAME	COMPANY	COMMENTS
MS-FORTRAN	Microsoft Corporation	Microcomputers
DR-77	Digital Research, Inc.	Microcomputers
WATFOR-77	WATCOM Products Inc.	Microcomputers
Professional FORTRAN	IBM	Microcomputers
Interactive FORTRAN	IBM	Microcomputers
F77L	Lahey Computer Systems, Inc.	Microcomputer
FORTRAN 86/88 – RTX 862	Real-Time Computer Science Corp.	Microcomputer
FORTRAN-77	Softech Microsystems	Microcomputer
SSS FORTRAN	Supersoft, Inc.	Microcomputer
Watcom FORTRAN	Watcom Products	Microcomputer
WATFIV	University of Waterloo	Mainframe
VS-FORTRAN, FORTRAN G1, FORTRAN XX	IBM	Mainframe (VM/CMS,MUS)

Some of the most popular spreadsheets commercially available are listed in Table A-7. The major differences between the programs are in their calculation mode, the freedom of formatting strings, the ability to manipulate strings, the number of functions included, the ability to execute sequences of commands called macros, and the ability to do graphics. Most spreadsheets will perform all the basic mathematical functions found on a calculator. Some have statistical functions such as linear regression. Logical functions such as IF, AND and OR are often available.

The major attraction of spreadsheets is their ability to perform multiple recalculations of a problem and to replicate cells for repeated calculations to tabulate results. Calculations are commonly performed by row or by column. The more sophisticated programs can also perform natural recalculation (i.e., evaluate the most fundamental cell first) or even iterative calculations. Graphic displays are available in sophisticated programs. Few programs have all the advanced features. Most have one or two of the complex features such as graphics, natural or iterative recalculation, free format string input, and string comparisons.

Many environmental engineering problems can easily be solved on a spreadsheet. Spreadsheets have been used for pilot plant data reduction, experimental data reduction, and other repetitive calculations. These programs are rapidly gaining popularity and industry will soon expect the graduate to be familiar with spreadsheet calculations.

Data Base Programs

Data base management programs allow the user to enter data in an organized fashion for easy retrieval at a later date. Data base management programs can be useful in research applications where data needs to be stored and recalled. Several data base management programs are commercially available (Table A-8). These programs can be used to construct a data base of information to organize data or information such as experimental results or references. Creating a data base forces the user to examine a problem thoroughly, including information such as experimental results or references, then organize his thoughts logically.

Table A-7.–Spreadsheets

NAME	VENDOR
CalcStar	Micropro International Corporation
Contest MBA	Context Management Systems
Lotus 1-2-3	Lotus Development Corporation
MultiPlan	Microsoft Corporation
Perfect Calc	Perfect Software, Inc.
ProCalc	Software Products International
SuperCalc	Sorcin Corporation

Publicly accessible data bases containing information on various topics (Table A-9) are available and can be used for instruction and research. Most of these data bases contain references and special data sets, such as water quality data on the Great Lakes. The challenge to the environmental engineering educator is to use these services in education. Instructors may extract specific entries from the data sets and make these available to their students for assignments, or require students to obtain the information.

Table A-8.—Commercially Available Data Base Managment Programs

NAME	VENDOR
DBASE III-plus	Ashton Tate
RBASE	Micro Rim
NOTEBOOK	Pro Tem Software
PARADOX	Ansa Software
Informix	
Oracle	

Statistical Packages

Statistical packages allow the user to manipulate data sets and perform statistical calculations on the data. Programs can compute correlations, regressions, distributions, standard deviation, and curve fitting. These programs are available for mainframe and microcomputers (Table A-10). Statistical packages have their main application in research, analyzing large data sets and establishing correlations between data or determining the significance of the results. It is therefore important that students learn to use statistical programs.

Table A-9.—Available Data Bases

Name Comments	Supplier	
AERDS	U.S. Environmental Protection Agency, Research Triangle Park, NC	The main components of this data and air pollution source and emission data. Search fee.
AFEE	Association Francaise pour l'Etude des Eaux, Paris, France	Bibliographic database. French language.
APTIC	U.S. Environmental Protection Agency, Research Triangle Park, NC	Citations of the sources, prevention, and control of air pollution. Covers the years 1966-1978.
AQUALINE	Water Research Center, Buckinghamshire, England	Worldwide literature on all aspects of water research.
AQUIRE	U.S. Environmental Protection Agency, Washington, D.C.	Contains information on acute and chronic toxicity, bioaccumulation etc. Data include chemical substances and organisms.
ASFA	Cambridge Scientific Abstracts, Bethesda, MD	Literature on all aspects of the aquatic environment, including oceans and seas, fresh water, estuaries, and marshes.
CENV	Environment Canada, Ontario, Canada	Environmental literature from and about Canada. Subject areas include water quality, pollution and water research.
DMS	Hydrocomp, Mountain View, CA	
Environmental Bibliography	Environmental Studies Group, Santa Barbara, CA	Contains citations to U.S. literature in the fields of pollution, solid waste management, health hazards.
HYDROLINE	Federal institute for Geosciences and Natural Resources, Hanover, Federal Republic of Germany	Hydrology, hydrochemistry, and "hydroeconomy". International scientific literature.
IRIS	U.S. Environmental Protection Agency, Columbus, Ohio	This file contains citations and abstracts identifying educational and instructional material in the areas of water quality and water resources.
NAWDEX	National Water Data Exchange, Reston, VA	Provides information on the identification, location and acquisition of water data. Source of hydrological information. Only to NAWDEX members.

Table A-9.—Available Data Bases (continued)

NAME	SUPPLIER	COMMENTS
OHM-TADS	U.S. Environmental Protection Agency, Washington, D.C.	A collection of published data describing materials designated as hazardous. Part of NIH/EPA Chemical Information System.
Pollution Abstracts	Cambridge Scientific, Bethesda, MD	Abstracts and citations to technical and nontechnical publications.
POLUMAT	Centre de Documentation Recherche Experimentations Accidentelles des Eaux Brest Cedex, France	Items of water pollution control equipment and related products
Selected Water Resources Abstracts	U.S. Department of the Interior, Reston, VA	Publications on water-related subjects. Citations and abstracts.
Solid Waste Management	Environment Canada, Quebec, Canada	Describes Canadian research projects in the handling and disposal of solid wastes.
UPGRADE	Sigma Data Services Corp., Rockville, MD	Five separate databases – contain an enormous mass of raw material for studies in environmental science. Subfiles are: IDB (Integrated Database). NASQAN (National Stream Quality Account Network). NEDS (National Emissions Data System). SAROAD (Storage and Retrieval of Aerometric Data). STORET (Storage and Retrieval for Water Quality Data).
WATERLIT	South African Water Information Center, Pretoria, South Africa	Biochemistry, engineering, aquatic life, food and public health. Citations to worldwide literature on the science, technology, engineering, management, and socioeconomics of water.
WATERNET	American Water Works Assn., Denver, CO	A bibliographic database that covers the total water industry – water resources, water treatment, water quality distribution, wastewater, industrial process water and reuse.

Integrated Application Software

Recently, several software programs have been introduced that combine spreadspheets, graphics, statistics, communication, data base management, and word processing into a single comprehensive package. These multipurpose programs are extremely flexible and ideally suited for complete project management and report generation. Table A-11 lists some of these programs

SPECIAL PURPOSE SOFTWARE

Special application software is designed to perform a predefined set of calculations to produce the desired end result. These programs are specific in their application and use.

Table A-10.—Statistical Packages

NAME	SUPPLIER	FUNCTIONS
BMDPC		
BMD		
RS/1	BBN Software Productions Corporation	Statistics—Microcomputer Graphics Curve fitting Spreadsheet Macros
SAS	SAS Institute, Box 8000, Cary, NC 27511	Statistics Graphics Regression
MIDAS		
SPSS		
STATGRAPHICS (Plus* Ware)	STSC, Inc.	Statistics Graphics Spreadsheets Numerical methods

Commercially available special purpose software is more expensive than general purpose software because of its limited market. These programs have a significant potential for application in education, but may be too expensive for universities. Table A-12 lists some companies with their products.

Table A-11.– Integrated Applications Software

NAME	SUPPLIER	FUNCTIONS
Engincomp	McGraw-Hill/	Statistics
-	Engincomp	Graphics
-	Software	Spreadsheet
Framework	Ashton-Tate	Word processing
-	-	Spreadsheet
-	-	Graphics
-	-	Database management
Jazz	Lotus	Worksheet
-	Corporation	Graphics
-	-	Word processing
-	-	Database
-	-	Communications
Open Access	Software	Spreadsheet
-	Products	Relational
-	International	database
-	-	Word processing
-	-	Graphics
-	-	Communications
-	-	Time management
Symphony	Lotus	Worksheet
-	Corporation	Graphics
-	-	Word processing
-	-	Database
-	-	Communications
Excel	Microsoft	Worksheet
-	-	Graphics
-	-	Database

The scope of the programs published by the Association of Environmental Engineering Professors in the computer manual is listed in Table A-13. These programs were contributed by volunteers and the manual is intended to serve as a desk reference for the profession.

LICENSING

Licensing of software is a major stumbling block for universities. Software developers need copyright protection to prevent illegal copying of their product and to protect their investment. The large number of users at a university make the software developer extremely vulnerable to illegal copying.

Table A-12.–Commercial Companies

Company	Programs
Sys Comp., CA	Pipe network
–	Open channel flow
–	Flood
Civil-Ware, CO	Open channel flow
Hydrasoft, UT	Open channel flow
–	Hydrographs
–	Flood analysis
Systec, Inc., MS	Pipe network
–	Pressure sewer
ES - Engineering Services, FL	Open channel flow
	Flood routing model
–	Storm sewer analysis
–	Hydrograph
Micromate, CA	Pipe network
Applied Software Technology, Inc., GA	Open channel flow
	Flood hydrograph
	Backwater profile
–	Pipe network
Environmental Control Systems, PA	Activated sludge settling
David Evans & Associates, OR	Pipe network
Civilsoft, CA	Pipe network
–	Sewer hydraulics
–	Open channel flow
–	Backwater profile
–	Hydrograph
–	Flood analysis
Envirosystems, Co., NJ	Activated sludge
Hilbern Engineering Software, FL	Hydrograph
	Flood analysis
–	Storm water
–	Pumping stations
–	Sewer design
Hydromantis, Ontario, Canada	CAPPET-PC, others

Universities face special problems in licensing software, since a single copy of a program is impractical. With multiple computers accessible to the students, many software developers adopted the policy that the software must be licensed for each potential user. This raises the price of the product out of reach for most universities. For example, to obtain a site license for 50 copies of a program at $250 each will cost the university $12,500. One would hope that software developers will use the university to advertise their product and familiarize the future engineers with their product.

Student versions of some computer programs (Table A-14) are available at a greatly reduced price, often below $30. The capacity of the student version program is reduced to allow the software developer to sell the program at the reduced price. For example, the IBM student version of Framework restricted the word processing capacity to 16 pages. Instructors may require students to purchase a program at this price in the same way that students are now required to buy textbooks.

Table A-13.—Programs Included in the Software Manual

TOPIC	NUMBER OF PROGRAMS
Activated Sludge	5
Adsorption in the Gaseous Phase	1
Adsorption - Inorganic	1
Air Pollution	2
Anaerobic Processes	1
Biofilm Reactors	4
BOD Analysis	1
Cyclone Design	1
Chemical Equilibrium	3
Economics	2
Filtration	1
Groundwater	5
Lake Models	2
Lagoon Design	1
Math Applications	2
Multi-Media Fate of Contaminants	1
Pipe Flow Networks	3
Risk Assessment	2
River Models	5
Scrubbing	1
Stripping	2
Water and Wastewater Treatment	2
Programs from EPA, public domain	2

Table A-14.—Student Version Software (under $30)

NAME	SUPPLIER	FUNCTIONS
Framework	McGraw-Hill	Word processing
–	–	Spreadsheet
–	–	Graphics
–	–	Database management
Numericomp	McGraw-Hill	Numerical methods
Engincomp	McGraw-Hill	Statistics
–	–	Graphics
–	–	Spreadsheets
Open Access	Prentice Hall	Word processing
–	–	Spreadsheet
–	–	Graphics
–	–	Database management
–	–	Communication
DBASE II	Prentice Hall	Data Base
Wordstar	Prentice Hall	Word processing

OPEN DISCUSSION

John Crittenden, Michigan Tech: Before I open the floor for discussion, I would like to make some remarks concerning the justification for increasing computing in the curriculum. I think one of the most important reasons for this increased emphasis is that any student who can explain how to solve a problem to the computer must understand it. In the process of having to specify the input, the algorithm, and the output, the student actually learns how to do the problem in much the same way that he would in a process course with an associated wet lab. The same idea applies to computing in that when you write the equations, transform them into an algorithm, and then try to explain that to a computer, there is an additional learning experience that students benefit from. We had some discussion earlier about how much computing science we should have. I think part of the computing science that we do apply is a valuable learning experience and should be emphasized. With those remarks, I would like to open the floor for some discussion.

Ryan DuPont, Utah State University: One major question that I have with regard to the discussion today is where do the older students, the students who are out in the working profession, the continuing education segment, where do they fit into all this? My experience with the profession is that our students are not going to have nearly as much trouble in the development of computer skills as the faculty and as the people that are out actually using and working in the profession, so what do we do with them?

John Crittenden: Anyone care to respond?

Walter Weber Jr., University of Michigan: You raise the question about students who have been out for awhile and faculty. I think most universities are developing fairly effective programs for bringing faculty up to speed on computer applications and computer use. There are a number of schools, Michigan amongst them, who have also developed summer institutes, week-long programs, that are designed specifically for the retraining and updating of students who have either not been exposed to computers before, or who simply want to become upgraded in their use. That is probably the most viable mechanism.

John Crittenden: One more question.

Paul Roberts, Stanford University: One problem arises associated with proprietary software, spreadsheets and the like: How do you deal with the situation where students are put in a position where they are tempted to copy someone else's intellectual property?

Jon Liebman, University of Illinois: That is a fun one and creates incredible numbers of difficulty. I have only one suggestion. I have been putting students into a position where it is very easy to make copies of things that they are not supposed to be making copies of. I do with it just what I used to do with cheating on exams. I start out with a comment about professionalism and ethics. Period. To the best of my knowledge, it works most of the time. That is, you folks are in training to be engineers, engineers are professionals, there are these things called ethics, and let's talk about that a little bit; and among the ethical requirements floating around are that thou shalt not steal someone else's intellectual property. If you start to police it, you are effectively saying, "I expect you folks are going to try to steal this stuff," and they will.

Steven Chapra, Texas A&M University: Commenting on that, I believe that in the future there will be a lot more low cost software available. The reason people steal software is because it costs $600 to buy Lotus, and that makes theft very attractive. But, for example, Framework now is available with $29.99 student versions, and that is an integrated software package that you can use for spread sheets, word processing, for a whole lab report. So I think that problem will eventually work itself out.

Jon Liebman: Let me just add a couple of comments. I do try to make accessible to my students, as much as possible, the things that they are legally permitted to copy. The word processor that I make available to them is a freeware word processor and so forth; in part to remove that temptation, and in part to point out that, yes, if you want something you can find something that will do the job without stealing it, by looking for something that you can get at a reasonably low cost. The other thing from an educational institution point of view is that more and more of even the high cost software is being made available on a site license basis, Gino and Linda, for example. Gino is $600, Linda is $400, or something like that, but for a few thousand you can get a site license that allows you to make as many copies as you want.

Joseph DePinto, Clarkson University: I was just going to add that at Clarkson we have quite a few of those types of university licenses. For example, I think the students can purchase the latest version of Lotus now for $100, so I think it is a problem that is going away. It is not as bad as it was.

Position Paper

INTEGRATED AIR-WATER-LAND APPROACHES IN ENVIRONMENTAL ENGINEERING EDUCATION

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CONTENTS

INTRODUCTION

An integrated approach to environmental engineering is holistic. It is founded on an understanding of the multimedia behavior of substances in the environment, and it seeks to manage the shifting of problems from one medium to another. Integrated air-water-land approaches in education are needed to further advance environmental engineering and to maintain the prominence of environmental engineers in ranking concerns and solving critical problems.

Some organizations are structured to deal with the multimedia nature of environmental problems and others are not. The environmental control group in a large industry is likely to have staff examining problems that involve all media, and a growing number of consulting firms offer multimedia services. In contrast, most university departments and regulatory agencies are organized into compartments that focus on individual environmental media, and many professional organizations are confined to specific areas of environmental science and engineering. Additionally, individual laws and regulations tend to cover only a single medium.

The segregation of environmental media may appear efficient on an organizational chart or in a curricular outline. In practice, however, its utility is questionable for problems beyond those with weak links between media, such as conventional problems in water or air pollution control. Habits remain from our preoccupation with traditional concerns that limit our approaches to the more difficult and important issues of today that have strong connections between environmental media. Such issues include geotechnical aspects of land disposal; the cleanup of contaminated soil or groundwater; the identification, treatment, and disposal of hazardous materials; and acid deposition impacts.

This paper recommends how curricula and teaching styles might be modified to better address the multimedia nature of many environmental problems. Comments are also directed at integrated research. Teaching efforts should be reoriented, at least in part toward an integrated approach. This educational orientation is clearly different from merely expanding the amount of effort spent on one or more of the typical curricular options pertaining to air, water, or solid waste management.

DEFINITION OF AN "INTEGRATED APPROACH"

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 gaseous, liquid, and solid materials so problems are not shifted unduly from one medium to another, and (3) the use of both anticipatory (recycling and source reduction) and reactive (treatment and management) measures. An integrated approach can apply to both natural and engineered systems and can involve both analysis and design.

"Unified" and "multidisciplinary" are two adjectives that have been used to describe educational approaches in environmental engineering. These approaches deserve brief discussion to distinguish them from integrated ones.

A unified approach draws attention to similarities between phenomena that arise in different media. It usually is applied to the unit operation or process. Filtration, for example, is employed in the control of both water and air quality, and the concepts and equations are the same or nearly so.

The multidisciplinary approach is as old as our profession. Early public health and pollution control engineers realized the solution to most problems of significance required basic scientific knowledge obtained from other disciplines (chemistry, microbiology, ecology, meteorology, etc.). Modern engineers gain knowledge from various disciplines of science and a large catalog of new and evolving engineering skills, including many that originate in mechanical and chemical engineering. The number of scientific and engineering disciplines from which modern engineers derive useful knowledge has increased both in variety and complexity. The multidisciplinary strategy among practitioners employs a team approach in which specialists act together to solve a problem. More than ever, a partnership is needed between scientists and engineers from many disciplines.

The terms "unified" and "multidisciplinary" suggest a broadening of the view and practice of environmental engineering. The approaches they describe share similarities with and can be used in conjunction with integrated approaches. Neither term is synonymous with the word "integrated," however.

CURRENT SITUATION WITH ENVIRONMENTAL ENGINEERING EDUCATION

The Teaching Staff

Environmental engineering programs tend to be small. The typical program usually consists of a three- to six-member teaching staff, most of whom specialize in water quality management, regardless of whether they are engineers, chemists, or biologists by training. Most programs would find it difficult to hire additional faculty members so that new or more specialized subjects could be added to their curriculum.

Having a small staff does not preclude excellence, but it can limit the range of courses offered. A conflict may easily develop between maintaining excellence in an existing area and attempting to broaden a program to achieve a better balance between air, water, and solid waste management. Excellence rather than breadth probably should be the goal in such cases, as there is no reason to make all programs or graduates the same. Furthermore, students can be provided with elements of an integrated philosophy irrespective of program breadth.

The Student

Most students entering graduate programs in environmental engineering are civil engineers, but some hold degrees in other engineering fields as well as the natural and applied sciences. Most programs have the flexibility to allow nonengineers to make up deficiencies in engineering subjects and civil engineers to improve their backgrounds in chemistry or other sciences. The diversity in students and flexibility in programs have been important to the vitality of environmental engineering.

The Curriculum

Graduate degree programs in environmental engineering are a mixture of engineering courses and courses in basic science, which may be taught in-house or by other departments. A candidate for a master's degree typically will take about eight courses in total, two or three of which may be outside the chosen area of specialization within environmental engineering.

Environmental engineering education often begins at the undergraduate level with a survey course. Time may be allocated unevenly among the many topics that are introduced, in which case emphasis usually is placed on drinking water treatment and water pollution control. Despite the presentation of topics covering all environmental media, the course does not accomplish integration if, as is too often the case, the topics are not presented in a well connected manner.

