Within a Context: The Benefits of Teaching Introductory Environmental Engineering
With a Detailed Case Study

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Abstract

The teaching of introductory environmental engineering can easily lead to students complaining that they are receiving too much broad, general instruction. Engineering students, more than liberal arts students, often require an early and clear demonstration of the applicability of course content. A way to provide this is through frequent and detailed case studies and examples. Unfortunately, this approach can either take too long or make it difficult to explain the complicated interdependencies that arise in real-world environmental problems. An introductory engineering course at the University of Canterbury is described. It has the objectives of introducing environmental engineering fundamentals, systems/management, and professional communication methods. In 1996, the course used one local site as a re-occurring case study. A field exercise at the site at the beginning of the course provided a common background for the students to build upon. Lecture examples, homework problems, and test/exam questions continued the use of the case study to develop the course content. Complex analyses, such as for the proper balance between recreational and ecological benefits of the bay, were more able to be understood by the students because of their familiarity with the site and the small-scale of the problem. It is hoped that students will see the applicability of the case-study analysis and develop the confidence to deal with the more serious, larger-scale, environmental problems they would face in their professional careers.

Introduction

There is a need to teach concepts of sustainability to engineers early in their university education. Most would agree that teaching sustainability will involve instruction in ecology (and other environmental sciences), social needs, and the complexity involved in managing people's interaction with the natural environment. The teaching of these topics can easily lead to students complaining that they are receiving too much broad, general instruction. This in turn can lead to conclusions by the students that the course is full of "warm fuzzies" or is merely teaching "political correctness". Either accusation can serve as an excuse for students to turn off their learning sensors. Engineering educators involved with teaching sustainability will find it essential to keep young students convinced of the relevance of the course material.

Engineering students, more than liberal arts students, often require an early and clear demonstration of the applicability of course content. A way to provide this is through frequent and detailed case studies and examples. However, first or second year engineering students are unlikely to have enough background knowledge to understand many of the better examples one might choose. In addition, many useful case studies have a series of interrelated issues; as a result, one can either reduce the scope of the case study and thereby lessen its impact, or one can explain the case study in detail and take up a lot of lecture time.

Case studies can be a useful route to learning. When used judiciously, they can be used almost exclusively as a way to teach course content. However, they do require much more student-teacher interaction, when teaching contact hours at most institutions are already overstretched. One possible compromise is to introduce the case study in a high-interaction environment, and then build on the introduction through lectures, readings and assignments.

This paper describes the approach taken at the University of Canterbury to teaching sustainability concepts to second-year students. Background to the course is provided, followed by discussion of the case study. Details are then given on how lectures, readings, and assignments are used to continue the learning related to the case study. Finally, a discussion is provided of the advantages and disadvantages found for this teaching method, compared with more traditional approaches.

**Background**

The University of Canterbury requires the course entitled *Environmental Analysis* of second-year university students who have been accepted into the Civil, Environmental and Forestry Engineering degree programmes. The course typically has 120 students and lasts about twelve lecture weeks. At the University of Canterbury, students must complete a series of first-year, university-level science, maths and optional courses before being admitted to the engineering school. Entering engineering students are unlikely to have studied any social sciences or humanities at the university-level, and will be introduced to many new concepts in *Environmental Analysis*. Students who take Environmental Analysis will have studied their first-year subjects at one of many NZ and overseas universities. This, in addition to the optional courses students take, means that students with highly varied educations enter the course.

The objectives of the course are to:

- introduce fundamental environmental engineering and environmental science concepts
- introduce how the engineer must work within society
- introduce the systems (hard and soft) approach to solving complex problems
- improve study skills, and oral and written communication skills

The course is built on in different ways for the three degree paths. Students in the course are expected to use their learning in later management, systems, and environmental quality courses.

