

SCIENCE IN UNDERGRADUATE ENVIRONMENTAL ENGINEERING CURRICULA

M Milke

Lecturer, Department of Civil Engineering
University of Canterbury
Christchurch, New Zealand

INTRODUCTION

Increasingly, engineers work on projects involving the protection of human health, the protection of natural ecosystems, the control of pollution, and the management of water, air, and solid wastes. It is convenient and increasingly common to term these engineers *environmental engineers*. Universities have responded to the increased demand for environmental engineers by developing more post-graduate opportunities and developing new undergraduate degree programmes. The tradeoff between developing post-graduate or undergraduate degrees is well described in Baillod and Mihelcic (1993).

As might be expected in a highly dynamic situation, a number of universities have created undergraduate environmental engineering curricula without co-ordination between them. As a result, a *post-facto* comparison of environmental engineering curricula can now be a valuable method for identifying the desirable features of an environmental engineering curriculum. Recent reviews for the U.S. (Baillod, et al., 1991) and for Australia (Dandy and Daniell, 1992) have started the process with overarching comparisons of curricula.

As in other engineering disciplines, science courses are a major portion of environmental engineering curricula. An examination of environmental engineering curricula shows general agreement that science is important, but that they split along one of four fault lines:

1. The balance between science and other requirements.
2. The selection of required science subjects.
3. The degree to which science courses should be required rather than optional.
4. The degree to which science courses should focus on depth rather than breadth.

The author has recently worked on an undergraduate environmental engineering curriculum for the University of Canterbury, and this paper will analyze the four issues mentioned above.

Table 1 is provided as an aid to discussion, and provides an estimate of the percentage of each of five curricula that is devoted to science (maths, general science, environmental science, and engineering science), applied engineering, or social studies (management, law, policy, regulation, humanities, social sciences). The science component is further divided by subject matter. The figures provided in Table 1 are not values approved by the respective universities, but estimates made by the author based on subject matter and workload descriptions for individual courses. Omission of curricula in the table is due solely to a lack of detailed information on other courses.

	Massey	Canterbury	Michigan Tech.	New South Wales	Western Austr.
Maths	13.3	15.0	13.2	13.3	15.6
Physics	6.7	3.6	5.1	3.6	4.4
Fluids	3.3	7.3	2.5	5.2	6.6
Chemistry	13.3	3.6	8.1	6.2	9.7
Gen. Biol.	3.3	0	2.1	3.1	6.2
Microbiol.	3.3	0	2.1	0	0
Ecology	3.3	0	0		3.1
0					
Geology	0	2.6	0		3.6
0					
Phys. Geogr.	0	0	0		5.2
4.5					
Optional Sci.	0	15.9	4.6	0	6.3
Total Science	46.7	48.0	37.7	43.3	53.3
Applied Engin.	45.0	44.0	38.0	42.8	39.0
Social Studies	8.3	9.0	24.3	13.9	7.7
Grand Total	100	100	100	100	100

Table 1: Comparison of Environmental Engineering Curricula--
Percentage Distribution of Course Content

OBJECTIVES OF SCIENCE EDUCATION IN ENVIRONMENTAL ENGINEERING CURRICULA

Before analyzing the science questions posed in the introduction, it is useful to step back and explicitly consider the goals or objectives of science education. These objectives might be grouped as related to:

1. Job preparation
2. Learning skills
3. Topic familiarity
4. Social skills

Job Preparation

Clearly, science education in an environmental engineering curriculum must prepare students for jobs in environmental engineering. Graduates might be expected to work with concepts from chemistry, fluids/physics, microbiology, ecology, geology,

analytical mathematics, or probabilistic mathematics. Almost as clearly, for this objective to be met there should be more education in those subjects more likely to be needed in jobs. Not very clear would be a ranking of the relative importance of these science subjects in today's workplace. Very murky would be the relative importance of these subjects 20 years in the future.

Learning Skills

Science education develops analytical reasoning skills necessary for success as an environmental engineer. Some might argue that these skills are much more easily learned at the formative age of university students rather than as part of a continuing education scheme. Similarly, science education helps to improve the organisational and synthesis skills important to learning.

Topic Familiarity

Even when environmental engineers do not specialize in a certain branch of environmental-related science, they often find it useful in a job if they have been introduced to the subject while at university. By learning the vocabulary of a discipline and by having some idea of how practitioners work, they are able to understand the basis of work in the field. The environmental engineer is also able to more easily develop knowledge in the subject, as needed, by building on the familiarity of the topic that has been gained through university studies.

Social Skills

Science education allows for social interaction with environmental scientists. This can be a valuable component of an environmental engineering degree. The experience can increase respect for environmental scientists. It can also provide for practice at teamwork between environmental engineers and environmental scientists. These social skills could be especially valuable for graduates working on projects involving multiple disciplines.

An analysis of the place of science in the environmental engineering curriculum should consider the relative importance of these four objectives, and how fulfillment of these objectives is weighted against fulfillment of objectives related to non-science components of the degree.

SCIENCE VERSUS NON-SCIENCE IN ENVIRONMENTAL ENGINEERING CURRICULA

In addition to science subjects, applied engineering and social studies must be part of an environmental engineering curriculum. This doesn't imply that the objectives discussed in the previous section must be compromised to include the non-science subjects-- some of the objectives can be met through teaching of the non-science subjects.

For the five curricula examined (see Table 1), the science component varies from 38 to 54 %, while the applied engineering content varies from 38 to 45 %, and the social studies content varies from 8 to 24 %. The odd curriculum is the one at Michigan

Technological University, where about 24 % of the curriculum is on social studies resulting in proportionate decreases in the science and applied engineering content. The relevance of social studies in a technical degree is a topic for another paper, but it should be noted here that as the social studies component increases, the science component of a degree is likely to diminish.