At most schools the goal of the survey course is limited to developing a basic vocabulary and to practicing the most fundamental calculations. The course may, but most do not, accomplish satisfactory skill at making a material balance. It generally does not give a working understanding of system kinetics. The course as a rule does not ask the students to formulate alternative solutions, to synthesize treatment systems from process units, or to use information resources. It develops no real design skill and provides only a primitive notion of how scientific and engineering fundamentals are applied to environmental problems. Such matters are left to second-level or graduate courses.

Second-level or graduate courses tend to be organized according to the specialties of air, water, or solid waste management. Whatever their orientation, be it theoretical or design, they tend to stand alone, with little or no reference to similar courses about other media that students may be taking in parallel. They usually do not involve consideration of multimedia effects or system integration. Further, in most programs there is no "capstone" course to integrate the concepts presented in the several specialty courses.

At some schools a possible exception to the orientation toward segregated specialties is the offering of a course in each of the microbiological, chemical, and less commonly, physical principles. A unified approach in these courses reduces the division of problems according to environmental medium. Regardless, such courses aid in remedying deficiencies in students' educational backgrounds.

The Graduate

It is true but simplistic to state that good engineers have always endeavored to identify and solve real problems. Many practicing engineers have not been too narrow in their view of the problems that face us and have not set arbitrary or artificial bounds that restrict their solution to, say, "water pollution" or "air pollution." The most respected and successful practicing engineers can now routinely solve problems that they at one time found difficult, and they solve types of problems not being taught in many universities even today.

Typical educational programs have not failed, even though may be limited in their structure or declared goals. They have produced many "good engineers." The fact that many graduates from traditional programs have successfully adapted to the changing nature of environmental problems can be taken as evidence that much of the current educational system deserves to be maintained. It is, on the other hand, impossible to say how much of the adaptability derives from educational background and how much from the intellectual curiosity and capacity of the individual. Continuing education in the form of workshops and the like may also play an important role.

Whichever factors have been important, some teacher retraining and curriculum revision are necessary to meet the needs of the engineering profession for graduates who are better prepared to work on multimedia problems. Because they have been largely successful in the past, existing programs should be able to restructure their curricula.

BASIC GOAL FOR AN INTEGRATED APPROACH

In terms of basic goals, an educational program with an integrated approach to environmental engineering should:

1. Develop a sound understanding of the material balance, providing knowledge and skills for systems ranging in size from a single unit process to an extensive ecological complex. Until an accounting is made for all significant components, a problem is not sufficiently defined.

2. Provide general problemsolving skills, including how to construct and validate models and evaluate conclusions arising from their solution; how to critically appraise the accuracy of information and the reasonability of assumptions and approximations; and how to assess the need for additional data and design experiments to obtain it.

3. Enhance computational skills, including the ability to apply statistical methods, to analyze dynamic systems, and to find optimal solutions.

4. Provide practice in solving a range of realistic problems, including several that involve important links between the air, water, and land sectors of the environment, taking into consideration the environmental impact and cost effectiveness of solutions.

5. Develop skill in using information resources: the modern technical library, computerized bibliographic bases, and various chemical and toxicological data bases.

6. Develop the ability to communicate the analysis and solution of problems to a range of audiences.

7. Impart a sense of the role of ethics in engineering decisions.

In many respects these goals are fundamental and applicable in general, whether or not one employs an integrated approach. Elements of each goal are probably more essential to the integrated approach, though, particularly the following: (1) the systems studied are more varied in terms of size and complexity; (2) the information base is growing so rapidly in terms of journal articles and tabulated data that manual search techniques may not suffice, and students are not able to search effectively with direction and practice; (3) data required to construct and validate models dealing with intermedia effects are often not available and no historical records of performance exist with which to construct empirical models, making it essential to learn to critically assess assumptions and approximations; (4) most traditional courses concentrate on steady state solutions for process design, but in the multimedia setting system dynamics are often of interest; and (5) students must solve some fairly complex and realistic multimedia problems, including searching for data and making approximations where usable data do not exist.

SPECIFIC AREAS OF STUDY FOR AN INTEGRATED APPROACH

The ideal environmental engineering education should include the following areas, including several subjects that have not been part of most university programs. The latter are shown in boldface type.

1. Environmental transport (initial entry of chemicals into an environmental medium, i.e., mixing and dispersion; mass, momentum, and heat transfer; interfacial mass transfer; mass transfer with reaction; **movement and partitioning between media**)

2. Fate of chemicals in the environment (environmental transport plus biodegradation, **photodegradation, chemical degradation, precipitation, sorption, leaching, volatilization, biological uptake and depuration, metabolic transformation**)

3. Systems approach to environmental engineering (modeling and simulation; methods of management science; **cost estimating and optimization; reliability and fail-safe design; system dynamics**)

4. Waste treatment (physical, chemical, and biological treatment processes; design of unit operations and processes; treatability studies; **system synthesis, integration, and management; pollution prevention**)

5. Waste disposal (discharge or dispersion into the environment; assimilative capacity; **containment; source reduction; recovery and recycling**)

6. Risk assessment (environmental impacts, **exposure estimates and body burden; biomagnification; pharmacokinetics; safety and health; toxicity; biostatistics**)

7. Societal system (laws and regulations; **sociology; journalism; public relations**)

Though the subject matter to be covered is broad, the profession will not be well served by producing only generalists. Beyond the basic goals and within specific areas mentioned, it is important for most students to obtain some degree of specialization, be it in air pollution control or another area. To acquire the substantial specialization required for most environmental engineers, students have to compromise, achieving only modest skills in the relevant supporting areas.

IMPLEMENTATION OF AN INTEGRATED APPROACH

The number and types of topics that can be presented in an educational program depend on curricular structure, the length of the degree program, and the quality and availability of courses in supporting departments outside of environmental engineering. An integrated approach depends, nonetheless, on the attitude of the professors as much as on the structure of the curriculum.

Within the Existing Curriculum

To a considerable extent, an integrated approach can be managed within existing courses and without adding new teaching staff. Nearly any teacher can help students think in an integrated manner by introducing suitable assignments into almost any course. The result would be that most courses would not have "teaching an integrated approach" as their primary purpose.

The survey course provides a natural opportunity to add an integrated approach because all three media are likely to be included already as subject matter. Because the course is at an introductory level, however, the coverage of multimedia problems may be limited mostly to basic concepts.

Any design course on air, water, or solids management provides convenient opportunities to teach integration. A single integrated problem in a course can have a strong influence on students. The teacher should allow enough time for good solutions to be found and should provide constructive evaluation of the solutions. A hastily contrived problem, such as one which is nothing but number crunching, or a problem assigned at the end of a course does not make the correct impression.

Courses on environmental modeling and industrial pollution control are probably the best candidates for emphasis of an integrated approach. As to the former type of course, the fundamentals of model building and system simulation can be easily developed for various situations covering each medium and intermedia transport. It may be necessary to slightly expand the time spent on environmental modeling if the existing course deals only with water systems. Having done this, the integrated approach should come automatically, so long as the teacher holds the belief that intermedia effects are important.

Industrial pollution control problems typically involve consideration of liquid, gaseous, and solid components, and excellent opportunities exist for both cross-media analysis and integrated design of treatment systems. Effluent and emission standards can be related to toxicological information in the environment and in the work place. Exposure estimates, risk assessment, safety, reliability, and fail-safe design can be introduced into the course.

Unit operations and other laboratory courses may be suitable for dealing with multimedia issues, as the underlying principles governing the behavior of substances in the environment are the same as those for behavior within treatment systems. New experiments could be developed to stress a point about environmental behavior. An experiment to investigate liquid-solid partitioning might use soil rather than activated carbon as the solid phase, for example. In conducting traditional experiments related to treatment units, analogies to behavior in the environment could be noted.

Engineers and scientists outside of academia have had to work on problems requiring an integrated perspective. Experiences pertaining to multimedia issues of those in industry, consulting firms, and regulatory agencies could be shared with students in the form of seminars or guest lectures.

Expanding the Course Offering

In spite of an already crowded curriculum, some schools may find it necessary to develop new courses in order to adequately cover certain topics which have gained in importance in recent years. Such topics may be ones noted earlier under specific study areas, or others of a specialized nature. In some cases new courses outside the department, or older ones that environmental engineering students have tended to ignore in the past would fulfill the need for knowledge on a particular subject.

A reason for developing a new course is that some subjects are inherently difficult and cannot be handled lightly if any competence is to be developed. Groundwater modeling is an example. Spending a few hours is helpful in providing an introduction, but a semester-long course is needed to enable a student to solve simple flow problems. Constituent transport problems and systems with complex geology require additional study. An intrinsic difficulty is the calibration and verification of models from limited field data.

Students are prone to have deficiencies in background that hinder their ability to analyze and solve multimedia problems. Civil engineers as an example are deficient in chemistry, both physical and organic, and in the fundamentals of transport phenomena, especially mass transfer and heat transfer. Conversely, chemical engineers are strong in these subjects but weak in open channel flow, hydrology, and geology. Both types of engineers have the mathematical background to master the subjects in which they may be deficient without first taking all the prerequisite courses that might ordinarily be required for undergraduate students. Even so, the mastery of each subject judged to be necessary or desirable could require a rigorous one-semester course.

Organic chemistry has long been considered useful in comprehending biological systems. Today it is probably more important in the context of toxic materials and hazardous waste management and in understanding the toxicological studies that constrain our designs. The traditional mini-course on organic chemistry as part of a course on water chemistry, environmental microbiology, or biological waste treatment may no longer be adequate, however. For one, organic chemistry is difficult to successfully condense into a few lectures. Furthermore, chapters on organic chemistry in existing environmental engineering text books are oriented strongly toward biological processing, whereas organic chemical texts contain much on the laboratory and industrial synthesis of chemicals and little about bioprocesses. Neither type of text addresses the chemicals or the reactions that are of great importance in toxic chemical problems.

Organic chemistry with a slant toward toxic chemicals is a vital subject that somehow should be included in environmental engineering programs, despite the possible difficulties in developing such a course. In developing the appropriate course for the environmental engineering student, chemists and toxicologists may need to be consulted to help define the specific branches of organic chemistry that are essential to engineers working in toxic materials and hazardous wastes.

A course on multimedia problems is highly desirable so students can concentrate on cross-media analyses and learn to think more fully in an integrated mode. Students would need to assess and solve complicated, realistic problems that require creativity. It should be stressed to students that such problems can have more than one "correct" solution. They should, in fact, be taught to find alternate acceptable solutions and to recognize and reject unacceptable solutions. Students should be allowed to work in one or more groups to take advantage of different backgrounds and to experience the team approach employed by practicing engineers. The use of various information resources, including discussions with practitioners, should be encouraged.

Constraints to an Integrated Approach

There are several constraints on implementing changes in teaching style and curricular content. Two important constraints are described in the following paragraphs.

Few Good Teaching Materials Exist. Most existing environmental engineering textbooks do not employ the integrated approach. Moreover, there are no resource collections of problems, laboratory assignments, or course outlines to use. Years have been spent collecting problems and laboratory materials for current courses in unit operations and design as applied to water pollution control. The Association of Environmental Engineering Professors, the National Science Foundation, and the U.S. Environmental Protection Agency have all con-tributed to organizing and sharing this material throughout the teaching profession.

Now, a body of new teaching material must be created for integrated approaches, which require a different teaching emphasis. Realistic, complex problems are needed in particular. Case histories from the experience of industries and consultants should be quite valuable in constructing more realistic problems.

Most Professors Lack Free Time to Change Direction. Professors are fairly skilled at learning new material, but change requires an investment of time. Making time for new activities is not often possible for professors busy with research and teaching.

Opportunities to arrange training away from the regular job are also somewhat limited. Funds for conferences often are tied tightly to research projects, and hence the conferences attended are apt to deal with familiar subjects. Professors need the chance to go to meetings that cover subjects outside of their expertise. This would greatly increase the rate of change in teaching interests. Unfortunately, funds to attend training courses about new subjects are almost impossible to find. Sabbatical leaves are supposed to alleviate problems of this kind, but they may not help dramatically because (a) not enough people will get sabbatical leave in the next two to five years during which a rapid rate of change is desirable, and (b) those who do have a sabbatical usually feel they should use the opportunity to produce publications, which may not be possible if the time is used to study a new area.

Of the two constraints, preparing new teaching materials is the easiest to solve and will be, therefore, almost certainly the most helpful activity to stress. It can be accomplished quickly without great expense, and it should help a large number of people. For the longer term, though, professors should strive to attend conferences with multimedia themes and to pursue sabbaticals with industries, consulting firms, and regulatory agencies to gain first-hand exposure to the handling of multimedia problems.

Integrated Research

To some extent, multimedia research by professors and students will follow once integrated approaches are introduced into the classroom. On the other hand, despite the time constraint just noted, a number of professors in the last few years have been able to move into new areas of research and study problems that have stronger multimedia links than traditional problems. A professor's research could stimulate the formulation of a topic suitable for the classroom.

Because of the complexity inherent to many environmental problems with a strong multimedia nature, student research will often be restricted to a small part of an issue, such as a specific transfer process, in order to be manageable. A modeling exercise would likely make the examination of a larger portion of a problem more practical.

CONCLUSIONS

Most educational programs today neither teach all the subject areas needed by the practicing environmental engineer in the 1980's (who must deal with complicated problems that involve strong links between water, air, and land) nor use an approach that affords the student an integrated view of the environment. Existing courses and curricula tend to be too rigidly segregated along environmental media. Environmental engineers generally do need to master one of the specialty areas associated with air, water, or solid waste management, yet they also should understand (a) how actions taken in one medium may influence the quality of the other media, and (b) how substances move and partition among the three media.

Traditional programs do not necessarily require massive restructuring to accommodate an integrated approach. Rather, by introducing the proper concepts and assignments into existing courses, teachers can better equip students to handle multimedia problems. Certain subjects however, such as groundwater modeling or toxicology, may deserve sustained attention in the form of new courses. A course dedicated to the analysis of realistic multimedia problems could greatly aid students in their preparation for a career as practicing engineers.

Of the noted constraints that hinder the implementation of integrated approaches in the classroom, the lack of adequate teaching materials and the lack of free time among professors, the former is the most easily addressed. An effort to develop and compile new teaching materials for integrated approaches needs to begin. Professors are encouraged, nonetheless, to seek out conferences and sabbaticals that increase their exposure to multimedia issues.

The well-prepared graduate should have mastered the fundamental and critical concept of the material balance, and be able to apply the concept to problems on a global, regional (e.g., lake or river system), or local (e.g., treatment facility or landfill) scale. The graduate should comprehend aspects of transport phenomena, environmental partitioning and fate of chemicals, and dynamic modeling and simulation. An understanding of the toxicological significance of substances is also vital. The graduate should be able to efficiently use the modern library and computer data bases, design experiments and surveys to gather additional data, and assess information for its validity and relevance.

More than a discipline in itself, integration is a way of approaching problems. Obviously, information and tools from many disciplines are needed to address most real problems. But merely being multidisciplinary, even over an expanded range of subjects, does not necessarily produce an engineer that can integrate such diverse information into a solution that makes the parts whole, that has integrity.

RECOMMENDATIONS

The educational system must heed the example of industry and the consulting profession in facing multimedia problems. It must make a substantial effort to produce graduates who think in an integrated mode. Otherwise, the graduates will be handicapped.

As guidelines for changing educational programs in environmental engineering, these recommendations are forwarded:

1. Teachers in every course should strongly consider assigning at least one prob-

lem set that requires an integrated approach.

2. A "capstone" course that focuses on multimedia problems should be offered. Ideally, this would involve some fieldwork and cooperation with experienced professionals.

3. More time should be devoted to education on the assimilative capacity of the environment, particularly the soil and atmospheric sectors.

4. The necessity of developing new courses to adequately cover topics of great importance to multimedia problems should be closely scrutinized despite the constraints of program budgets, faculty expertise, and time. Such topics may include groundwater modeling, the chemistry of toxic organics, and risk assessment.

5. Professionals from industry and the consulting field should be invited frequently to give seminars and guest lectures on multimedia problems and to assist with integrated class assignments.

6. An organized national effort should be made to develop and share teaching materials for integrated approaches, such as course outlines, lecture notes, problem sets, and laboratory experiments.

7. Professors should use leaves and sabbaticals to work with consulting firms, industrial organizations, and regulatory agencies to gain experience in using integrated approaches.

Appendix A

RULES, ETHICS AND MORALS IN ENVIRONMENTAL ENGINEERING EDUCATION

P. Aarne Vesilind
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In professional engineering practice, as in everyday life, we are continually confronted by decisions which are value-laden, or where several equally important personal values come into conflict, or where our sense of right and wrong conflicts with what we are expected to do. Often problems which might seem simple if only technical or economic decisions are involved become highly complex when human values, ethical conduct, and a sense of morals are introduced. In the course of environmental engineering education, it would be highly instructive to introduce the concept of values and the role of engineers in the resolution of value-laden problems. There is, however, great confusion about what is meant by various words used in ethical dialog, especially as practiced by the engineering societies.

Rules in engineering are either natural laws, man-made laws and regulations as enacted by the various governmental agencies and legislative bodies and enforced by police power, or codes of conduct developed by the professional societies and enforced by boards of ethical conduct. Ethics, by contrast, is a systematic methodology for making value-laden decisions. There are many systems of ethical thinking, and each individual chooses one such system, whether consciously or subconsciously.

Most often, people choose to follow the rules, and thus, choose to conduct their life according to an ethical system that requires obedience to authority, whether democratically or autocratically established.

Other people choose not to follow laws, and their ethical behavior may be different from ours. For example, if one chose to follow the ethical theories of hedonism, it would be perfectly acceptable to cheat, lie, and steal as long as one gets away with it and if it is to one's personal pleasure and profit.

Morals are the underpinnings of personal values that allow us to choose the system of ethics that is most comfortable to ourselves. If our morals are such that cheating is considered acceptable, then we will choose a system of ethics that allows us to cheat at every opportunity.

Teaching rules relating to environmental engineering is a simple matter. Teaching engineering ethics is also possible, but more difficult, since there are no hard and fast facts on which all will agree. Finally, teaching morals is not only impossible, but undesirable. Moral behavior must emerge from within each individual, and the best education can do is to illustrate the differences and broaden the scope of moral thinking.

OPEN DISCUSSION

P. Mac Berthouex, University of Wisconsin: Well done, Jim. On behalf of the committee we thank you for presenting our paper. We are behind schedule but we will have about 15 minutes or so for comments and discussion. The panel members represent the industry and consulting and education. You are welcome to address your questions or comments to people individually or to the panel in general.

Louis Guy, Guy & Davis, Consulting Engineers: I am from off-campus and I understood that the purpose of the conference was for some exchange, so I will pitch in. I think the latest presentation talks about additional knowledge and additional approaches. I have some thoughts on the specialist versus generalist, but it is more education that we are saying is required in the multimedia approach, and how do we do this? Dean Gloyna gave us some very provocative subjects this morning about the need for spending more time in order to adequately prepare the environmental engineers with everything they are going to need in order to do their job. One question I would like to ask the industry representatives on the panel is, Would industry, in their opinion, be willing to compensate adequately engineers who take more time to get out of school, so that we can have enough time on campus to add all of these additional elements that we agree are necessary to educate a practicing engineer?

For purposes of discussion, let's use Earnest Gloyna's five years. I think the additional elements that he suggested are compatible with what Mr. McKeown was suggesting as new things that are needed, and that is in the right direction. Let's talk about the five years, whether it's a four plus one or two plus three or three plus two, or whatever. A key stumbling block, obviously, is whether or not industry, and it is from an industrial perspective that we were hearing that this additional preparation is essential, be willing to pay for it? Will they be willing to not take a four-year graduate, who does not have this, and instead hire a five-year graduate with whatever kind of degree, who does have this kind of background? Will we get that kind of support from industry?

Stacy Daniels, Dow Chemical: I can't speak directly to the compensation issue, but I can relate from a personal standpoint, having taken 11 years to get a Bachelor's, two Masters' and a Ph.D. It was not necessarily all of my own making, but I did work part-time in industry while I was doing that sort of thing. Another reaction is I did not know there was such a thing as a four year Bachelor's anymore, at least coming from the schools that I was familiar with. I think that there are always going to be time constraints of trying to squeeze as much into a 5-year or a 7-year or a 9-year program wherever we go. The question is to make it as relevant as possible to the real-world problems. It is like our speaker at lunchtime said, "Our perspectives on life change as we grow older." We go from fundamentals and mathematics to arts and sciences. I am reminded of the time in 1982 when I participated in a Chemical Engineering soire, similar to this one. They had sessions in process engineering, computers, in bio-engineering and they had one on human engineering. All of the younger professors that had not gained tenure by the publish or perish route and were interested in widgets, all went to the gadgets and gismos sessions, and all the deans and the over-40 crowd went to the human engineering sessions.

Doug Wallace, EDI Engineering and Science: Let me speak from the consulting profession, and I don't want to say consulting engineering profession because as I am going to explain tomorrow, my consulting firm has more scientists than engineers. Yes, I would pay more for that kind of person because I feel that the kind of problems we face in the environmental consulting field get exceedingly complex, particularly when they are dealing with chemicals out of place or hazardous waste. I find that any training, any background that enhances the person's humanistic approach, their political understanding, and their legal understanding, pays off dividends many times, perhaps not when they begin work, but as they get more and more experienced and work their way into the project management level. I support a more extensive undergraduate degree, and I think we would definitely pay more for that graduate. I am not so sure all industry would, and I am not so sure all consulting firms would, but I think our consulting organization definitely would.

Ronald Neufeld, University of Pittsburgh: How do we consider integrated approaches in a program or a Master's program that has basically 30 credits? I am glad to see that someone from industry raised that question. Having had the question raised with no solution, let me try to propose a solution. I am glad to see that someone from industry is willing to say that these kinds of programs are worth more. Is it feasible or should our profession consider an advanced degree somewhere between a Master's and a Ph.D.? A Ph.D. is basically a research degree. Some schools have heavy course requirements toward Ph.D.s, ours happens to be one. Some schools do not have very much of a course requirement beyond that of a Master's degree but really emphasize the research. Being in an urban area, we see a large number of part-time students who really do want to go back to school, but do not have the incentive to do so, meaning that they need some sort of a degree in-between. There is an emerging trend in some areas on a degree, let's call it a professional engineer's degree, and if I could summarize it briefly, the course requirement would maybe double that of a Master's degree, 50 to 60 course credits. The student would have a Master's degree. He may do a project or he may not do a project. He may take a very comprehensive examination, but in his formal training he would have the basic fundamentals that he would pick up in a 30 credit Master's degree. He would also pick up some of the integrated approaches, some of the health related questions, the things that a normal Masters student would not get. Right now ABET and others do not sanction such degrees. Certainly, industry, I believe, anyway, needs such people. The last person that answered indicated that such people are worth more. Is there something that our society should do to develop a more formalized curriculum that develops such people that might be more valuable in the marketplace and have what I call an integrated knowledge in environmental engineering? My own philosophy of a Ph.D. student is I would like to see my Ph.D. students funnel-shaped, and I don't mean around the middle. Funnel-shaped in the sense that they have diverse knowledge in many areas, but certainly the depth of that funnel represents their doctoral dissertation and that becomes the depth of their knowledge. I suppose that what I am proposing now is someone who has that funnel-shape, at least on the top, has much of that depth in cross-section but perhaps does not have to go all the way toward a research degree, which all of our institutions so heavily cherish.

Yoram Cohen, UCLA: I would like to say that your idea of a professional engineering degree is not such a new idea. It is an idea or a program that has been at UCLA, for example, where I am from for quite a few years since the establishment of the School of Engineering, where practitioners can come back and obtain a professional engineering degree which essentially is equivalent to a Master's degree and it is primarily course work. I think that it is not just for environmental engineering but probably for any engineering discipline where new knowledge would benefit those who are in industry and would like to come back and perhaps build on their background. I think that point is very well taken and can be easily implemented in various schools since such programs do exist, but that is more in continuing education as I understood your comments to be. Or are you proposing a totally new degree also for full-time students?

Ronald Neufeld: Not on a continuing education basis, necessarily, but a degree which allows them to go beyond the Master's degree.

Edward Thackston, Vanderbilt University: I am intrigued by this idea because there is at Vanderbilt in another school, The College of Education, a similar arrangement. In The College of Education they have not only a Master's of Education in a variety of specialties, and a Ph.D. and a Doctor of Education but they have something they call a Specialist in Education which consists essentially of what Ron just said. We find that our M.S. graduates do not have enough courses. Just as everybody doesn't have enough courses, and some of them want to take more but they do not really want a Ph.D. Something intermediate, and if you want to call it Specialist and Ultra-Specialist or think up your own term. Something with a little more formality than just M.S. plus four more courses, something with a name and a piece of paper you can hang on the wall and that you could talk a few more coins out of industry with, I think would solve a lot of these problems. I agree with Ernie, we need a 5-year Bachelor's degree. Actually he didn't say that, he called it a Master's. I would say we need a 5-year Bachelor's degree plus a Master's degree, and then the opportunity for the Super-specialist, if you want to call it that, to go to the Specialist's degree without really getting into the real research phase yet.

Doug Wallace: I like the idea but I tend to think that the idea comes from the fact that we do not have a Bachelor's degree in environmental engineering. I still maintain that a properly structured Bachelor's degree in environmental engineering, coupled with a Master's degree in environmental engineering, would turn out the kind of person that we need in the consulting field, and I mean more complex consulting. I also think that what we end up doing at the Master's level is making up for deficiencies at the undergraduate level if it is Civil Engineering, Mechanical Engineering or Chemical Engineering, and then we say they have a Master's in environmental, but they are not quite there. They have not had all course work that they need. When I made the transition from a traditional water and wastewater treatment kind of environmental engineering into the hazardous waste field six years ago, I did it fairly successfully because I have a Ph.D. in environmental engineering, and I had a year of organic chemistry, I had biochemistry, and I had a lot of these courses that I would not have had if I had had only the Master's degree.

Edward Thackston: I agree. At one time we had a Bachelor's degree in environmental engineering and you could give course work equivalent to about 35 to 40 percent of what a normal M.S. takes, then you add an M.S. on that and it is almost enough.

Thomas Shen, New York State Dept. Environmental Conservation: I have a simple question. I sense there is a need for this committee to develop some teaching materials to retrain engineers working in the field in the concept of integrated intermedia approaches. Is this committee involved in developing teaching materials or short courses to give some training to those who are out of school and actually working in the field?

Mac Berthouex: Yes, it seems to me that is a need. We did not address the problem of continuing education but we did say in our report, and it is a condition that I felt myself in trying to make a shift in this direction, that one of the reasons it is difficult to begin to teach in this way, is the lack of teaching materials. There is a lack of really suitable textbooks, lack of problems, and a lack of homework assignments. We need to develop those kinds of materials. We have an expert in continuing education aspects of environmental engineering here, Jack Quigley, the Chairman of the Department of Engineering Professional Development at the University of Wisconsin. I hope we can get Jack involved in some of these discussions.

Perry McCarty, Stanford University: My comment goes back to the earlier question about an intermediate degree between the Master's degree and the Ph.D. Stanford has had what they call an Engineer's degree, which is one year beyond the Master's degree. They have had it about as long as they have had an engineering school. MIT also has that degree, one year beyond a Master's degree. In the Environmental Engineering program at Stanford about two or three students elect that route after they finish the Master's degree. They realize that there are a lot of courses yet that they have not taken. I know in the 50s when I went to MIT, that was specifically why I went there because they did have such a degree, which is a year beyond the Master's degree, and a lot of courses to go along with it. I am sure there are other schools that have a similar thing so it is not a far out thought.

Yoram Cohen: If I may just inject into that. It is sort of interesting, I know that UCLA has a similar program and I have learned that it is about to be phased out. One of the reasons is that the School of Engineering at UCLA was initially operated according to a unified curricula and then in recent years went back to the traditional engineering disciplines and so the engineering degree still remains. However, the number of students that select it every year has been dropping steadily, so that the projections are that it will sort of disappear on its own. What I am hearing here is that if we need to have such a program primarily for environmental engineering, then this is perhaps a degree to latch onto.

Leslie Grady, Clemson University: I hate to see us talking about added degree programs. It seems to me that it begs the issue. The reality of the situation is that for most of us we have a certain time period that we can work with our students and that we have to do a better job there. It also seems like that with proper design of our chemistry and mass transport courses, this integrated approach then becomes a much easier thing to do. It should be a basic philosophy that is in all of us, or that we are trying to transmit to our students. Mac, I agree with you wholeheartedly that there is not adequate instructional material available. Maybe what we need is for NSF to put some money into a program where we can take a half dozen people who are very good at doing this already and fund them for a six months sabbatical workshop to develop these materials.

Mac Berthouex: It is my own opinion that trying to create new degree programs and another 30 credits is not what we need to do. I think that this approach needs to show up in more and more of the existing courses. At Wisconsin we have been reasonably successful in making small changes in courses year by year. Not in all the courses, but in the industrial pollution control course, the solid waste course, and the chemistry courses. That is why one of the recommendations we made was to try to get one problem of this kind into each of the design courses. I like an idea that John Andrews has reminded me of from time to time, that you cannot expect to make big changes in a hurry in biological systems, and John's philosophy that you have to ramp it in, or you upset the whole thing. That is why some of the recommendations in our paper are directed toward making some changes now, and at least at Wisconsin, if the only thing we can do is design a new degree program, we would never get it done because it takes years to get one approved. I think to start making some small changes as we can is very important, and I am glad you said that you think it should be a philosophy that kind of pervades the curriculum.

Stacy Daniels: I react positively to the word "sabbatical" because I think there is quite a tendency for the graduate to hurry through his degrees and get out there and start earning the almighty buck, or start a family, and get out into industry or wherever he is going, to be doing his ultimate professional career. I think there is also an interesting feedback. After about five or ten years in industry, you get a feel for what you would like to do, but sometimes you would also like to go back and just take six months to one year off and take a few of those courses that you wish you had. Some industries have these kinds of programs and some do not. We have had industry exchange programs with government agencies in the past, where we have sent what I would call a career industrialist to a government agency and in return we would take a government agency person and he would work in industry for a period of time. Or we have taken professors from the various campuses and they have come in and done various research projects in our laboratories. This way you get a cross-fertilization among all of the disciplines. This may be one way of getting some cross-pollination.

Ralph Hodek, Michigan Tech: A few days ago I received a request from Amos J. Alter of Juneau, Alaska, to make a statement for him since he couldn't be here. His comments are relative to both the present paper and the following position paper. His perspective comes from more than 40 years of working in Alaska in education, research, construction, administration of environmental works and systems.

Integrated environmental engineering approaches in the role of design and operation in environmental engineering education demand increased emphasis on the significance of the low-temperature dimension. Current educational preparation is inadequate to provide reasonable expertise to cope with below freezing temperatures. Without proper consideration environmental works may be damaged wherever freezing occurs and the threat increases with increases in intensity and duration of low temperatures. A delineation and application of basic engineering science and economics gives little attention to low temperature implications. The thermometer appears to have stopped at the freezing point, insofar as most environmental issues are concerned. Concepts, methods, hardware, specifications and standards and measures of acceptability and efficiency are all based on temperate climate experience. There is little reason to believe that the principles applicable to management of cold environments differ from those for temperate climates. Manifestations of common phenomenon may bring vastly different results at low temperatures; although the initial variant may be temperature, the physical, chemical and biological relationships may be dramatically different than expected. This must be strongly stressed in academic instruction. Under some conditions low temperature has proven a resource to be utilized. When low temperature is used to advantage or managed by use of non-frost susceptible methods, expensive approaches to fighting the cold can be avoided. Major portions of the nation's resources remain to be developed in the North. Significant development has occurred over the past few years but the tempo promises to increase. A need for adequately educated environmental engineers with an appreciation for and a capability in cold regions environmental engineering on the horizon.

In summary, cold regions needs are not being addressed adequately in the educational community. All aspects of their significance, particularly the low temperature significance, must be addressed both in research and in teaching. A holistic approach will be impossible until the full significance of the temperature dimension is introduced at all points in the educational system. A three-pronged attack is needed to initiate and stimulate improved cold regions environmental management. Cold regions significance must be addressed in greater depth in basic science and engineering undergraduate work, in undergraduate and postgraduate programs as topical material, and in continuing education offerings. The practicing engineer and the public that is served must also be alerted to recognize the need for cold regions engineering expertise. Educators, consultants and the public, to be served, must work together to make full cold regions capabilities a reality.

Position Paper

ROLE OF DESIGN AND OPERATION IN ENVIRONMENTAL ENGINEERING EDUCATION

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CONTENTS

INTRODUCTION

Environmental engineering derives from many bodies of science and applies diverse principles to the design and operation of facilities for environmental protection. The potential scope is large, and this makes it difficult to define exactly what is meant by design and operation in environmental engineering. Design and operation of complex, macroscopic facilities and systems are hallmarks of environmental engineering.

The objective of this paper is to stimulate discussion on issues related to design and operation at the Fifth Conference on Environmental Engineering Education. This document, along with the conclusions and recommendations that will be reached at the Conference itself, should assist professors in improving instruction in design and operation. In addition, they should influence the criteria applied to accredit environmental engineering programs.

DEFINITION OF DESIGN

The term design can generally be defined as the invention and disposition of the forms, parts or details of something according to a plan. According to the Accreditation Board for Engineering and Technology (ABET)[1] engineering design is the process of devising a system, component, or process to meet desired needs. It is a decisionmaking process (often iterative) in which the basic sciences, mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation.

The process of engineering design of physical facilities generally involves multiple levels, each a refinement of previous levels. A conceptual design may include alternative comparisons, process flow diagrams, mass balances, basic siting of alternative processes, and preliminary cost estimates for alternatives compared. At this stage, a feasibility study of various alternatives is often included. At the intermediate level of design, facilities sizing is often again refined, major components may be laid out on a site, and major support systems may be sized. Sometimes, preliminary outline specifications for materials and equipment are included, along with another cost estimate.

At the detail design stage, previous work is further refined. Detailed drawings and technical specifications for equipment and materials are prepared for construction. Often, the construction contract documents, including the contract form, general conditions, special conditions, and the bid form are prepared at this stage, along with a final cost estimate.

In addition to the preceding levels of design, an even more detailed level occurs during construction. This involves preparation of manufacturing, shop and fabrication drawings for approval of the engineer and/or the construction contractor, and for use in manufacturing or fabrication of equipment and materials. Usually, this level of design involves mechanical, electrical and structural engineers, but environmental engineers often have a peripheral role. At present, shop drawings are almost totally neglected in environmental engineering education. In the past decade, major projects have also included value engineering and constructibility reviews as an additional level of design.

Another variation of the design-construct process which is often employed on international projects is termed the European system. In this system, a preliminary design is completed and distributed to vendors. The exact equipment to be supplied is then identified, and the final design completed around the vendor submittals. It may be worthwhile to teach this concept in design courses because it is likely that engineers of the future will become increasingly more involved in international projects.

The physical facilities designed and operated by environmental engineers include

- Water and wastewater collection and transmission facilities.
- Wastewater and water processing plants.
- Solid waste processing plants.
- Solid waste landfills and other disposal facilities.
- Air pollution control equipment and facilities.

- Hazardous waste processing plants.
- Hazardous waste disposal facilities.

In the broad sense, design and operation pertain to more than physical facilities. Many environmental engineers are involved with the conceptual design of research plans, regulatory systems, plans for spill cleanups, etc.

Design of environmental control facilities is performed by consulting engineering firms, governmental agencies, engineering staffs of private industries (for design of facilities for use by those specific industries), turn-key contractors, engineering staffs of equipment manufacturers, and owners of specific process patents. At the present time, most environmental control facilities in the United States are designed by organizations in the private sector.

REQUISITES FOR COMPETENCE IN DESIGN AND OPERATION

The competent design and operation of environmental control facilities and systems require the creative application of scientific and engineering principles. The word "competent" refers to the necessity that the facility or system include all the parts and features to enable a reasonably informed operator to make the facility perform its intended function with a high degree of reliability. This requires that the engineer has the ability not only to create and establish the design, but also to communicate the instructions for its construction and operation.

To define the role of environmental engineering education in preparing designers and operators, it is necessary to consider the skills required for competence in those specific careers. The skills required of environmental engineers in design versus those in operations careers are similar but with some important differences.

Requisites for Competence in Design

In general, requisites for competence in environmental engineering design depend on the type and complexity of the project. Design of larger facilities is generally more complex than design of smaller facilities. Plant design work is generally more complex than design of collection and transmission facilities for similar-sized projects. Desirable requisites for competence in design are summarized in Table 1. Of those listed, the most important is the ability to define and communicate the problem. The amount of time and money wasted by environmental engineers who start work without clearly understanding the problem from the view of all parties can be enormous.

Table 1.—Requisites for Competence in Design

- Foundation in the basic sciences pertinent to the design: physics, chemistry, geology, biology, soil science.
- Foundation in the engineering sciences pertinent to the design: statistics, materials science, fluid mechanics, soil mechanics, thermodynamics, electric circuits, chemical and biological processes.
- Ability to apply and integrate the basic and engineering sciences to produce a simple but realistic design.
- Competency in project and team personnel management techniques.
- Knowledge of engineering economics and project financing.
- Knowledge of government regulations affecting the project.
- Ability to define and communicate an engineering problem.
- Excellent oral and written communication skills.

Should environmental engineering education attempt to produce a graduate having an in-depth knowledge and competence in all of the areas listed in Table 1? Probably not, unless we are willing to go back to a five-year program for a B.S. in engineering coupled with a two-year M.S. program in a specialty. The questions then are:

What are the absolutely essential requirements for competence in environmental engineering design?

Which of these requirements can be best provided by university-based education, and which can best be provided by education based on practical on-the-job experience?

The answers to these questions depend somewhat on the unique strengths of the particular university program and on the career path taken by the individual engineer. Alumni surveys show (and engineering educators and design engineers sometimes forget) that only a strong minority of engineering graduates pursue careers that are primarily design or primarily operation. Yet, exposure to the practicalities of real world problems afforded by a design course seems to be an essential finishing touch to engineering education. In the evolution of environmental engineering education, areas of special competence have developed in the faculty of various universities, and the graduates of these schools should receive maximal benefit of this competence. Thus, for example, the graduates of ABC University may be particularly strong in filtration design, while the graduates of XYZ University may be particularly strong in process optimization.

Even in a large engineering design firm, the choice of career path influences the requisite competence in design. These organizations typically provide five distinct career paths:

1. Work in a specific engineering specialty division (e.g. structural, process, mechanical) often leading to the role of specialty chief.

2. Project management, including control of budgets, operation of the project team to perform the work, and interfacing with the owner of the facilities.

3. Sales of engineering services.

4. Administration and personnel management.

5. Forensic engineering and legal work.

Generally, the new environmental engineering graduate starts in a design organization in the actual production of conceptual, intermediate or detailed design, most often on the least complex work available. He then graduates to more and more complex assignments at various design levels until he is given a project to manage. After managing several projects, he either stays in project management or branches off into one of the other career paths, or serves in a combination of the career paths.

What then do engineering design organizations desire in newly hired environmental engineering graduates? If most of these organizations were to compose a "shopping list," it would contain most of the items listed in Table 1 with major emphasis given to:

- Foundations in the basic and engineering sciences,
- Excellent communications skills and computer literacy,
- Demonstrated ability to apply and integrate the basic and engineering sciences into a simple but realistic design of an environmental engineering system or component and to communicate that design to a user.

Requisites for Competence in Operation

Operation can be defined as the act or process of functioning. Environmental engineering operation is the process of making environmental engineering systems and facilities function according to the intent of the design. Requisites for achieving competence in operation are similar to those for design. In general, requirements depend on the type and complexity of the facility or system. Operation of larger systems is generally more complex than smaller ones. Operation of process systems is generally more complex than operation of collection and transmission facilities.

Primary differences in requisites for competence in design versus operations and maintenance of environmental control facilities are as follows:

1. A traditional civil engineering background is less valuable. Knowledge of structural engineering, for instance, is less valuable to the operations engineer than it is to the designer.

2. Certain aspects of process dynamics, process optimization, process control, instrumentation, and safety are more valuable to the operations engineer than to the designer.

3. Education in administration and management techniques is often more valuable to the operation and maintenance engineer than it is to the designer. Operations engineers typically reach the pinnacle of their careers in an administrative role, often with staffs of more than 100 people. They are often responsible for much larger budgets than are design engineers. These facts lead to the conclusion that university course work in business administration, personnel management, and similar courses would be highly desirable for operations engineers.

4. Techniques from the industrial engineering area should be highly applicable to the oper-

ation of complex environmental control systems. Therefore, it may be possible for an environmental engineering graduate student to develop additional competence in operations by taking appropriate industrial engineering coursework.