Each university that devises a curriculum must balance the relative advantages of science and non-science components. In Australia and New Zealand, typical figures seem to be 45 % science, 45 % applied engineering, and 10 % social studies. Even though universities have set varying requirements on which science subjects are taken, it is notable that all are within 8 % of a 45 % science component.

REQUIRED SCIENCE SUBJECTS

An examination of Table 1 reveals differences in how universities view the necessity of various science subjects. All universities devote the greatest fraction of the science component to mathematics, and all require mathematics to an advanced level.

Chemistry is the next most important science component of the curricula selected for analysis. Environmental engineering degrees that develop from chemical engineering programmes (such as the one at Massey University) are more likely to have more chemistry required. The curriculum with the lowest required chemistry content is the one at Canterbury. There, the rationale for the low chemistry content is that many jobs in environmental engineering require no more than a basic chemistry education. Since many jobs in environmental engineering do require more than basic chemistry, other universities are likely to see more chemistry as being needed to provide students with flexibility in job selection.

All the curricula selected for analysis require teaching of physics and the fundamentals of fluids. The fluids content of the curricula varies from 2.5 to 7.3 %. It's difficult to say how much this difference is due to an improper interpretation of course descriptions.

All curricula, except Canterbury's, require course work in the biological sciences. The high optional science component in the Canterbury curricula means that the Canterbury curriculum has less required science, but a similar total amount of science.

REQUIRED VERSUS OPTIONAL SCIENCE

Although the total amount of science is similar in all five curricula, the amount prescribed varies from 67 to 100 %. The high optional content at the University of Canterbury comes from the reasoning that the key objective was science teaching rather than specific science concepts. In this sense, the importance of topic familiarity is lessened, while the importance of analytical and social skills is increased. Analytical and social skill development should be greater when students find their science subjects more interesting and less of a hurdle or burden. Also, by allowing options, students might be more enthusiastic regarding their science coursework and thereby more likely to learn.

The issue of required versus optional science content seems to boil down to whether one believes that an undergraduate education should shape a student's abilities, or take maximum advantage of pre-existing abilities. In the author's opinion, forcing students with no interest and little ability in chemistry, biology, and so on, to take such courses is unproductive and not necessary to produce a useful graduate. Perhaps by increasing the optional science fraction while maintaining a high total science component, educators can better meet the objectives of science education in environmental engineering degrees.

BREADTH VERSUS DEPTH

A final dimension to the development of science content in environmental engineering curricula is the trade-off between breadth and depth. The argument for breadth relies on maximising the achievement of the objective of topic familiarity and stresses that environmental engineers need to be **interdisciplinary** in order to deal with the varied facets of environmental engineering problems. The breadth argument sees the need for a "renaissance" education, in the sense of an education with a firm foundation in all subjects, allowing for more cogent integrated analyses of environmental engineering problems.

The argument for depth relies on a belief that the job preparation and social skills objectives of science education require advanced rather than introductory level science teaching. The job preparation objective is developed through depth since experts rather than generalists are increasingly needed in environmental engineering positions, while the social skills objective is developed better when engineering students advance to high levels of training along with scientists. The depth argument sees the environmental engineer as being **multidisciplinary** rather than interdisciplinary, with the distinction being that multidisciplinary environmental engineers work as specialists as part of teams of people from numerous disciplines.

The author agrees more with the depth rather than breadth side of the argument. Weis (1990) analyzed the strengths and failings of the numerous degrees in Environmental Science that grew in the 1970's in the U.S., and she shows that one of the failures of the degrees was their emphasis on breadth and interdisciplinary education rather than on depth and multidisciplinary education.

The argument for depth over breadth also impinges on the topic of optional versus required course work. If the best method to achieve the objectives of science education is through depth, then the logic behind requiring science weakens, and the reasoning for optional courses is strengthened.

CONCLUSIONS

The evaluation of the science content in an environmental engineering curriculum must start with a clear examination of the objectives of that portion of the curriculum. An important objective that is often overlooked is the development of social skills-- that is, by studying science to an advanced level, one is able to gain respect for non-engineering disciplines, and have an opportunity to be part of multi-disciplinary

teams. The curriculum must allow a chance for practice in multidisciplinary teamwork as preparation for such teamwork in employment.

The development of science curricula should acknowledge that certain students could find worthwhile careers in environmental engineering even though they do not excel in certain science subjects. The acknowledgement would likely point to a decrease in prescribed science courses, and an increase in optional science courses.

Finally, environmental engineers must deal with material from many disciplines, but increasingly, they must be multi-disciplinary rather than interdisciplinary. The implication is that the science component of the curriculum should put an increasing emphasis on depth rather than breadth.

REFERENCES

- Baillod, C R, et al. (1991). Development of environmental engineering baccalaureate programs and degrees: position paper. *Sixth Conference on Environmental Engineering Education*, Corvallis, U.S.A.
- Baillod, C R, and J R Mihelcic (1993). Baccalaureate programs in environmental engineering: an american perspective. Accepted for publication in *Australasian Journal of Engineering Education*.
- Dandy, G C, and T M Daniell (1992). A review of undergraduate environmental engineering degrees in Australia. *Proceedings of National Conference on Environmental Engineering*, Gold Coast, Australia, 59-64.
- Weis, J S (1990). The status of undergraduate programs in environmental science. *Environmental Science and Technology*, **24**, 1116-1122.