5. Graduates of environmental science programs are generally lacking in the engineering science and design requirements necessary for an engineering degree. Nevertheless, these graduates may take additional coursework in management techniques and can be well prepared for careers in operations.

Environmental engineers working in operations often start at a higher level in the management structure than those working in design. They tend to be responsible for administration and not for actual performance of the operations work itself. At present, most individuals involved in management of system operations may not have baccalaureate degrees, especially for the smaller systems. However, this will probably change as the complexity of these systems increases and adequately trained baccalaureate degree holders enter the marketplace.

Organizations that operate and maintain environmental control facilities include

- Municipal public works departments, water and sewage authorities, and power utilities.
- Private water, wastewater and power utilities.
- Private industries operating environmental control systems to serve their own production facilities.
- Engineering and process equipment firms who operate systems as part of performance guarantees or under contract.

A typical career path for an environmental engineer in operations would begin with an interest and involvement in operation of facilities either as part of his graduate independent study or as part of his first job. The normal progression would be from assistant process engineer to operations engineer to chief engineer and sometimes to higher administrative roles.

PRESENT SITUATION FOR INSTRUCTION IN DESIGN AND OPERATION

Undergraduate Programs

The ABET Roster of Accredited Programs[2] lists seven undergraduate programs designated and accredited as environmental engineering and another seven accredited undergraduate programs that use the word "environmental" in their titles. In 1980, Patterson[3] listed 27 universities that offered baccalaureate majors or degree programs in environmental engineering. Most of these 27 programs are presumably offering these environmental engineering majors as part of baccalaureate degree programs designated and accredited as civil engineering programs. In addition, several other accredited civil and chemical engineering programs offer various options or minors in environmental engineering.

Environmental engineering education at the baccalaureate level generally parallels the civil or chemical engineering curricula. The specific content and degree of orientation toward design and operation varies between programs. In general, though, these programs fall somewhere inbetween the traditional civil and chemical engineering curricula in that the student receives more exposure to process design and operation than the civil engineer and more structural design exposure than the chemical engineer.

All accredited baccalaureate engineering curricula are required to meet the minimum categorical requirements for mathematics, basic science, engineering science and engineering design shown in Table 2. Environmental engineering has a broad foundation in basic science. This foundation includes not only elementary physics and chemistry but also biology, microbiology, geology, soil science, organic chemistry, and physical chemistry. Because of this, it is desirable that baccalaureate environmental engineering programs include significantly more than the minimum 16 credits of basic science.

Depending on other constraints at a particular university, it may be difficult to design baccalaureate curricula to include the desirable basic science courses as well as the required mathematics, engineering science, and engineering design courses. This is particularly true for certain conventional broad-based civil and chemical engineering curricula. It is much easier to include the desirable basic science, engineering science, and engineering design courses in a baccalaureate curriculum designed specifically for environmental engineering, and this is a principal advantage of an environmental engineering curriculum and degree designation.

Another advantage of an environmental engineering degree designation is that it gives the profession more visibility and identity. Whether a baccalaureate program tailored specifically for environmental engineering is any better than a conventional civil or chemical engineering program with an environmental engineering minor depends on the strengths of a particular university and the future career path of the student.

Table 2.—ABET Requirements and AAEE Suggestions for Baccalaureate Environmental Engineering Program Accreditation

ABET CATEGORY	MINIMUM SEMESTER CREDITS REQUIRED	SUGGESTIONS FROM ENVIR. ENGR. VISITORS GUIDE[4]
Mathematics	16	Diff. Eqns, Appl. Statistics
Basic Science	16	Chemistry, 8 cr, Biology 4 cr, Physics
Engineering Science	32	Mechanics, Thermodynamics, Electric Circuits and Systems, Geology, Materials, Electives
Engineering Design	16	Unit Operations and Processes, Environmental Systems, Anal. Electives

Table 2 also summarizes suggestions on specific subjects made by the *Guide for Environmental Engineering Visitors on ECPD (ABET) Accreditation Teams.*[4] Additional program criteria published by ABET[1] require that instruction in at least three of the four following areas of environmental engineering be provided in the curriculum:

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

The following observations are reasonable in light of the foregoing discussion:

1. Significant weight is placed on design in undergraduate engineering program accreditation and evaluation, but little guidance is given on what constitutes a design course. It is reasonable to expect that instruction in engineering design should include conceptual design and intermediate design as well as some elements of detailed design.

2. With 16 semester credits devoted to design, graduates of accredited baccalaureate engineering programs should have ample opportunity to develop an appropriate level of competence in design. However, what is design to one engineer may be engineering science to another. There is a big difference between discussing a design and performing a design. It is important that instruction in design provide students with opportunity to perform trial designs and to receive constructive feedback.

3. The level and depth of environmental engineering design provided in baccalaureate programs varies significantly between programs at the various universities. The few accredited programs designated as environmental engineering ensure an adequate exposure to environmental engineering subjects. The accredited programs offering environmental engineering options under other degree designations produce more graduates, but the exposure of these graduates to environmental engineering subjects varies.

4. At the undergraduate level, the exposure to the **design process** is probably more important than the technical details of a specific design. A single design project carried through the conceptual, intermediate, and detailed stages is more beneficial to the student than three conceptual designs.

5. Little explicit emphasis is placed on instruction in operation. However, good engineering process design must be based on analyses, which require that process operation be thoroughly understood. This is a critical link between design and operation. Most environmental engineering design coursework should place additional emphasis on system and facility operation.

6. It is likely that environmental engineers with adequate competence in design are educated in the few baccalaureate environmental engineering programs as well as in the environmental options of many of the existing civil engineering and chemical engineering programs. However, environmental engineering has an identity problem in that most of the graduates are not properly identified by degree title and this contributes to the fact that many employers and prospective students are not aware of the specialty.

Graduate Programs

Historically, education in environmental engineering has been concentrated at the graduate level. The 1984 *AEEP Register of Environmental Engineering Graduate Programs*[5] describes graduate programs in environmental engineering at 101 universities. Most of these programs are associated with other engineering disciplines, notably civil engineering and chemical engineering, and most of the masters' degrees granted in environmental engineering are not specifically designated as environmental engineering. Only a handful of these graduate programs have pursued advanced level ABET accreditation.

Students in environmental engineering graduate programs originate from various backgrounds. Some of the more typical backgrounds are

- Baccalaureate degree in civil or chemical engineering with major or minor emphasis in water and wastewater.
- Baccalaureate degree in environmental engineering with major emphasis in water, wastewater, air pollution or solid wastes.
- Baccalaureate degree in mechanical engineering with minor emphasis in air pollution control.
- Baccalaureate degree in one of the physical or natural sciences such as chemistry, biology, physics, or geology.

Several plausible and convincing arguments can be made favoring one or the other of these backgrounds as being the best for environmental engineering graduate work. However, the reality is that each preparation has its advantages and disadvantages, and which is best will depend on the individual student's interests, abilities, and career path as well as on the strengths of the particular graduate program involved. The relation between baccalaureate and graduate environmental engineering programs is discussed in more depth in the Proceedings of the 1980 Conference on Environmental Engineering Education.[6]

Some environmental engineering programs offer somewhat parallel degrees in environmental science. Students with degrees in the basic sciences are usually limited to environmental science degrees under those conditions, unless they are prepared to take significant course work in mathematics, engineering science, and engineering design. A reasonable requirement for granting an engineering master of science degree to students not having an engineering baccalaureate degree is that, between the two degrees, the student satisfy the ABET categorical requirements shown in Table 2. At least in some states, this will facilitate professional engineering registration for graduates who do not hold an ABET accredited degree in engineering.

Many environmental engineering educators have observed that superior students having baccalaureate science degrees can do very well in environmental engineering design courses after having taken only a minimum amount of mathematics and engineering science prerequisite courses (e.g., statics, fluids). This might be explained by the observation that most baccalaureate engineering graduates study more topics in mathematics, basic science, and engineering science than they will ever use again in their subsequent academic and professional careers (and yet, some useful topics are left unstudied). A baccalaureate science graduate beginning an environmental engineering graduate program can carefully chose only those prerequisite courses which are likely to be useful to him.

With these appropriate prerequisites, many instructors have found no particular pattern of student capabilities based on their engineering or science backgrounds. Most of the non-engineers have little or no design experience, but are eager to learn and are intrigued by the thought of applying what they have learned at the university in the past four or five years into tangible designs. Moreover, they seem to be intrigued with the complexities of successfully operating such facilities once they are designed and constructed. A more thorough discussion of this topic can be found elsewhere.[7]

It might be argued that, because students without engineering backgrounds can do well in environmental engineering graduate curricula, these curricula do not contain a rigorous engineering design component. That is, if environmental engineering programs provided a thorough complement to the design courses presented in the undergraduate curricula of the major branches of engineering, nonengineering students would be less likely to excel in environmental engineering. However, as pointed out previously, these are generally superior students whose extra preparation generally includes only those courses likely to be useful.

A cursory review of the titles and catalog descriptions of environmental engineering design courses offered at various universities suggests that most of these courses are oriented to sizing and control of facilities for various processes. Few courses consider design of a complete plant system. The reasons behind this approach apparently are

1. Some exposure to basic engineering design should have been covered at the baccalaureate level.

2. Some engineers believe that the student should receive university training in the basic fundamentals of engineering and science and should develop design skills during professional practice.

3. ABET criteria for program accreditation allow for a very broad interpretation of design. What may be engineering science to one engineer is engineering design to another.

4. A good engineering design course is very difficult to prepare and teach. This difficulty is compounded by the fact that most engineering faculty are relatively inexperienced in design and operations. Another difficulty is that good practical design problems and examples are not widely available in the environmental engineering literature.

ROLE OF THE GRADUATE RESEARCH PROJECT

Most environmental engineering graduate programs lead to the Master of Science degree in civil, environmental, or chemical engineering, and nearly all of these programs require some sort of graduate research culminating in a thesis or independent study project report. For the student interested in design and operation, the graduate research component presents an excellent opportunity for an in-depth study of system and facilities design and operation. There are numerous opportunities for students to define and solve practical problems in design and operation of environmental engineering systems as part of their graduate research. This would normally require close cooperation between the faculty advisor and a consulting firm or facility owner. A financial arrangement for student support between the consulting firm and either the student or the university would also be helpful.

Example Design Courses

Various approaches to teaching environmental engineering design and operations have been tried and tested at various universities. Two examples of recommended approaches to teaching design and operation are described in the following paragraphs.

WASTEWATER TREATMENT DESIGN–UNIVERSITY OF TEXAS

This is a senior level and graduate course taught by Davis Ford as an adjunct professor. The instructional approach and outline for this course are described in Appendix A.

WASTEWATER TREATMENT DESIGN–IOWA STATE UNIVERSITY

This is a senior level and graduate course taught by E. Robert Baumann and other faculty at Iowa State. Appendix B describes the instructional approach. This course emphasizes the adequacy of a real-world engineer's design of a wastewater treatment facility along with an evaluation of its operability. A complete set of design documents, from preliminary report through plans, specifications and bid documents are obtained from a consulting firm. Each student then studies, evaluates and critiques the design.

THE MARKETPLACE

Placement of environmental engineering graduates can vary depending on the economy, the political infrastructure, and the location. Three major entities that hire graduates can be simply categorized as the private sector, the public sector, and the academic sector. Generally, those students who wish to pursue careers in design gravitate toward the private sector whereas those pursuing careers in operation have gravitated toward the public sector. In the past few years, environmental engineering graduates have migrated predominantly toward the private sector, working with industry, private consultants, or nonprofit corporations. Most designs are now produced in the private sector. Although designs are still produced in the public sector, engineers in this category most often find themselves in administrative or regulatory roles where they are often responsible for reviewing designs.

Operation of environmental control facilities is more evenly divided between the public and private sectors. However, many public utilities that were traditionally financed through the public sector are now being privatized. Whether this trend continues, of course, depends on tax law changes and political and economic patterns. At any rate, employers in both the public and private sectors need environmental engineers who can skillfully fuse their theoretical knowledge with the ability to carry a design from conception to the production of construction documents. Employers in both sectors also need environmental engineers who can operate and administer the operation and maintenance of their environmental control facilities.

At the present time, the marketplace for environmental engineers who specialize in design or operations is excellent, although there are some regional biases. Most of the opportunities in design now are in high-growth areas, those areas with a particular environmental sensitivity, or both. Opportunities in design are closely followed by opportunities in operation as the facilities are constructed and placed on-line.

Additional areas of opportunity for environmental engineers specializing in design and operation include

- Rehabilitation of old, obsolete facilities. Rehabilitation will gain in popularity as compared to new construction and deserves special emphasis in environmental engineering design courses.
- Management of hazardous wastes in industrial and military areas as well as in the major municipalities.
- Compensation programs to offset falling groundwater tables in many portions of the nation and concern for interstate and international transfers of resources and pollutants.
- Design of systems emphasizing simplicity of operation and tailored to the manpower and financial resources available in small communities. It is better to have a reliable simple system that works consistently rather than an optimal sophisticated one that requires a great deal of operator attention.

Accelerated growth and population migration toward the U.S. Sunbelt have created many environmental conflicts, correspondingly producing many environmental engineering opportunities. Concurrently, the Resource Conservation & Recovery Act of 1976 in directing a significant amount of attention toward hazardous wastes has created additional opportunity.

These and related environmental problems have created a larger than normal demand for the production of engineering design documents and specifications, which serve as the guideline for constructing containment and treatment facilities. Such demand for designers precedes but parallels similar demands for operations engineers.

Along with this domestic demand for design, operations, and maintenance engineers, many other developed and underdeveloped countries throughout the world greatly need environmental engineers. Thus, one can easily make the case for increased emphasis on design and operations courses in the environmental engineering curriculum based solely on the current marketplace.

While driving forces behind the market, such as the Resource Conservation & Recovery Act, are important and real, it is wise to remember past mistakes. Several years ago, universities designed specialized environmental engineering graduate programs to cater to the Environmental Protection Agency's training grants in support of the Clean Water Act. It is important that the emphasis in environmental engineering curricula be balanced to the future longer-term needs of the marketplace, rather than merely responding to specialized, short-term situations.

RECOMMENDATIONS FOR IMPROVING ENVIRONMENTAL ENGINEERING EDUCATION IN DESIGN AND OPERATION

Teaching Qualifications

At least three basic approaches provide the practical experience necessary for an instructor to effectively educate an environmental engineering student in design and operation.

The first is use of full-time faculty members who have been exposed to design or operational experiences during some phase of their professional careers. This experience enhances the quality and credibility of the courses. This could be implemented by selecting faculty who have had the requisite experience or by encouraging faculty to develop this experience through summer employment or sabbatical leaves to industry. One problem with the latter approach is that industrial experience does not generally provide the research funding and publication base necessary for junior faculty to overcome the tenure hurdle.

The second approach is to offer adjunct professor status to distinguished environmental engineering practitioners in the consulting and industrial sectors. This could be implemented on a part-time basis, e.g., teaching one course per year, or it could be implemented as a full-time, short-term sabbatical leave from industry to academia.

The third approach is a variant of the first and would rely upon instructional materials and design projects developed with the help of distinguished practitioners. Special efforts would be made to schedule lectures by practicing engineers familiar with the design projects. This approach is probably the most practical because it can be implemented by an individual professor. However, for this approach to be generally successful, it would require an increased effort on the part of the profession to utilize our professional journals for the publication of case studies dealing with complete practical design and operational problems and their solutions.

Additional Emphasis on Operation

To date, environmental engineering education has emphasized analysis and design of facilities and systems much more than it has emphasized their operation. It is recommended that a better balance between design and operation be achieved, and that more emphasis be given to instruction in topics related to operation. This could be achieved by

- Providing additional course work in operation as a part of environmental engineering curricula. These courses could be taught by qualified environmental engineering faculty or by cognate departments, depending on the situation at a given university. For example, management courses might be best taught by a business department and operations research courses by an industrial engineering department.
- Providing the opportunity for environmental engineering students to emphasize or "option in" either design or operation. Adding visibility to these options could benefit both the students and potential employers.

Additional Emphasis on Practical Research and Publication of Results

Additional emphasis should be placed on using the graduate research component of environmental engineering graduate programs to solve practical problems and to thereby provide the student with additional competence in design and operation. Consulting firms and governmental agencies should be encouraged to provide support and limited guidance for students working on such problems.

It is important that environmental engineers who solve interesting, applied, practical problems in design and operation publish their solutions in environmental engineering technical journals. These papers should be clearly written and intended not only for the authors' professional peers, but also for environmental engineering students. Fundamental derivations, sample calculations, and detailed attention to dimensions and units should be an integral part of such papers. It may be necessary to convince the editorial staffs of various professional journals to encourage such "teaching papers."

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Appendix A

WASTEWATER TREATMENT DESIGN COURSE UNIVERSITY OF TEXAS

This is a brief description of a design course recently (1985) taught at the University of Texas at Austin. Although this is an undergraduate course, the graduate course outline is similar. It is updated each year to reflect changes in the design criteria, technology, and methods of financing. The format can also be altered to represent the specific needs within certain geographical sections of the country. Moreover, the subtopics can be sufficiently flexible to reflect the interest and expertise of the person teaching the course, either a full-time faculty member or an adjunct professor.

The course outline is presented in Table A1. In introducing the course, the objectives are explained and the financial business elements of producing an engineering design are presented. The elements in both the private and public sectors are outlined, establishing the basis for formulation and control of engineering budgets in the public sector and determining engineering fees in the private sector. The establishment of design budgets and schedules, and the production of contract documents within these budgets and schedules is mandatory to successfully complete the process. Such control should be clearly outlined to the student at the outset.

With budgeting and scheduling methods established, a design project for municipal wastewater treatment facilities is presented. This is done in a sequential manner, beginning with the initial establishment of design criteria and population projections, preparing the preliminary engineering report with design computations and flow diagrams, writing of the specifications, preparing the detailed construction drawings, determining the engineering cost estimates, and establishing the basis for financing the municipal treatment facilities.

The establishment of design criteria in the course is critical for cost-effective evaluation of the overall project, with emphasis directed toward preparing adequate population projections and per capita usage based on the best statistical information available. This can be translated into the sizing of gravity collection systems and lift stations followed by the preliminary and field survey layouts of such systems.

Following the design of the collection system a review of the candidate treatment facilities must be made from an array of biological, physical, and chemical processes. Once the unit processes have been selected, it is necessary to go into the basic plant hydraulics to establish control elevations and hydraulic profiles.

Interaction with manufacturers is a key element in understanding the production of design drawings or specifications. It is normally prudent to invite manufacturers or manufacturers' representatives to present brief lectures to the students throughout the semester. The protocol in sending out requests for quotations from manufacturers and evaluating their proposals with respect to the design drawings and specifications is imperative. This interaction then continues in the preparation, the review, and approval of shop drawings, the concomitant guarantees, and the manufacturers' overall obligations to the owner.

Estimating the capital and operating and maintenance costs necessary for financing the facilities is then developed in order to prepare the necessary applications for grant assistance or to provide the financial consultant with the information necessary to prepare bond packages or other financial arrangements. As indicated in Table 1, alternative forms of financing, including privatization, should be discussed. It is particularly important for the student to understand the economic aspects relative to underwriting public utilities.

An industrial wastewater treatment facility design is included in this format as this entails some unique design requirements. For example, the federal effluent guidelines must be understood because the National Pollutant Discharge Elimination System (NPDES) for establishing effluent quality limits for individual industrial facilities in effect dictates the level of design required by the environmental engineer.

Industrial waste systems can be much more complex than publicly- owned systems treating only domestic wastewaters. For example, segregation of biologically toxic streams and the routing of other streams coming from selected industrial processes to the treatment complex can be quite critical based on the quality of that particular stream. This requires different levels of engineering and layout.

Following the general process design and conceptual layout based on these inputs, it is then necessary to introduce the student to the development of process and instrumentation diagrams (P&IDS). Such diagrams are commonly used for construction in the industrial sector and the student should be familiar with the approach used in such a presentation.

The last major design problem deals with the treatment of water for municipal supply. The first phase of this problem is developing data sources and methodologies for making population projections and estimating water demand for usage on a per capita basis. A comparison is made of the water sources with respect to its historical water quality as required by state and federal standards. The water quality parameters are then evaluated in terms of what future regulations may require, particularly as related to conservative constituents. Once the design criteria have been established and the water quality standards reviewed, the student is introduced to the engineering details of unit processes such as solids contact, sedimentation, filtration, stabilization, and removal of selected constituents through chemical and/or activated carbon addition.

Depending upon the amount of time available, this format includes field trips to water or wastewater treatment facilities, which is an excellent way of demonstrating plant layout, pump and valve arrangements, and process operations. At some place in the format the operations should be fully discussed, particularly on a trouble-shooting basis.

The preparation of an operations manual is normally a part of the engineering design package. To effectively prepare an operations manual, one has to have adequate operational and trouble-shooting experience. Ideally, the design engineer will have several years of actual "hands on" experience in a water or wastewater treatment facility prior to actually going to the drawing boards. Recently, municipally-owned utilities have been using private contractors for operational services. If this trend continues, it will create an additional demand for private sector engineers who can both perform operating services and manage operating companies.

Appendix B

WASTEWATER TREATMENT DESIGN COURSE IOWA STATE UNIVERSITY

The Iowa State University program has elected to teach two 2-credit courses in water and wastewater treatment design. In these courses, primary emphasis is on the adequacy of a real-world engineer's design of a water or wastewater treatment facility and an evaluation of its operability. In effect, consulting firms are asked to provide preliminary reports, SSES reports, facility plans with process design calculations, plans, specifications, and change orders for a recently constructed facility of interest to the faculty. The design is then analyzed independently by the graduate class members and the analysis of each unit is discussed in class. The analysis is focused on a single facility which is already designed rather than on a student-generated design because it is easier to critique the analyses.

Based on the consultant-provided design information, the class is asked to critically analyze and report on the design adequacy. For a wastewater treatment plant design, for example, the student conducts his independent analysis to determine

Plant Facility Plan

- Are the design flows justified and reasonable?
- Are the BOD, SS, N design loads justified and reasonable?
  - ▸ Is the BOD rate constant known adequately or assumed?
  - ▸ Are the potential industrial contributions and potential toxic components evaluated?
- Are the plant alternatives really comparable and properly considered?
  - ▸ Are the treatment units compatible?
  - ▸ Are the scientific/engineering principles involved properly and accurately analyzed?
- Etc.

Plant Units: Clarifiers (as an example)

- Are the unit volumes, detention times, overflow rates, weir loading rates, solids flux values properly calculated? Are the results in accord with treatment objectives?
- Can sludge be removed automatically? Manually?
- Is sludge removal adjustable?
- Can the sludge volume and strengths be obtained easily and accurately?
- Can the piping, weirs, and channels handle peak hydraulic loads?
  - ▸ What happens at low hydraulic loads?
- What happens to the grease and flotables?
- Is equipment maintenance a problem?
- Do the plans and specs get us what we need? Are there loopholes?
- If there is a performance spec, is it reasonable to determine whether the equipment is meeting it?
- Can the units be drained independently?
- What happens at high water table?

The entire focus of the design/operation courses is directed to determining whether the facility can be operated effectively and economically to provide the desired treatment result.

Open Discussion

E. Robert Baumann, Iowa State University: I might make one comment about this interim degree that everybody is talking about. You might go back to your universities this fall when school starts and look at the new appointments to university faculty and you will find an extremely large number of people who have what they call ABD degrees in political science and English and history. The ABD degree is all but dissertation, and that is a recognized stage of education, interim between the Master's degree and the Ph.D. degree. It might be applicable for people working toward Doctor of Engineering degrees, because many of these people could go into professional practice. A number of engineering firms do a lot of research that these people might be engaged in and complete their dissertation for Doctor of Engineering degree in industry or in consulting engineering firms.

Paul Jennings, Florida Institute of Technology: I was interested in the comment about Texas requiring a P.E. registration for promotion. About six or seven years ago the state of Florida made it illegal to teach a design course if you were not registered. Unfortunately, most of the faculty in the state of Florida don't realize that. Fortunately, the state of Florida has not figured out how to enforce it yet. The question I wanted to ask is, the last time I saw the national exams for professional licensing, they still did not have a category for environmental engineering, and if we are going to consider ourselves a field, do you think that is something we should be pushing for, as opposed to the classical sanitary engineering registration?

Earnest Gloyna, University of Texas: That may clarify a point. The Texas registration law does two things. First of all, it recognizes the teaching of engineering as being a professional practice. Secondly, it requires that you must have a registration if you have a title that carries the name engineering. If you are an associate professor of Engineering, then you must have the registration along with it. If you don't have registration, then you may have to have a different title, and we do have professors who are not registered, some are professors of Biomedical Sciences, some are professors of Electronic Sciences, some are professors of Materials Sciences, etc. It does not mean you can't hire people in engineering that are not registered, but we have that peculiarity in our Texas law.

Louis Guy, Guy and Davis, Consulting Engineers: Let me answer the latter part of the question first, and then I have a question of my own. Except for California, which of course has to be different, I believe that in the rest of the states, the engineering license is general. It is not branch specific. That is the same practice that is used in medical licenses. Within the medical field the branch specialties are by peer certification. This certification is private and is above the medical license. Within our branch of the engineering profession, we have now a more than 25-year-old specialty certification program in the American Academy of Environmental Engineers, and I would welcome anybody in the room who is not board certified in Environmental Engineering to talk to Bill Anderson who has plenty of applications to hand out for that program. That is the answer to how we demonstrate our specialty qualifications in engineering.

I would like to respond to the design elements. One of the fallacies in our system of engineering education is off-campus, in the assumption that there is an internship in practice in industry or in consulting firms in that four-year period between the EIT exam and the P.E. exam. Most engineering employers do a poor or nonexistent job in bringing along the young engineer on these other factors that Dr. Ford was saying might be taught following the degree. This situation exists partly because we do not have the guidance, structure, and follow-through of the engineering schools to ensure the quality of the internship. Therefore, I would strongly suggest that until there is some way of putting some requirements into that internship and bringing it under the auspices of the academic community and the dean of Engineering, it is all the more essential that these other factors be, if not fully taught on campus, at least introduced to the student. I couldn't help thinking in the description of the design project that Dr. Ford was giving, that my biggest problem for a number of years after I went into design with consulting firms, was to try and figure out how I could get rid of the handcuffs that prevented me from using the technology that I had been taught, because of the outdated design guidelines applied at the regulatory level. I would suggest that a way of educating the student of design in this very real problem would be to go through the design project and have him or her come up with a product. And then take a 20- or 25-year-old set of 10 state standards and apply that to the design, marking it up with red, and showing how it is not going to be approved and can't be built that way, because the standards that have been applied at the regulatory level will not let you do it the way that you were taught. I think that would be a real-world factor that he needs to learn. Then I think the second element is ethical, and that is, how does he respond? Does he accept that and roll over and play dead, thereby abandoning his responsibilities to the client or employer or the public for that matter? In many cases, the difference between the modern practice, the efficiency of the modern practice, and the old-fashioned rule of thumb is millions of dollars. In other cases, it is a difference between something actually working to accomplish the objective, or not working. The next element of this project, this experiment, is to educate the individual in the responsibility he has to do his best job as a commitment to the public and as a part of engineering ethics.

Rudy TeKippe, James Montgomery Inc.: I have a couple of comments to make that relate to that to some degree. You emphasized, if I understand you right, that the university should cover more design topics because the consulting engineering firms or other organizations do an inadequate job of preparing people for the professional registration. I do not know if that is exactly the problem, if we look at the people we have hired over the years. We have a firm of 650 people, and probably 200 of those are registered engineers. We have relatively few people who ever fail the professional engineering exam in any of the states in which we work, and we are registered in most of the states. The graduates coming from all these different universities, and we have graduates from many of the schools represented here, are, I believe, trained adequately to pass these professional engineering registration exams. I think if we want to improve the overall state of environmental engineers in practice, it might be to stiffen and make those exams more specific to environmental engineering than to try to change the university system.

Another thing I have not seen mentioned yet today that I think is vitally important to all of us is that many of our environmental engineers, no matter how well you teach them, go out into practice knowing enough to be dangerous. You can not, in four years or six years, even if you give them a Ph.D., properly prepare them for going out and designing a wastewater treatment plant or a water treatment plant, or, particularly now, some of these hazardous waste facilities and expect them to do a competent job on their own. I cannot overemphasize the point John Andrews made earlier. Your graduates coming out know very little when it comes to doing competent, full environmental engineering design. They have to be taught that they are a member of a team. We need more depth in engineering design than we have had in the past, and we also need broader breadth. The only way you are going to get more depth and broader coverage is to teach people that they are part of a team. They are going to be at first a very small part of a team, and as they get larger and more experienced they are going to become more prominent members of those teams and eventually lead the teams. Our company, for example, does basically 100 percent environmental engineering, yet only a small fraction of our engineers are environmental engineers or graduates from environmental engineering programs. The bulk of the manhours put together even in designing a water treatment plant is not environmental engineering. It is the combination of chemical, structural, electrical, civil, and architectural; all of these things have to come together to form a set of biddable documents. We have attorneys on our staff who go through our specifications continuously, looking for flaws that might get us into legal problems. Our society has shifted greatly in the last 10 years from being one of getting the job done, to one of looking into the legal aspects and trying to find somebody at fault so one member of society can squeeze money out of another, rather than creating a more productive society. Again, the message I want to transmit is convince your students that they have been exposed to a small part of the overall environmental world, that they know enough to be dangerous, and convince them how little they know when they graduate, and how much trouble they can get into if they think they know it all.

William Busch, Illinois Environmental Protection Agency: I really would like to underscore the importance of process operation. I think it is very important that curricula include a lot of emphasis on operating a facility, and that goes beyond just being able to put it down on paper. Over the years in Illinois, I have had occasion to review many, many designs and visit many, many treatment plants. The first thing the operator does is explain to me why he cannot operate his plant. I have seen many examples of what I call ergonomics. A person has to literally walk a pipe to get to a control valve he has to manipulate twice a day, and in the winter when that pipe is a little icy, it gets a bit treacherous. That is only one of many, many examples which have led me to say that if design engineers had to operate these plants they would design them a lot differently. Over the years I have collected a slide show of different dumb things that have been built, and I have put on this show for designers. A lot of the things that you learn in design classes do not correspond to what is out there in the field. A lot of the things that my field staff has observed are factored back into our design criteria. We have implemented what we call a design operability review. We review the design submissions for these control valves that are going to freeze up in the winter because they are not housed, and for other things that you do not normally think about when you are sitting in a warm room at the design board. I think that is valuable experience, and the more of that we can have in the curricula the better. I emphasize field trips, possibly even some guest lectures by operations people from regulatory agencies. It is important that your students appreciate the problems of operation, the cold-weather operating problems, proper housing of blowers. I have seen blowers that are unhoused, and obviously they always break down in January, and you have to be laying out there under a motor or blower fixing it with no shelter around. We have picked up many things over the years that students could benefit from.

E. Robert Baumann, Iowa State University: I do a lot of forensic work, and in almost every case I find that the engineer has failed to do those things which are so obvious, that if he had taken the time to think or to view the whole picture, he would not have created the mistake. An example of this is designing of $20 or $30 million treatment plants on the basis of a BOD without the determination of K-rate. There are other odd, stupid things that we do in practice. Don't blame all the litigation that we are into today and the high insurance rates on the insurance companies and the attorneys. Engineers still don't design competently as frequently as they should.

Susan Jasper, University of British Columbia: I think I might be speaking as the only non-engineer here. I am an environmental chemist, and I teach environmental engineers at UBC. I just wanted to make a comment on two of the earlier thoughts that were presented. One was that we should be teaching people how to think. I find a lot of the engineering students I get have not been taught how to think, and they don't even realize the difference in what I am trying to teach them. You can't possibly turn out an environmental engineering student or graduate who can be competent in all of the things we have been talking about, and yet they are often expected to be. The other comment that was made earlier was to teach them to be part of an integrated team and use the resources that are available. That is why I am interested in hearing these comments from the point of view of an environmental chemist. In our research we often draw on microbiologists and chemists at UBC, and they are often really interested to find out that environmental engineers know about bacteria and chemistry. We turn around and say to the microbiologist, we want you to help us understand what these bacterial processes are. I often get engineering students in the graduate courses I teach who are totally amazed to find out that there are all these other resources available. I find that if I can just make them realize that they don't have to know everything themselves; if they can admit that someone else might know something that will integrate with what they're doing, so that they might go and speak to that individual; if they realize that every thought might not exist in a table or a book somewhere, if only they delve deep enough to find that table; then perhaps they might have to think for themselves, and come up with some of the concepts themselves and think of whom to go and speak with to develop these concepts. If I can make that breakthrough, I feel like I have really made a significant change in that person's thinking. I think perhaps a lot of the problems that we have been bringing up today might be addressed at least in part by taking our graduates and making them think along those lines more than thinking along the traditional lines that we have been teaching and discussing today.

Earnest Gloyna: I would like to take my engineer's hat off and put on my deanly hat and say thank you. I think you have made a very important point. One of the things that is happening is a very simple thing, and is so obvious that we sometimes overlook the fact that we are now really working in a very complex arena, and it is team effort that is going to be very, very important. We see this in the educational world of engineering. Take, for example, engineering graphics, which is a very important part of our design operation. It suddenly occurred to us a year ago that we had some departments in our college that were really not up-to-date, and we had to put a lot of money into those departments in order to transfer the information that was very highly developed in our manufacturing systems programs where they had CAD/CAM. This was necessary just to transfer from one building to the next building in engineering. We have the same problem in the business of transferring information from the sciences to engineering. That brings me up to one more point. I have heard several comments about having this interim degree. This morning I did not talk about an interim degree at all; I did not intend to talk about an interim degree. I intended to talk about something new. Please read the paper.

Charles Jennett, Clemson University: We have the National Council of Engineering Examiners off-campus at Clemson. The suggestion was made earlier that environmental engineers should be certified as Diplomates of the Academy. I think that is a very good thing. But to get that certification, you have to be registered as a Professional Engineer. On the last registration exam, at least this spring, less than half the people who identified themselves as sanitary environmental engineers passed that examination. By comparison, more than 70 percent of the electrical and computer engineers did. Whatever it is that we are teaching, either it is not sticking with them for four years, and I doubt that, or the exam has absolutely nothing to do with what people are doing in the field, which is what I suspect. In any case, you are not going to get an academy certification until you pass that exam, and last time an awful lot of people didn't do it, and I thought you ought to know it.

E. Robert Baumann: I might make one last comment. If you really want to evaluate the communication skills of your students, try what I do in every class I teach. The first day I go in and require the students to prepare a letter of application for a job and a copy of an up-to-date resume with all the information that they want to convey about their skills as a potential employee. Review how little information you will get from them that would make you want to employ them as engineers.

Final Plenary Session

COMMITTEE REPORTS AND RESOLUTIONS

C. Robert Baillod, Michigan Tech: Each Task Committee, at this point, has produced a report consisting of a series of resolutions. I want to emphasize that it is important that what we do both in our proceedings and in our resolutions should find its way into the revised criteria for ABET accreditation of environmental engineering programs. It is my understanding that the American Academy, which is the lead agency for our accrediting procedure, is going to be revising its criteria and guidelines soon. The real importance of what we do in our resolutions and in our conference here, the lasting effect of it, will be realized if it is reflected in the revised guidelines for accreditation. We can pass many good resolutions prescribing what environmental engineering educational programs should do, but based on past conferences, it seems that these resolutions are easily forgotten.

The procedure will be for each Task Committee chairman to have about 45 minutes to present that group's proposed resolutions. Some are longer than others. Since we have a limited time, the questions will have to be moved on schedule. The groups have packaged their recommendations for maximal efficiency. Items that should be least controversial are grouped together, and the more controversial items are factored out and presented separately. We will vote on each resolution, or package of resolutions, by show of hands.

CONTENTS

Report of the Committee on the Role of Computers in Environmental Engineering Education and Research

John C. Crittenden, Chairman

PROPOSED RESOLUTIONS

1. It is recommended that students entering graduate environmental engineering programs be able to do the following:
   a. Prepare simple programs in a high level language.
   b. Use word processor and spreadsheet programs.
   c. Understand the limitations, strengths and weaknesses of major numerical methods.
2. Graduate curricula in environmental engineering should emphasize basic understanding of processes and mechanisms and the mathematical expression of these principles through models. Graduating M.S. students should be able to implement these models on a computer. In addition, the students must recognize the limitations of the model computations. In order to spend more time on the formulation and interpretation of the problem, students should also be exposed to commercially available programs that reduce the computational and solution effort.
3. Easy access to computers is important. Accordingly, students should be encouraged to buy their own computers and universities should establish programs to facilitate their acquisition. To facilitate the implementation of computing into coursework, Universities should provide personal computers to all engineering faculty.
4. The Association of Environmental Engineering Professors (AEEP) should establish a standing committee on computer software. The charge of the committee is to encourage development and distribution of computer applications in environmental engineering. Specific objectives of the committee are to continue to update the computer software manual, to actively solicit the support of professional organizations through seminars and workshops, and to encourage state and federal agencies to fund the development of computer software.
5. University administrators should provide support for the development and integration of computers into the curriculum, namely, teaching assistantships, release time, summer support, hardware, and purchase of commercial software. Developing software for classroom instruction should be recognized as a creative and demanding activity, for which credit should be given in career evaluation.
6. To avoid legal and ethical problems that may arise with the educational use of proprietary software, faculty should make sure students are aware of copy restrictions and the consequences of violating them. Classroom assignments should incorporate available freeware and shareware, where feasible; otherwise, universities should seek site licensing agreements that allow students to acquire proprietary software at an affordable cost.
7. In order to provide a variety of educational opportunities, graduate curricula in environmental engineering programs should include exercises in advanced computing applications such as simulation, process control, data acquisition, and data base use.

John Crittenden, Michigan Tech: We have only 45 minutes and there are 7 resolutions, so we should limit our discussion to approximately 5-7 minutes on each. I think some of those resolutions are fairly straightforward. Is there any debate on the first resolution?

Aarne Vesilind, Duke University: Does that mean that I should not accept people into my program unless they have these qualifications?

John Crittenden: No, I don't think it means that. I think that it is intended as a goal that we would like to see programs move toward. Our second resolution is related to what we would expect from the graduate students upon completion of their programs.

Jon Liebman, University of Illinois: One way of interpreting this is that since these skills are not difficult to acquire, we are saying that our graduate programs will proceed on the assumption that incoming students have these skills. That is not to say we won't admit them if they don't, but we will simply assume that they have this base. If they don't have this base, they will have to do some remedial work.

Charles O'Melia, Johns Hopkins University: I want to just make a small comment. I support the goal, but I am worried about the interpretation that we are telling the graduate schools that they must require numerical methods. It is easy to say we should improve this or that, but there is always a tradeoff in these things. If you are going to put numerical methods in, something has to come out of an engineering undergraduate program. I see no mention in the resolution of what is going to come out. Everything that we want to add in these resolutions is going to require that something be removed from a curriculum. I think that the numerical methods is maybe the least dangerous of the examples. I would like the students to have numerical methods. It is the fifth math course they take at Hopkins. The first four are required. Numerical methods is an optional course. I don't think Hopkins is going to require numerical methods within the near future. I would like us to say something like it is desirable of students. I don't want to say it is expected. I don't expect the students coming into our graduate program are going to have numerical methods. I would like them to have it. I don't expect them to have it, and I don't think a resolution that says I expect them to have it is reasonable.

John Crittenden: I will interpret your comments as a friendly amendment to change "recommended" to "desirable." The language is now: "It is desirable that students entering environmental engineering programs be able to do the following . . ."

The amended resolution passed without opposition.

John Crittenden: The second resolution pertains more to what we would expect of graduates. Is there any discussion on the resolution?

The second resolution passed without opposition.

General discussion on the third resolution resulted in the last sentence of the resolution being modified to *<u>Universities should provide computers to all engineering faculty and easy access to computer labs for student use.</u>*

Jon Liebman: I am not sure I like that last modification. I am concerned that if we don't watch out we will go overboard, and our students will all know how to use a personal computer and will be scared to death of mainframes. And mainframes do have their purposes. I would prefer to have the first sentence read something like: Easy access to both personal and mainframe computers. . ., and the rest can proceed to talk about personal computers.

This was accepted as a friendly amendment and the amended resolution passed without opposition.

John Crittenden: The intent of the fourth resolution is to create a standing committee that would try to carry out these objectives. Is there any discussion on the resolution?

Joseph DePinto, Clarkson University: Why are we calling this a committee on computer software? Shouldn't it be a little bit broader? It might be important for the committee to consider hardware. Can we say something like computer applications?

DePinto's suggestion was accepted as a friendly amendment and the amended resolution passed without opposition.

General discussion on Resolution 5 resulted in the addition of software developers following teaching assistantships.

Richard Luthy, Carnegie Mellon University: There is something about this last line here related to promotion criteria. Every university places different weight on teaching and research, and software development for instruction sounds a little bit like course notes and handouts which may or may not count for much, depending on the institution.

John Crittenden: I realize that and my feeling is that the amount of credit should be considered at least equal to that for developing a new course.

Richard Luthy: It struck me as being a little bit peculiar in the sense that it encroaches upon policy at the institutions.

John Crittenden: The reason for the resolution is that individuals who spend a lot of time in this activity should receive credit; maybe the same credit that the individual university would give for coursework development. I want to recognize that this is an additional activity over and above just a normal development of course materials. Is there any other discussion?

General discussion ensued related to the revision or elimination of the phrase "in career evaluation."

Steven Chapra, University of Colorado: An individual should be judged based on what he or she has done. Some people write publications, some write books, some write papers, some make presentations. I think each institution will judge accordingly. Some software is developed which may be comparable to a textbook and may be used all over the country. I think it should have an effect on an individual's career. I don't see why it should be narrowed down.

The chair ruled to leave the last sentence unchanged. The question is in its original form, with the addition of "software developers."

The resolution passed without opposition.

The floor was opened for discussion on Resolution 6.

Carlos Diaz, University of Pittsburgh: I think that the obligation of making the students aware of copyright matters belongs to the university. The faculty shouldn't have to enforce this.

John Crittenden: The intent of the resolution is to avoid the copyright problem by encouraging freeware, shareware, or a site license.

Carlos Diaz: The university should make students aware of the copyright problem through announcements.

Jon Liebman: I strongly disagree with that. It's an ethical issue, it's a professional issue, and it is the faculty job to tell the students what is ethical and what is professional. I do not believe we should be policing, but I do believe we should be telling. I have one other thing I would like to suggest. Software vendors should be encouraged to make software available to students at a reasonable price. We can help to do that.

Thomas Keinath, Clemson University: I would like to pick up a word that Jon mentioned, namely "ethics." I would like to insert the word ethics in here. In fact we should make students aware of the ethical considerations regarding copying restrictions.

James Alleman, Purdue University: It seems to me that motion is two separate things, that one is ethics, and the other is availability and provision of software itself. I think it should be split into two separate motions.

Perry McCarty, Stanford University: I think it could be together because part of it is reducing the temptation and admitting that there is a problem. Using the freeware and shareware is a way of getting around the problem.

The chair accepted the suggestions of Liebman and Keinath as friendly amendments.

The amended resolution passed without opposition.

Discussion was opened on on the seventh and last resolution and resulted in the elimination of "data base" and addition of "artificial intelligence."

The amended resolution passed without opposition.

Report of the Committee on Integrated Air-Water-Land Approaches

P. Mac Berthouex, Chairman

PROPOSED RESOLUTIONS

WHEREAS environmental engineering involves understanding the transfer and transformation of substances in the land, air, and water media, the design and operation of control and management systems, environmental systems analysis, and assessment of numerous risks from a variety of sources, and

WHEREAS, while schools and programs differ greatly in their goals, approaches, faculty interests and capabilities, resources and facilities, and no one approach is valid for all situations, most university programs are addressing this issue in varying degrees; and there is a need for underscoring certain main themes which should be incorporated in these educational programs.

THEREFORE, BE IT RESOLVED THAT:

1. Environmental engineering programs should include educational elements that focus on multimedia problems and incorporate an integrated approach to their solution and these programs should provide the graduate with
   (a) a strong background in fundamentals,
   (b) technical competence in an environmental engineering specialty,
   (c) an appreciation for limitations on data acquisition and availability for adequately characterizing multimedia problems, and
   (d) sufficient familiarity with other engineering and science specialties to be able to communicate and work effectively to solve multimedia problems.

BE IT FURTHER RESOLVED THAT:

2. Practicing professionals from the industrial, governmental, and consulting sectors should be encouraged to participate actively in the development and implementation of integrated multimedia environmental engineering programs.
3. Teaching and research faculty should seek and utilize opportunities for professional development in the solution of multimedia problems. Academic institutions should recognize this need and encourage and support such activities on a routine basis.
4. An organized national effort should be undertaken to develop and provide for the effective use of educational materials supportive of teaching integrated approaches.

P. Mac Berthouex, University of Wisconsin: We had quite an active discussion yesterday. A lot of good advice was provided in the papers during the morning session, and I want to take this opportunity to thank the people who presented papers and participated in the discussion.

William Thacker, National Council for Air and Stream Improvement: I would just like to point out that the position paper had more specific recommendations. In our discussion yesterday we decided to make the resolutions more general, so as not to specify specific things that a program should do. If you think this is sort of general, that was the intention.

Donald Aulenbach, Rensselaer Polytechnic Institute: On the organized national effort, do we have a plan to implement this? It sounds like a tremendous undertaking.

Mac Berthouex: An organized national effort should be undertaken to develop and provide for the effective use of educational materials for support of teaching. It is a tremendous undertaking. The committee hoped that AEEP or some other organization might be willing to provide support in some way, organizational support, moral support, financial support, or perhaps some group of people might organize themselves and prepare a proposal for funding to some wealthy benevolent charitable organization. It was suggested by someone late yesterday afternoon that the committee on the whole might like to formulate some specific resolution as to how that might be done, but the committee itself did not feel that we could do that. My own feeling about it is that until somebody has taken some time to investigate who might be willing to work on it, and what possible sources of funding would be needed and what sort of logistic support is needed, that it is premature to be too specific about how it is to be done. Rather we should set it as a goal. There was strong agreement that we need teaching materials in this area. We need case studies, and we need homework assignments. The kind of thing that AEEP has done with computers and laboratory manuals that have helped people so much, might also be done for the integrated multimedia approach. An important part of it is to find not only a way to develop the materials but to share them around and make sure that they get into use.

Francis DiGiano, University of North Carolina: I wonder if a forum does not already exist in AEEP for a possible workshop on this.

Edward Thackston, Vanderbilt University: In the original draft of this clause there was a list of possible things to be done at a workshop; for example, manuals, or exchange of homework problems. It was a list of three or four items. Because someone thought that list might be interpreted as being exclusive, the whole list was taken out. Personally, I think that is an overreaction, but that is why there are no specific things there.

Jon Liebman, University of Illinois: Given that, and in order to make sure that something happens, wouldn't it be appropriate to add to that item simply a recommendation that AEEP ought to establish committees to proceed?

Mac Berthouex: I think that would be appropriate and a very good idea. Does anyone on the committee have any problem in adding that as a friendly amendment to the last clause?

Aarne Vesilind, Duke University: Doesn't AEEP already have educational methodology or something like that?

Jon Liebman: Perhaps we could simply say AEEP should take the lead in organizing this effort. Let AEEP decide what committee takes it on.

Mac Berthouex: I will accept your suggestion as a friendly amendment. The last item will be amended to say that AEEP should take the lead in doing this.

Charles O'Melia, Johns Hopkins University: Can I raise a point? I also raised this in our discussions. Most of us here are in the middle of this air, water, land integration, where mostly we have expertise, competence and experience in water. Most of us come from relatively small programs of three to six people. My point is that when we make this integration, we are not going to make an equal integration of expertise in air and land with what we know in water. And so, the product is going to be a biased and probably not complete and maybe not even good integration. I think we have a problem with the way our educational groups are organized and structured, and the real implementation of an integrated air, water, land approach, and I wonder if there is some way that we could first of all see if that is a problem, and if it is, add some kind of a statement about not only going to industrial and government groups, but actually going out on the campus and trying to integrate equivalent expertise and experience on the campus rather than saying everybody else has got to help us outside the university. I think that part of the problem here is actually in the university. A major part is in the university and I don't see that addressed in the resolutions.

Mac Berthouex: It is not addressed specifically in the resolution. It was discussed and the feeling was that each program and each institution will have to decide how much integration they can do and how they will accomplish that. Whether they can do it within an existing group, or whether they need to reorganize in some way or reach out. Certainly it is good to reach out, and it certainly is also true that the intent of this is not to try to train people equally well in air, water and land. We expect that people will continue to have a dominant strength in one of those areas. I don't have any disagreement with what you said.

Richard Luthy, Carnegie Mellon University: If we look around, we are all water based sanitary environmental engineers, and it seems that we should try to expand our membership base and to bring into the organization our colleagues who work in soil media and in air.

Mac Berthouex: I agree, there is nothing wrong with that. We will consider approval of the document as amended by Jon Liebman.

The amended resolution passed without opposition.

Report of the Committee on Design and Operation

Davis Ford, Chairman

RESOLUTIONS

1. Be it resolved: that we express concern that liability of practicing engineers will have an adverse effect on the ability of faculty members to get functional design experience.
2. Be it resolved: we encourage the use of computers and teaching tools to enhance training in design.
3. Be it resolved: hazardous waste management and remediation be included and expanded in future design courses.
4. Be it resolved: operation and maintenance, including process dynamics and control, be included and expanded in future design courses.
5. Be it resolved: functional design should include the appropriate integration of forensics, regulations, finance, ethics, in-plant control and conservation, risk assessment and management, and the private practice of engineering and that these items (and others) be an integral part of design.
6. Be it resolved: design courses should be taught by registered professional engineers.
7. Be it resolved: undergraduate degree programs allowing specialization in environmental engineering, while maintaining breadth are encouraged.
8. Be it resolved: up to one-fifth year of advanced (beyond first courses in chemistry and physics) quantitative physical or natural science courses which have environmental engineering applications can be counted as engineering science in satisfying ABET requirements.
9. Be it resolved: that graduates from programs in environmental engineering shall satisfy the minimum ABET criteria, and functional design and synthesis is an integral component of these criteria (concern was expressed about the "pure" definition of ABET criteria).

Davis Ford, Engineering Science Inc.: Does everybody have a copy of the resolutions? Let me say that we had a very active group yesterday. We ran it in a very democratic manner. We consequently got a good distillation of ideas into the resolutions that we have before us. Believe me there was a significant amount of discussion on each of these issues. What I would like to do this morning is to first deal with the ones that I believe to be the least controversial. Then we will take up those which may precipitate more discussion. I will try to give you just a brief background of each resolution based on the committee's comments as we go through them.

Davis Ford: Resolution Number 1: A big question that came up late in the discussion was one of liability. As in the medical profession, the liability cloud is hanging over the engineering profession. We tried to limit our consideration of liability to its effect on design. We further distilled that into how it might affect faculty. The idea here being as faculty members get more and more design experience on faculty leave, or in consulting activities, that they have more and more exposure. I know that professional liability insurance for individuals is getting more and more difficult to handle and certainly liability insurance for companies is becoming much more onerous as is malpractice insurance for physicians. Any discussion?

John Andrews, Rice University: I have subscribed to the ACS program for professional liability insurance but it is no longer offered.

Davis Ford: I personally subscribe to the Water Pollution Control Federation Insurance Program for personal liability, which is a good one, and I understand that it is no longer going to be available. I think the purpose of this first resolution is simply to address this issue.

Anonymous: Do you expect that the increasing cost of liability insurance is going to make consulting firms more reluctant to hire faculty members during the summer months?

Davis Ford: Not necessarily, but that is part of it. The other part is that it is going to make faculty more reluctant to take on consulting jobs and to work for consultants. There was also some discussion as to liability professors have in terms of omitting certain things in their design courses and what exposure they may have. I frankly think that it is very small exposure. There have been suits in that regard, but I do not think there have been any successful suits.

There was a very interesting article in Wall Street Journal about four to five weeks ago on what physicians are doing. Namely, they are dropping their insurance, keeping their practice, and shifting assets. There are lots of ways, very ethical and proper ways, of shifting assets in corporations, to provide another layer of protection. There was universal support for this.

Resolution Number 1 passed without opposition.

Davis Ford: I would like to go to Resolution Number 2. Be it resolved that we encourage the use of computers as teaching tools to enhance training in design.

Resolution Number 2 passed without opposition.

Davis Ford: Resolution Number 3: Be it resolved that hazardous waste management and remediation be included and expanded in future design courses. We discussed this briefly Monday. The big question here was whether to incorporate it in our present design courses or create new courses.

Fred Pohland, Georgia Institute of Technology: You should eliminate "and remediation." Part of hazardous waste management is remediation.

Davis Ford: There was some discussion on that. I agree with you. Maybe we can alter that by striking "and remediation"? Do we have any comments in that regard?

Fred Pohland: To anybody that teaches hazardous waste management, remediation is an integral part of the hazardous waste management. I could read it to say hazardous waste management and its remediation, which makes absolutely no sense.

Edward Thackston, Vanderbilt University: If you are going to highlight one aspect of it, you need to highlight some other aspects. Hazardous waste management is an all inclusive term. Remediation is one particular part. Remediation of past problems is only one part, it is an important part, but it is not an overwhelming part. I don't really think it makes any sense to highlight one without putting a few other things in there to at least get some idea of the scope.

Davis Ford: Will you put it in the form of a motion before the floor, that we strike "remediation"? Let's act on that motion, then we will get back to the resolution. It has been moved and seconded that we strike "remediation" from the motion. Is there any discussion on that motion?

Stacy Daniels, Dow Chemical: As a practitioner, I support hazardous waste management as a collective term.

Don Aulenbach, Rensselaer Polytechnic Institute: I think one of the discussions we had was that the management implies ongoing wastes, whereas remediation implies those discharged previously.

Fred Pohland: I strongly object because that is a reactive posture to the way EPA happened to segregate old sites from new sites, and I don't think we should be led in that direction.

Ryan Dupont, Utah State University: I agree with separation. If you look at the fundamentals and the problems associated with ongoing activities in plant versus soil contamination and in situ treatment, there really are two different topical areas, and I think they should be separated. Fundamentally they are different.

The motion to strike "and remediation" from the resolution carried.

Charles O'Melia, Johns Hopkins University: I would like to bring us back to one of the discussions about mass balances. It is a good idea to have mass balances in education. There are several resolutions here which say we want things included in the curriculum, and I think that that means you have to take something out. We don't address what we are going to take out here. Since we can't do that this morning, I would like to see this collection of resolutions altered to say that we recommend or encourage that this be done, but not that we say that this must be done in design courses, because that means something else has to come out of design courses.

Davis Ford: That is a good point.

Charles O'Melia: If we think we can create time, then this is fine, but if we cannot create time, I think we have to do it a little bit differently. I would like us to say that we encourage that hazardous waste management be included.

Davis Ford: Would you like to put that in a formal motion?

The motion has been made and seconded that we use the word "encourage" in Resolution Number 3.

The amendment carried.

John Andrews: AEEP did form a Committee to study the issue of how we should incorporate hazardous waste into our teaching and research programs. If you would like to have input to that Committee, the Chairman is Jim Patterson.

Davis Ford: I would like to say, representing the consulting community, that there is going to be more and more demand for a university product who has good formal training in hazardous waste management.

The amended resolution Number 3 passed without opposition.

Davis Ford: Resolution Number 4: Be it resolved that operation and maintenance, including process dynamics and control, be included and expanded in future design courses.

Charles O'Melia: I make the motion that we use the word "encourage".

The amendment was seconded and carried.

Davis Ford: A question considered by the Committee was what do we mean by operation and maintenance? There is the pure definition of O&M, which was the original intent. It goes past that though, and that is process dynamics. John Andrews had some input on that, and I would like him to comment on it.

John Andrews: I encouraged the use of the words process dynamics and control. Chemical engineers have for years included a course in process dynamics and control in their undergraduate curriculum. I consider that to be very useful for operation of wastewater treatment plants. One has to understand the dynamics of the process.

Aarne Vesilind, Duke University: I have trouble supporting the encouragement of plant maintenance in a graduate course. I don't wish to teach students how to change pump seals. If operation embraces process dynamics and control, I agree; but, if maintenance implies how to tear pumps apart, I disagree.

Davis Ford: Let me respond to that. We are not talking about pulling seals on pumps or changing impellors or things like that, but M goes with O. I think that was the reason we just said O&M. Certainly it is not the intent of the committee to get involved in any kind of maintenance in the traditional sense, but I think it might be irresponsible to leave it out. We are talking about O&M and sensitivity to that, plus process dynamics as compared to just teaching design. We may want to change some wording on that if you have some ideas.

David Long, Penn State University: I would suggest that we encourage that O&M considerations, including process dynamics and control, be included. I think that in design of facilities considerations that affect O&M are important, but not the act of maintaining or the act of operating.

Thomas Keinath, Clemson University: I think in that light it would be good to use the words operability and maintainability.

Davis Ford: That is a good suggestion. Can we have that in a form of a motion? All in favor of the amendment signify by a show of hands. Any more discussion on Resolution Number 4 which now reads: Be it resolved:we encourage that the operabilitity and maintainability, including process dynamics and control, be included and expanded in future design courses.

Khalil Atasi, Wayne State University: I would like to see the word "including" removed because process dynamics is not part of O&M. Process dynamics is a different topic.

David Long: Over the years EPA has held several workshops and seminars to address the issue of operability and maintainability and there are a number of materials that are available to teaching faculty to point out the problem areas with respect to these two items.

Edward Thackston: I believe Khalil is right. We need to change the wording, because process dynamics and control is not a part of operability and maintainability.

It was moved and seconded to replace "including" with "and." The amendment passed.

Fred Pohland: Why is the word "future" used in Number 3 and Number 4? It really doesn't make a lot of sense.

Davis Ford: I will do that from the chair. Strike the word "future." I am not too sure we ought to be too quick to denigrate O&M as part of a design course, because I have seen as many as you have, good O&M's save a design. I think that should be factored into design courses, and operability and maintainability is a good way of putting it. Be it resolved we encourage that operability and maintainability, and process dynamics and control, be included and expanded in design courses.

The resolution passed without opposition.

Davis Ford: Let's go to Resolution Number 5. Be it resolved that functional design should include the appropriate integration of forensics, regulation, finance, ethics, in-plant control and conservation, risk assessment and management, and the private practice of engineering and that these items (and others) be an integral part of design. This is rather soft language, and a wish list, but we felt like it was important to include these sub topics into design. The relative emphasis given to each topic, of course, is up to the option of the professor. Although, I personally think, as does the committee, that these are very important.

Charles O'Melia: I agree that they are integral parts of design. Do you mean that they should be integral parts of design courses?

Davis Ford: We mean to encourage the use of these in design courses as an integral part of the design problem.

James McKeown, National Council for Air and Stream Improvement: I suggest we also include the word "safety" here.

C. Robert Baillod, Michigan Tech University: One important consideration here has to do with the way design credits are counted, particularly in a school using the quarter system. Sometimes you segregate things into three courses where you otherwise would have two courses and when topics such as risk assessment and economics which may seem rather soft, are segregated into a separate course. There is some tendency to not count them as design. The intent here is to allow a broad base design course that deals with the integration of all these things to be counted as engineering design. That is one of the considerations.

Charles O'Melia: I support that.

David Long: I also support that.

Eugene Glysson, University of Michigan: How does the private practice of engineering come under functional design?

David Long: I think in our discussion, that what we are trying to do is to make the students who are in a functional design course aware of the fact that the practice of engineering is a business and it is the one opportunity to make this point. What we were thinking of in terms of functional design is a truly integrated design course as opposed to the design components of a physical chemical treatment course or a biological treatment course.

Eugene Glysson: What does that have to do with private practice? It is either a design course or it is not. It doesn't matter if a person is going into private practice, going into a regulatory agency, going into equipment sales or whatever. I don't think that the word "private" is appropriate here.

David Long: I think it is important for students to be aware of what is involved in private practice in engineering, and the thought was that it does tie in with some of the decisions that are made during design.

Davis Ford: I might comment on that. I would say that historically 60-70 percent of students that I have taught have gone into private practice. It is important that they understand overhead, insurance, and profitability.

Eugene Glysson: The public sector also needs a balance sheet to function.

Davis Ford: These considerations are not exclusive to private practice.

Eugene Glysson: I think that maybe the word "private" is the wrong thing to put in there, just say practice of engineering. You could say public just as well as private.

C. Robert Baillod: How about professional practice?

Gene Glysson: That is okay. I just don't see that there is anything sacred about private.

Michael Humenick, University of Wyoming: I would like to support the language as it is, so that the students who go out to the regulatory agencies and industries are sensitized to what the consulting engineer does to put a design together.

Khalil Atasi: I am not sure that risk assessment fits here.

Davis Ford: Again, it is part of that desirable list. Risk assessment, particularly in hazardous waste, is becoming a very big sub topic. It could almost be a course in itself. We just simply included it in the list of things that are desirable. Environmental risk assessment is where the interest would be.

Khalil Atasi: I think that this is too ambitious.

Perry McCarty, Stanford University: Resolution 5 as stated says nothing about education or teaching of courses that have to do with design.

Davis Ford: We could add "design course." Your point is well taken.

Fred Pohland, Georgia Tech: The last clause is redundant. You are already integrating these things into the design course and you repeat that it should be an integral part of design, which is a redundant statement. I would just strike the part following engineering.

Davis Ford: That is a good point.

C. Robert Baillod: This relates back to the point I made earlier. Part of the intent was to define design as including these things for the purpose of allowing instruction in these topics to be totaled as design credits. It is one thing to say risk assessment should be included in design courses, and something more to say that risk assessment really is an integral part of design.

Fred Pohland: ABET would not look at ethics as a design issue.

Discussion ensued concerning whether it would be appropriate for ABET to count instruction in ethical considerations as part of design.

Perry McCarty: Stated that: Incorporation of ethics into instruction is an important consideration in accreditation. It is appropriate to incorporate it into various parts of our courses and especially in design. No one should discourage the treatment of ethical considerations in the context of a design course.

Paul Jennings, Florida Institute of Technology: Florida Institute of Technology just went through ABET accreditation last fall, and we include ethics as part of the senior plant design course as one of the topics in the course outline. We counted it as design and were not questioned. We received no adverse comment about it. So apparently, our visitor considered it to be part of design.

Based on the friendly amendments offered in the discussion, the Chairman modified the resolution to read: <u>Be it resolved that we encourage that functional design courses should include the appropriate integration of forensics, regulations, finance, ethics, in-plant control and conservation, risk assessment and management, safety, and the private practice of engineering.</u>

The amendment passed by majority.

Discussion was opened on Resolution 6: <u>Be it resolved design courses should be taught by registered professional engineers.</u>

Davis Ford: This precipitated a lot of discussion. We talked about adjunct engineers, or professors who have been in practice, we decided to condense all of that to just simply registered professional engineers. This was the topic of discussion yesterday and the day before, and it will be the topic of discussion in the year 2000.

Carlos Diaz expressed strong objection to the resolution. Discussion ensued concerning *whether or not the practice of engineering through the teaching of design should require professional registration. Comparisons were made with the legal and medical professions.*

Dennis Clifford, University of Houston: It was mentioned by Earnest Gloyna that in the state of Texas, where we are from , the teaching of engineering is considered the practice of engineering and everybody who is in engineering and has that in their title must be a Professional Engineer in the state of Texas.

Charles Haas, Illinois Institute of Technology: Davis, I think you raised a false issue. Sure you need to be a bar-admitted lawyer to practice law and a licensed M.D. to practice medicine, but I am not sure that you need to be a bar-admitted lawyer to teach law, nor do you need to be a licensed M.D. to teach medicine, so it is a false note.

Davis Ford: The point I was making is that passing the bar or passing the medical exam, or passing the professional engineering exam, of course does not make you a better or worse engineer. That is not the point at all. The point is that if you are a professor and you get involved in consulting or forensic or any other works that go beyond the classroom, registration is necessary, and I would consequently say that you limit yourself personally, and professionally, by not being registered.

Jon Liebman, University of Illinois: I have a number of problems with this one, most of which I will just be quiet about. But when one starts to think about ABET and definitions of design, I think there is a real problem here. In item 5, we just used a broad definition of design. There are really two things hiding in here. If you are talking about a design project course, I have much less problem with this. But if you are talking about courses which we use to satisfy ABET requirements for so many hours of design, and in there you include forensics, which might well be better taught by a lawyer, or risk assessment and management, which might well be better taught by somebody with probability background who is not a registered engineer, then I see a problem.

Davis Ford: I agree with that. Let me speak for the committee and then I would like some of the members of the committee to speak. I think it was our intent to deal with design courses as per our definition, and there are those who would even disagree with limiting it to that. But that was our intent, which I think is consistent with what you stated.

Jon Liebman: I would like to put in form of a motion that design courses be termed design project courses.

The motion was seconded and opened for discussion.

Davis Ford indicated that the committee had been using the term functional design to indicate a design project course.

Ronald Neufeld, University of Pittsburgh: It is an excellent point to distinguish the ABET concept of design credits from a more comprehensive design course that either a graduate or undergraduate student might take, that would incorporate functional design giving some exposure to practical problems.

Fred Pohland: I don't know what a design project course is. I think the real issue here is whether or not we want to have registered engineers teach design, and the design element of a design course could well be taught by such an individual. You could bring in your lawyers for the forensics or whatever you wanted to do for that particular course. Perhaps what we ought to do is just strike the word "courses" and just say design should be taught by registered professional engineers.

Richard Luthy, Carnegie Mellon University: I don't like Resolution Number 6 either, and I would try to modify it by saying that design courses should be taught by competent professionals, period.

Davis Ford: We still have a motion on the floor that we simply change this to design project and we will continue discussion on that.

David Long: I think the committee intent in developing this resolution was to deal with courses such as those described in the position paper. I don't think there was any intent to broaden that to include any design output of any course that was taught. The main intent was that the design project course such as the ones outlined in the position paper would be taught by registered professional engineers.

Dennis Clifford: The ABET statement on engineering design goes something like, design considers alternative solutions to a problem along with economic considerations. The point is that ABET has a definition of design. I think that we need to separate that definition from what we are talking about here, which is a design project course. It is a good point and I think we should make it.

The amendment to replace design courses by design project courses carried by majority.

Charles O'Melia: I have some practical problems myself with this. On behalf of the undergraduate students at Johns Hopkins, I oppose this motion on the grounds that Bouwer can't teach our design course. I would have to teach it and the students would have to suffer with me. I think it would be difficult to implement with young faculty coming right out of school. I want them and I think they also want to do undergraduate teaching where there is some design. I am opposed to the motion as amended. I am sympathetic with its goal.

E. Robert Baumann, Iowa State University: Why don't you add "we encourage that"?

Charles O'Melia: That is what I am getting to, Bob. I am saying that this absolute statement is, first of all, not practical for me. I dislike it on those grounds. I also think that it is not really good educational practice.

It was moved and seconded that the motion be amended to read: Be it resolved that we encourage that design project courses should be taught by registered professional engineers.

Ronald Neufeld: Environmental engineering is a rather broad area, and we should encourage the utilization of distinguished practitioners in our neighborhood, particularly in places like Boston, Pittsburgh or Cincinnati, where they are appropriate. I think in the design course where it might be beyond the expectations of our standing faculty members to teach such a course, it might not be unreasonable to get the few thousand dollars necessary to use a qualified practitioner as an adjunct faculty. Having said that, with a design course, the good design engineering firm has a lot of vested interest in seeing that such courses are available at the local university, primarily because they can draw from that local university. Resolution Number 6 may have implicit in it perhaps some dollars, whether they come from gifts or hard money for the support of such courses. It doesn't mean that the adjunct faculty should not be under some supervision perhaps, or be accountable to the faculty for such courses, but I am encouraging the judicious use of adjunct faculty as appropriate, and I think it is appropriate here.

Charles O'Melia: I am encouraging that judicious use, but I do not want to require it. I absolutely do not want to require it.

John Andrews: I like Charlie's word "encourage." It is a long term way of moving towards the goal. We do wish to encourage more team effort and cooperation between us and practitioners.

Paul Roberts, Stanford University: I teach the hazardous waste course at Stanford. I am not a registered professional engineer. It is not high on my list of priorities to become registered. I don't think the course would be better taught if I were registered, and I oppose that resolution even as amended.

The amendment to insert the word "encourage" passed by majority.

Davis Ford: The resolution currently before us reads as follows: We encourage that design project courses be taught by registered professional engineers. Let's get back to discussion on that, and we are going to have to cut it fairly short. Any more comments?

Stacy Daniels, DOW Chemical: As an adjunct professor in training for 30 years but not a professional engineer, I think I have just been fired. A lot of us in industry who enjoy teaching are not registered. This is particularly true of the chemical engineers. I can't speak in precise figures, but one professional engineer in 100 engineers would not be unusual in industry.

Davis Ford: I speak not as a university administrator, but they always do have a different perspective. I could speak as an adjunct professor and I can certainly be sympathetic to some of the comments I have heard, including Paul's, but then I speak as a student and I might have a different view. There are all different kinds of views, and we understand this. I simply say that the resolution had unanimous support in our committee. We are bringing it before the floor. I would like to bring it to a call fairly soon.

Perry McCarty: I will just add a couple of comments, because I am not supportive of the resolution. In our group at Stanford, those who are registered are not the most competent to teach our design courses, and those who are teaching them are not registered, so I find that a problem. Registration is necessary to assure that practicing engineers have a minimum of competence in the broad professional aspects of civil engineering. However, registration is not intended to insure that one has expertise in environmental engineering design, and in fact, one needs no experience in such design to become registered. Thus, engineering registration is not an appropriate criterion.

Davis Ford: Perry made some good points. Unfortunately, Perry, it is not black and white. We might have a resolution that won't carry unanimously.

The resolution carried by majority.

Davis Ford: Let's move on to Resolution 7. There is a reason for putting this in. Be it resolved that the undergraduate degree programs allowing specialization in environmental engineering, while maintaining breadth, are encouraged. Do you want to comment on that, Bob?

C. Robert Baillod: We discussed some of the controversies that have surfaced in the past among undergraduate and graduate programs, and we decided to try to skirt that issue of undergraduate programs and realize that environmental engineering is a real profession and needs some sort of a foothold in the undergraduate curriculum, be it in a specialty of one of the other larger branches, civil or chemical, or be it as its own identified as such, depending on the situation at the institution. The important thing is not so much what we call it, but that it is encouraged to exist and begin at the undergraduate level.

Davis Ford: Do we have any discussion on that?

Bill Batchelor, Texas A&M University: I am not sure that I could support it as it is. I think that if we can just snap our fingers and have undergraduate environmental engineering programs, that might be good. But if we are encouraging undergraduate engineering programs now, we may be doing a disservice to some students who find that degree is less marketable than a more easily.

C. Robert Baillod: That is not what it says. It encourages programs allowing specialization in environmental engineering, but not necessarily degree programs in environmental engineering.

Charles O'Melia: I am a little worried about this question of tradeoffs and balances. When you decide you are going to do something you always have to give up doing something else, and I don't think I have had enough time to think about this. We have not had any discussion about what we are going to give up in order to implement this resolution, and I am worried about it. It just is not going to happen without not doing something else. Students are going to be here or there, they can't be in two places.

C. Robert Baillod: We may not have to give up anything. I think that to a certain extent, this is what we already have.

Charles O'Melia: There isn't any free lunch, you know.

Dennis Clifford: In answer to Bill Batchelor's comment, I think Earnest Gloyna's Keynote Address was encouraging an undergraduate program followed by a graduate program. We never discussed that issue at any great length. Maybe it doesn't fit in design, but still, I would like to hear the sense of the group regarding whether we should encourage undergraduate environmental engineering.

Charles O'Melia: Davis, I don't want to vote against the motion. We can have discussion, but I would like to consider tabling the motion because I don't think we have time to discuss it, and I don't know what to do about it.

Davis Ford: Do you make a motion that we table the resolution?

Charles O'Melia: That is what I would be inclined to do. If you would want to discuss it more I would be happy to listen, but I don't want to vote on it.

A motion to table the resolution was made, seconded and passed.

Davis Ford: We have approximately 10 or 12 minutes to stay within the time frame. Actually, we have gone way over our 45 minutes. Let's go next to Resolution 8. Be it resolved:Up to one-fifth year of advanced (beyond first courses in chemistry and physics) quantitative physical or natural science courses which have environmental engineering applications can be counted as engineering science in satisfying ABET requirements. The genesis of that is probably in the chemical engineering requirements which says essentially this.

Thomas Keinath: Does this refer to basic level accreditation?

Davis Ford: Yes, basic level might be indicated to distinguish it from advanced.

C. Robert Baillod: We got this idea from the ABET program criteria for chemical engineering under curricular objectives and content. The chemical engineering guidelines say, "Up to one fifth academic year of advanced chemistry may be counted toward the engineering science requirement, provided that such advanced chemistry demonstrates an application of theory that qualifies it as chemical engineering science." That is where this came from. Chemical engineers have run into the problem of coming up with enough engineering science courses without using some of their chemistry. I think we are in a similar situation where our profession is broadly science based. Not only do we need chemistry, we need geology, and we need biology. We are not proposing here that all sciences be counted as engineering sciences, but only those such as, for example, physical chemistry, which are quantitative and have applications to environmental engineering. One-fifth year would be approximately six or seven semester credits.

Leslie Grady, Clemson University: Point of order, Mr. Chairman. This Resolution is not relevant to the topic of design and operation.

Davis Ford: That same question was raised in our discussion. Let me have additional comments.

Perry McCarty: My comment is that I did not understand the term "satisfy ABET requirements." Does this refer to civil engineering undergraduate requirements or what?

C. Robert Baillod: This was prompted by Resolution 9 which referred to ABET criteria for basic level accreditation. We are dealing with basic level ABET accreditation for graduates of environmental engineering programs that use the word engineering in the degree title.

Ronald Neufeld: These are actually rather significant resolutions, Number 8 and Number 9. They do broaden our focus now from what is a design course. There is no question about that. It broadens the focus of the question to what are we graduating, what are we producing. We are producing engineers. We take a student who comes in with a biology degree or chemistry degree, for example, and we say that he has to take certain kinds of courses to be an engineer. Resolution Number 8 says that the student who comes in with a chemistry degree, with advanced physical chemistry and organic chemistry (things that we use in our profession as tools in design) we can count a portion of these toward the engineering science accreditation requirement. By the time he finishes the program, BS plus the MS, he has that area. Resolution Number 9 says that by the time he finishes his BS and MS he has the courses in the design area. It says to us that we should have a distinction between those who have taken that additional coursework, so that we can call them master of science engineers as opposed to those who have not taken it, who perhaps we should not call engineers. So Resolutions 8 and 9 are really a package because they do broaden our scope beyond that "design" course to the question of what is our problem?

Davis Ford: I am going to stop at this point and rule a point order which can be appealed, but in order to make it simple in concert with the Conference Chairman, we are going to pull this resolution out from under the design aegis and put it as a floating resolution for the overall conference. Does that solve the point of order? We will handle it that way. We will go to the resolution outside of design, and we have about 30 more seconds for comment.

David Long: Program criteria for accrediting environmental engineering programs are now being developed through the Academy for ABET and part of the intent of getting these two resolutions before the body was to get some guidance for preparation of those criteria.

Additional discussion dealt with the possibility of broadening the resolution to include courses in biology.

The resolution passed in its original form.

Davis Ford: We have a very brief period of time and one more resolution and I understand there may be some more resolutions from the floor. John is going to present a resolution. The chairman is going to leave soon but we can continue. I want to clean up my act first and that is Resolution Number 9, which is our last resolution: Graduates from programs in environmental engineering shall have satisfied the minimum ABET criteria, and functional design and synthesis is an integral component of these criteria (concern is expressed about the pure definition of ABET criteria). This again gets into the definition of design and ABET and that is somewhat of a problem.

Charles Haas: Being environmental engineers, and dare I say scientists in this room, I think many of us as the pure culture are highly unstable and often become extinct. I see a danger of that scenario in Resolution 9. I think many of us have good programs that have done well, and have taken a hybrid number of individuals and turned out a good product without necessarily meeting the requirements of ABET or somebody elses list. I find Resolution 9 objectionable, in that it tells us that we are doing something wrong, when I do not in fact believe we are.

Edward Thackston: May I ask a question first? Does this refer to graduate programs or undergraduate programs?

David Long: We are really talking about graduates who have engineering in the title of their degree.

Don Aulenbach: The word "engineering" was underscored in our original copy.

Edward Thackston: I will have to oppose it also because we take a number of people into our program with nonengineering degrees. We make them take a large number of background courses for no credit, depending on what they lack, in addition to all their graduate work, and we turn out, although a somewhat narrower product than a traditional civil engineer, we think a very good product. We do not worry about satisfying the exact number of credits in all kinds of categories. We believe that that is right for us. It may not be right for others, and I would really hate to see a start to being restrictive here and applying criteria which were designed for traditional undergraduate programs to other situations, and reduce the flexibility of some programs. Even if it is not a requirement, it still implies desirability and I don't agree with it.

Davis Ford: If you go back and read our position paper, I indicated that I had for a long period of time received a lot of science majors in the graduate course of design. I saw no difference in their ability to do design as compared to the engineering undergraduates. In fact they were nervous to the point that they tried harder, and in many cases did better. So I think that experience pretty well compliments what you are saying.

Ronald Neufeld: The students who come from biology and chemistry are superior students and they do succeed because they are superior to start with. If you take a look at what this says - it says that there is a distinction between a student who graduates with environmental courses and those students who graduate as full engineers.

Charles O'Melia: Just one point, I am going to vote against the resolution for a slightly different reason. We give our master of science in environmental engineering. We require all students that are admitted to our program to have an ABET accredited undergraduate degree. My concern is with the environmental part. I don't want ABET telling me what environmental is, and I am going to vote against it on those grounds.

The resolution failed.

C. Robert Baillod: I would like to recognize and thank the Michigan Tech students who have helped us and assisted us in so many ways during this Conference: Jim Miller, Pamela Hollingsworth, Tim Rigg, Vicki Jutila, Jennifer Miller, and Jim Andreini.

Robert Baumann: Closing remarks - I would like to move that this meeting go on record expressing our appreciation to the Academy, to AEEP and to Michigan Tech University for creating this opportunity to discuss environmental engineering education.

Leslie Grady: The Academy is one of the joint sponsors to this and most of our resolutions have been apple pie and motherhood sort of resolutions. I would like to propose the following resolution:

That the American Academy of Environmental Engineers should be encouraged to take a leadership role in developing and providing educational materials such as case studies, project reports, plant investigations, design manuals, etc. for use in graduate level functional design courses.

Passed by acclamation.

C. Robert Baillod: The meeting is hereby adjourned.

RESOLUTIONS RELATING TO THE ROLE OF COMPUTERS
AS AMENDED AND BROUGHT TO VOTE

1. It is desirable that students entering graduate environmental engineering programs be able to do the following:

   a. prepare simple programs in a high level language.

   b. use wordprocessor and spreadsheet programs.

   c. understand the limitations, strengths and weaknesses of major numerical methods.

   Passed without opposition.

2. Graduate curricula in environmental engineering should emphasize basic understanding of processes and mechanisms and the mathematical expression of these principles through models. Graduating M. S. students should be able to implement these models on a computer. In addition, the students should recognize the limitations of the model computations. In order to spend more time on the formulation and interpretation of the problem, students should also be exposed to commercially available programs that reduce the computational and solution effort.

   Passed without opposition.

3. Easy access to both personal and mainframe computers is important. Accordingly, students should be encouraged to buy their own personal computers and universities should establish programs to facilitate their acquisition. In order to facilitate the implementation of computing into coursework, universities should provide personal computers to all engineering faculty and should provide easy access to computer labs for student use.

   Passed without opposition.

4. AEEP should establish a standing committee on Computer Applications. The charge of the committee is to encourage development and distribution of computer applications in environmental engineering. Specific objectives of the committee should include updating the computer software manual, active solicitation of the support of professional organizations through seminars and workshops, and encouragement of state and federal agencies to fund the development of computer software.

   Passed without opposition.

5. University administrators should provide support for the development and integration of computers into the curriculum, namely, teaching assistantships, software developers, release time, summer support, hardware and purchase of commercial software. Developing software for classroom instruction should be recognized as a creative and demanding activity, for which due credit should be given in career evaluation.

   Passed without opposition.

6. To avoid legal and ethical problems that may arise with the educational use of proprietary software, faculty should make sure students are aware of the ethical considerations relating to copy restrictions and the consequences of violating them. Classroom assignments should incorporate available freeware and shareware, where feasible; otherwise Universities should seek site licensing agreements that allow students to acquire proprietary software at an affordable cost. Software vendors should be encouraged to make software available to students at a reasonable price.

   Passed without opposition.

7. In order to provide a variety of educational opportunities, graduate curricula in environmental engineering programs should include exercises in advanced computing applications such as simulation, process control, data acquisition, and artificial intelligence.

   Passed without opposition.

RESOLUTIONS RELATING TO INTEGRATED AIR-WATER-LAND APPROACHES IN ENVIRONMENTAL ENGINEERING EDUCATION

AS AMENDED AND BROUGHT TO VOTE

WHEREAS environmental engineering involves understanding transfer and transformation of substances in the land, air, and water media, design and operation of control and management systems, environmental systems analysis, and assessment of numerous risks from a variety of sources, and

WHEREAS, schools and programs differ greatly in their goals, approaches, faculty interests and capabilities, resources and facilities, and most university programs are addressing this issue in varying degrees, there is a need for underscoring certain main themes which should be incorporated in these educational programs

THEREFORE, BE IT RESOLVED THAT:

Environmental engineering programs should include educational elements that focus on multimedia problems and incorporate an integrated approach to their solution and these programs should provide the graduate with

(a) a strong background in science and engineering fundamentals,

(b) technical competence in an environmental engineering specialty,

(c) an appreciation for limitations on data acquisition and availability for adequately characterizing multimedia problems, and

(d) sufficient familiarity with other engineering and science specialties to be able to communicate and work effectively to solve multimedia problems.

BE IT FURTHER RESOLVED THAT

Practicing professionals from the industrial, governmental, and consulting sectors should be encouraged to participate actively in the development and implementation of integrated multimedia environmental engineering programs.

Teaching and research faculty should seek and utilize opportunities for professional development in the solution of multimedia problems. Academic institutions should recognize this need and encourage and support such activities on a routine basis.

An organized national effort should be undertaken to develop and provide for the effective use of educational materials supportive of teaching integrated approaches. AEEP should take the lead in doing this.

Passed without opposition.

RESOLUTIONS RELATING TO THE ROLE OF DESIGN AND OPERATION

AS AMENDED AND BROUGHT TO VOTE

1. Be it resolved that: We express concern that liability of practicing engineers will have an adverse effect on the ability of faculty members to get functional design experience.

   Passed without opposition.

2. Be it resolved that: We encourage the use of computers as teaching tools to enhance training in design.

   Passed without opposition.

3. Be it resolved that: We encourage that hazardous waste management be included and expanded in design courses.

   Passed without opposition.

4. Be it resolved that: We encourage that operability and maintainability, and process dynamics and control be included and expanded in design courses.

   Passed without opposition.

5. Be it resolved that: We encourage that functional design courses should include the appropriate integration of forensics, regulations, finance, ethics, in-plant control and conservation, risk assessment and management, safety, and the private practice of engineering.

   Passed by majority.

6. Be it resolved that: We encourage that design project courses should be taught by registered professional engineers.

   Passed by simple majority (36 - 29).

7. Be it resolved that: Graduates from programs in environmental engineering shall satisfy the minimum ABET criteria for a basic level engineering degree. Functional design and synthesis is an integral component of these criteria.

   Defeated by majority.

OVERALL CONFERENCE RESOLUTIONS AS BROUGHT TO VOTE

1. Be it resolved that: Up to one-fifth year of advanced (beyond first courses in chemistry and physics) quantitative physical or natural science courses which have environmental engineering applications can be counted as engineering science in satisfying ABET requirements.

   Passed by majority.

2. Be it resolved that: The American Academy of Environmental Engineers should be encouraged to take a leadership role in developing and providing educational materials such as case studies, project reports, plant investigations, design manuals, etc. for use in graduate level functional design courses.

   Passed by acclamation.

CONFERENCE PROGRAM AND SCHEDULE

MONDAY, July 21, 1986

7:15 am	Organizational Breakfast Meeting (Steering Committee, Task Committee Chairs, Program Speakers Software Demonstrators)
8:00 am	Registration
9:00 am	Call to Order and Opening Remarks
-	*C. Robert Baillod, Conference Chairman*
-	Welcome
-	*Dale F. Stein, President, Michigan Technological University*
-	Introductions and Brief Remarks:
-	*John F. Andrews, President of AEEP*
-	*Leo Weaver, President of AAEE*
-	*Ed Bryan, National Science Foundation*
9:30 am	Keynote Address
-	*Earnest F. Gloyna, Dean of Engineering, University of Texas*
10:15 am	Program Status Report
-	*J. Jeffrey Peirce, Duke University*
10:40 am	Role of Computers in Environmental Engineering Education and Research: Position Paper Summary and Discussion
-	*Walter J. Weber Jr., University of Michigan*
-	Resource Panel Presentations: *J.C. Crittenden, Moderator*
11:00 am	The Clarkson University Experience, *Joseph V. DePinto*
11:10 am	Numerical Methods and Trends, *Raymond P. Canale*
11:20 am	Accessibility of Computers and General Purpose Software, *Jon C. Liebman*
11:30 to 11:50	Open Discussion
11:50 am	Luncheon
-	Speaker: *John F. Andrews, Rice University, President AEEP*
1:00 pm	Integrated, Air, Water, Land Approaches in Environmental Engineering: Position Paper Summary
-	*James J. McKeown, National Council for Air and Stream Improv.*
-	Open Discussion From Floor, Resource Panel Composed of:
-	*P. Mac Berthouex, University of Wisconsin, Moderator*
-	*Yoram Cohen, University of California, Los Angeles*
-	*Stacy L. Daniels, Dow Chemical Company*
-	*James J. McKeown, NCASI*
-	*William E. Thacker, NCASI*
-	*Doug Wallace, EDI Engineering and Science*
2:00 pm	Role of Design and Operation in Environmental Engineering Education and Research: Position Paper Summary
-	*Davis Ford, Davis Ford & Associates*
-	Open Discussion From Floor, Resource Panel Composed of:
-	*E. Robert Baumann, Iowa State University, Moderator*
-	*Davis Ford, Davis Ford & Associates*
-	*Earnest F. Gloyna, University of Texas*
-	*Rudy TeKippe, James M. Montgomery Inc.*

3:00 pm	Organizational Meetings of Task Committees
3:30 pm	Adjourn

Banquet and Social Hour, Keweenaw Mountain Lodge, Copper Harbor; Followed by Lake Superior Sunset Cruise on the Isle Royale Queen.

TUESDAY, July 22

8:00 am to Noon	Concurrent Forums on Focal Issues

ROLE OF COMPUTERS

8:00 to 9:40	Teaching Presentations Moderator, *Jon C. Liebman, University of Illinois*
8:00 to 8:25	Programs for Water Quality Control Unit Processes, *J.B. Neethling, U.C.L.A.*
8:25 to 8:50	A Phosphorus Management Model for Lake Washington *Martin T. Auer, Michigan Tech*
8:50 to 9:15	General Purpose Software *Steven C. Chapra, University of Colorado*
9:15 to 9:40	Air Pollution *Mackenzie L. Davis, Michigan State*
10 to 11:40	Research Presentations Moderator, *Francis DiGiano, University of North Carolina*
10 to 10:25	Oxygen Dynamics in Green Bay *Ray Canale, University of Michigan*
10:25 to 10:50	Strategies for Using Computers for Biofilm Kinetics Research, *Bruce Rittman, University of Illinois*
10:50 to 11:15	Use of a Solute Transport Model to Aid in Understanding Organic Contaminant Transport in Ground Water *Paul Roberts, Stanford University*
11:15 to 11:40	Modular Construction and Error Analysis of Complex Numerical Models – An Example for Fixed Bed Adsorption *John Crittenden, Michigan Tech*

INTEGRATED AIR, WATER, LAND APPROACHES

8:00 to 11:40	Presentations and Discussion Moderator, *William Thacker, N.C.A.S.I.*
8:00 to 8:35	A Sampling of Multi-media Approaches in Environmental Engineering: Undergraduate Programs *Nick Clesceri, R.P.I. and Paul Jennings, Florida Institute of Technology*
8:35 to 9:10	Intermedia Problems in Acid Precipitation *Charles Driscoll, Syracuse University*
9:10 to 9:40	An Integrated Systems Approach to Environmental Education at U.C.L.A. *Yoram Cohen, U.C.L.A.*
10 to 11:40	Presentations and Discussions Moderator, *Fred Pohland, Georgia Tech* (Joint Session with Design and Operation Group)

10 to 10:35	Need for an Integrated Approach in the Consulting Profession *Doug Wallace, EDI Engineering and Science*
10:35 to 11:10	Integrated Multimedia Approaches Applied to Management of Industrial Hazardous Wastes *Stacy Daniels, Dow Chemical Company*
11:10 to 11:40	Role of Ethics in Environmental Engineering *Aarne Vesilind, Duke University*

DESIGN AND OPERATION

8:00 to 9:40	Presentations and Discussions Moderator, *Paul Busch, Malcolm Pirnie Inc.*
8:00 to 8:35	Current Role and Status of Design and Operation *Rudy TeKippe, James M. Montgomery Inc.*
8:35 to 9:10	Requisites for Competence in Design and Operation *E. Robert Baumann, Iowa State University*
9:10 to 9:40	Recommendations for Improving Education in Design and Operation *Earnest F. Gloyna, University of Texas*
10:00 to 11:40	Presentations and Discussion, (Joint Session with Integrated Approaches Group as noted above)
12:00 to 1:00	Task Committee Working Luncheon
1:00 to 5:00	<u>Concurrent Sessions:</u> Task Committee Expanded Discussion and Writing Sessions. Computer Group: Chairman, *John C. Crittenden* Integrated Approaches Group: Chairman, *P. Mac Berthouex* Design and Operation Group: EERC, Chairman, *Davis Ford*
1:00 to 5:00	AEEP Software Manual Exposition by Program Authors Informal Demonstrations by Program Authors Using 20 Microcomputer Work Stations

Biological Treatment

Packed Bed Biofilm Reactor Model (IBM PC), *F.A. DiGiano and N.W. Chang*

Unified Carbon and Nitrogen Oxidation and Denitrification Model for Single Sludge Reactors (IBM PC), *Les Grady*

Strategies for Using Computers for Biofilm - Kinetics Research (MAC), *Bruce Rittman*

Models for Activated Sludge Design (IBM PC), *Herbert E. Klei*

Water Chemistry, Soils, Stripping

MICEL - A Microcomputer Chemical Equilibria Model (IBM PC), *Bill Batchelor*

pC - pH Diagrams for Acid-Base Equilibria (IBM PC), *Walter J. Weber Jr.*

Breakthrough Curves from Soil Columns (IBM PC), *Neil J. Hutzler*

Design of Air Stripping Towers (IBM PC), *David W. Hand*

Adsorption, Risk Assessment, Activated Sludge Systems

Prediction of the Fixed Bed Breakthrough Using Mass Transfer Correlations and a Constant Pattern Solution to the HSDM (IBM PC), *Harish Arora*

Estimation of the Elution Order and Lowest Carbon Dosage Using a Multicomponent Equilibrium Model (IBM PC), *Tom Speth*

Microcomputer Implementation of Risk Assessment for Hazardous Waste Technologies (IBM PC), *Aaron Jennings*

Solids Inventory Control in the Activated Sludge Process (IBM PC), *Tom Keinath*

Programs for Water Quality Control Unit Processes (IBM PC), *J.B. Neethling*

Design and Water Quality Modeling

Unit - An Instructional Computer Program for a Design Oriented Engineering Course (IBM PC with VT 100 Simulator), *Frederick L. Hart*

A Phosphorus Management Model for Lake Washington (IBM PC), *M.T. Auer*

Oxygen Dynamics in Green Bay (IBM PC), *Ray Canale*

Steady-State, One-Dimensional River Network Model (IBM PC), *Jy S. Wu*

5:30	Hospitality Cocktail Hour, Memorial Union Ballroom

WEDNESDAY, July 23, 1986

8:00 am	Wrap-up Meetings of Task Committees
8:45 am	Plenary Session: Presentation of Task Committee Reports,
-	Discussion and Vote on Resolutions
-	Conference Chairman, *C. Robert Baillod*
9:00 am	Role of Computers in Environmental Engineering Education and Research
-	Group Chairman, *J.C. Crittenden*
9:45 am	Integrated, Air, Water, Land Approaches
-	Group Chairman, *P.M. Berthouex*
10:30 am	Role of Design and Operation
-	Group Chairman, *Davis Ford*
11:15 am	Final Wrap-up and Adjournment

ABSTRACTS FOR PRESENTATIONS ON ROLE OF COMPUTERS
AT FORUM ON TUESDAY, JULY 22, 1986

TEACHING PRESENTATIONS

8:00 a.m. J. B. Neethling – *Programs for Water Quality Control Unit Processes.* Simple menu driven microcomputer programs can illustrate the fundamental concepts of treatment processes and the influence of process variables on unit operations.Interactive programs are used to produce a graphical or printed screen output, or a printed listing.Typical programs with accompanying assignments for graduate and undergraduate courses are presented.

8:25 a.m. M. T. Auer – *A Phosphorus Management Model for Lake Washington.* Exposes the student to relationships among water clarity, algal growth, and phosphorus loading through a program which simulates lake response to phosphorus management.

8:50 a.m. S. Chapra – *General Purpose Software for Classroom Instruction*

9:15 a.m. M. L. Davis – *Computer Aided Teaching of Air Pollution Control.* A method of using a combination of available programs and programming assignments to aid in teaching and learning about air pollution control will be presented.Example air pollution programs and assignments will be used to illustrate the methodology.

RESEARCH PRESENTATIONS

10:00 a.m. Ray Canale – *Oxygen Dynamics in Green Bay.* Microcomputer model of total phosphorus, total organic carbon, and dissolved oxygen in Green Bay (Lake Michigan).The overall model package includes a computer graphics system orientation, data management capability, both steady state and dynamic simulations, and management applications.

10:25 a.m. Bruce Rittmann – *Strategies for Using Computers for Biofilm-Kinetics Research* Computer modeling of Biofilm Kinetics can be used predicting or simulating performance of a given reactor for understanding phenomena, and for developing simple and intuitive analysis techniques.Choice of computer hardware and-software should be suited to the modeling goals.

10:50 a.m. Paul V. Roberts – *Use of a Solute Transport Model to Aid in Understanding Organic Contaminant Transport in Ground Water.* A solute transport model which includes adsorption, desorption and mass transfer is used to interpret laboratory soil column experiments to give insight intothe likely controlling mechanisms of organic solute transport in groundwater.

11:15 a.m. John Crittenden – *Modular Construction and Error Analysis of Complex Numerical Models – An Example for Fixed Bed Adsorption.* Modular construction and dimensional analysis of complex models is perhaps the only way to successfully write computer algorithms for complicated problems.Unfortunately, students are rarely taught this in introductory coursework.This will be illustrated in an example for fixed-bed adsorption.

DESCRIPTIONS OF PRESENTATIONS AT INFORMAL SOFTWARE EXPOSITION

TUESDAY, JULY 22

BIOLOGICAL TREATMENT

"Packed Bed Biofilm Reactor Model," Francis A. DiGiano and Ning Wu Chang. The reactor volume to achieve a specified substrate conversion is calculated assuming mass transfer by diffusion through a stagnant liquid layer surrounding the biofilm and diffusion with reaction (Monod kinetics) in the biofilm.

"Unified Carbon and Nitrogen Oxidation, and Denitrification Computer Model for Single Sludge Reactors," Les Grady

"Strategies for Using Computers for Biofilm - Kinetics Research," Bruce Rittman. Computer modeling of Biofilm Kinetics can be used predicting or simulating performance of a given reactor for understanding phenomena, and for developing simple and intuitive analysis techniques.Choice of computer hardware andsoftware should be suited to the modeling goals.

"Models for Activated Sludge Design," Herbert E. Klei

WATER CHEMISTRY, SOILS, STRIPPING

"MICEL - A Microcomputer Chemical Equilibria Model," Bill Batchelor. MICEL is a program to calculate chemical equilibrium in aquatic systems.It is basically a conversion of the FORTRAN program MINEQL to BASIC with the inclusion of interactive input and menu-driven options.The chemical problems solved by MICEL must be able to be described in terms of 43 basic chemical components.Those components can be combined to form soluble species or precipitated solids.Oxidation-reduction reactions can also be considered.A thermodynamic data base is included which can be used to supply MICEL with a relevant species and formation constants. Alternatively, this information can be entered from the keyboard. The set of non-linear equations which describe chemical equilibrium consist of material balance equations for each component and mass action equations for each specie.They are solved iteratively by a Newton-Raphson technique.

"pC-pH Diagrams for Acid-Base Equilibria," W. J. Weber, Jr. The program, PCPH, is an interactive tutorial dealing with the development and use of pC-pH diagrams for acid-base equilibria. The tutorial is designed to accompany an introductory course in aquatic chemistry. The program is written in microsoft Basic version 2.0 and can be used on IBM or IBM compatible systems having a graphics package. The program has five menu-driven options that guide the user throughthe development of pC-pH diagrams for both single and multiple mono and diprotic acid-base systems. Input parameters include Ka or pKa value(s) for the selected acid-base system and the total concentrations of the acids and/or bases in the system.

"Breakthrough Curves from Soil Columns," Neil Hutzler. A model which includes the transport and retardation mechanisms of advective flow, axial dispersion, liquid-phase mass transfer, diffusion into immobile liquid, and local adsorption equilibrium was developed to describe the migration of nondegradable, organic chemicals through a column of saturated, aggregated soil. Analytical solutions to the model were adapted from the literature and solved using BASIC in the attached computer programs. The program is menudriven.The user specifies chemical, soil, and column properties and the program calculates relative column effluent concentration as a function of chemical throughput (normalized time).

"Design of Air Stripping Towers," Dave Hand. The design of air stripping towers is illustrated by selecting the gas pressure drop, type of tower packing, and air to water ratio such that the tower volume and power requirements are minimized.

ADSORPTION, RISK ASSESSMENT, ACTIVATED SLUDGE CLARIFIER

"Prediction of the Fixed-Bed Breakthrough Using Mass Transfer Correlations and a Constant Pattern Solution to the Homogeneous Surface Diffusion Model," Harish Arora. Solutions to the HDSM for single solutes that take less than a minute on an IBM-PC are presented. Correlations for all mass transfer parameters are built into the program and all that is needed are single solute isotherm parameters.

"Estimation of the Elution Order and Lowest Carbon Dosage Using a Multicomponent Equilibrium Model," Tom Speth. A solution to the multicomponent equilibrium column model is illustrated. The ECM calculates competitive interactions between multiple solutes using ideal adsorbed solution theory. It estimates the elution order, highest overshoot concentrations, and lowest carbon usage rate from the single solute isotherm parameters.

"Microcomputer Implementation of Risk Assessment for Hazardous Waste Technologies," Aaron Jennings. Two user-interactive microcomputer codes have been developed to automate a relative risk assessment of alternative hazardous waste management technologies. RISK 1 conducts a deterministic assessment based on the Decision Alternative Ratio Evaluation (DARE) procedure. RISK 2 implements a probabilistic analysis designed to accomodate user uncertainty and imprecise information. Both codes offer extensive user support including default analyses and "expert systems" to help select management technologies and maintain assessment consistency. Both approaches are capable of generating cardinal scale risk penalty functions necessary for quantitative optimization planning.

"Solids Inventory Control in the Activated Sludge Process," Thomas M. Keinath. This menu-driven program allows the user to assess the solids flux loading condition of a secondary clarifier of an activated sludge system of any size and configuration. It also allows the user to implement various solids inventory control strategies when the clarifier is overloaded either with respect to thickening only, clarification only or both thickening and clarification.

"Programs for Water Quality Control Unit Processes," J. B. Neethling. Simple menu driven microcomputer programs can illustrate the fundamental concepts of treatment processes and the influence of process variables on unit operations. Interactive programs are used to produce a graphical or printed screen output, or a printed listing. Typical programs with accompanying assignments for graduate and undergraduate courses are presented.

DESIGN AND WATER QUALITY MODELING

"Unit–An Instructional Computer Program for a Design Oriented Engineering Course," Frederick L. Hart. This program provides instruction to undergraduate civil engineering students (second or third year) on methods of sizing wastewater treatment units.Although brief descriptions and figures of treatment units are given in the program, it is assumed that classroom instruction is being provided along with the use of this program.Complete user documentation is provided within this program.

"A Phosphorus Management Model for Lake Washington," M. T. Auer. Exposes the student to relationships among water clarity, algal growth, and phosphorus loading through a program which simulates lake response to phosphorus management.

"Oxygen Dynamics in Green Bay," R. P. Canale Microcomputer model of total phosphorus, total organic carbon, and dissolved oxygen in Green Bay (Lake Michigan).The overall model package includes a computer graphics system orientation, data management capability, both steady state and dynamic simulations, and management applications.

"Steady-State, One-Dimensional River Network Model," Jy S. Wu A steady-state, one dimensional water quality model was developed to evaluate spatial variations of BOD, DO and NH3-N for nontidal, branched river systems, with point sources of wastes and uniform nonpoint source loads, under aerobic and/or anaerobic conditions. The model is applicable to stream impact analysis under non-storm condition as

well as under sustained wet weather condition, during which storm runoff loads are generated by storms of sufficiently long duration to approach steady-state in the river system.

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