The content of the course has included the following topics:

- Environmental Engineering and Science-- systems ecology, population ecology, dilution calculations, first-order kinetics, environmental box models
- Engineer in Society-- causes of pollution, ethics, social assessment, environmental regulation, environmental philosophy, indigenous communities, public consultation
- Systems Approaches-- systems’ definitions, influence diagrams, feedback processes, dynamic modelling, approximations
- Study/Communication skills-- note-taking, library use, essay writing, oral presentations
Case Study Background

The case study used in 1996 to develop these concepts was McCormacks Bay in Christchurch (see Figure 1). The bay today adjoins the Avon-Heathcote Estuary, which is the natural drainage point for the city of Christchurch (population of about 300,000). The estuary is the discharge point for the city’s treated sewage, as well as untreated stormwater. The estuary is home to a complex food web, with many rare birds using the estuary and its surrounds during one or more parts of the year. In addition, the estuary is used in a limited way for recreation in the form of windsurfing and yachting. Prior to European settlement in 1850, the estuary was an important food-gathering place and home for the indigenous people of New Zealand— the Maori. As pollution impacts increased in the later 1800s and early 1900s, the spiritual and practical value of the estuary to the Maori decreased to zero. The Christchurch City Council, which (along with the central government’s Department of Conservation) oversees use of the estuary, has crafted a delicate compromise that attempts to improve the sustainability of the estuary. They are attempting to increase its aesthetic value (to Maori and non-Maori), its ecological value, and its recreational value, while limiting the costs to the local residents.

A study of McCormacks Bay contains many of the same issues involved in the adjoining estuary. The bay’s ecology was compromised around the turn of the century by the construction of a rail causeway across it. This causeway in turn was later expanded to a road for motor vehicles. To allow exchange of water between the bay and the estuary, culverts have been placed under the road. Part of the bay was once used as a dump, and sediment gradually accumulated in the bay. Also over the years, the hills around the bay became almost completely filled with closely-settled residences. The council decided to improve the bay and hoped to increase its aesthetic, ecological and recreational value without excessive costs. It improved the effectiveness of the culverts, developed grassed park areas, emplaced islands in the bay to allow for bird resting areas, added native plants to the area, and improved controls on stormwater quality.

Field Exercise

On each of three afternoons, groups of 40 students were taken to McCormacks Bay for the field exercise. As preparation, the students received a lecture on the ecology of the estuary, a lecture on the interrelationships involved in managing the estuary, and handouts on what would happen on the day of the trip and how they should prepare. On the day, each student completed two of the four, one-hour activities below—

1. Hydraulics— Estimate the flow through the culvert linking the estuary and the bay.
2. Water Quality— Explore the variations in the bay of specific water quality parameters (eg, dissolved oxygen, salinity).
3. Ecology— Examine how the ecology varies in different parts of the bay. Practise common ecological study methods. Describe the results of the ecological survey.
4. Social Assessment— Knock on the doors of nearby residents and survey their opinions on the bay and its management. Discuss as a group the limits of the survey and other methods of public consultation.

The field exercise required a substantial amount of preparation and a large number of staff (eight, including three lecturers) on the three afternoons. The preparation for the social assessment required the most time. Prior to that activity, residences in the vicinity of the bay were counted and bunched into 25 groups of about 12 residences per group. Each student team was then assigned one
Figure 1 McCormacks Bay Located at the Eastern Edge of Christchurch, New Zealand.
of the 25 groups of houses for the survey to assure that no residence was surveyed more than once. In addition, a letter was put into the mailbox for each residence that might be surveyed to notify the resident that a survey would be conducted in their neighbourhood. In the end, there were 83 responses to the survey.

After the field exercise, the students submitted reports (similar to laboratory reports) describing their methods and results. Due to variable weather, tidal variations, and the large number of nearby residents, the activities and results also varied from day to day-- these were not reproducible experiments, but rather real-world situations. The students' reports were marked, and their results were taken out of the report, photocopied, ordered and distributed to the students as an information packet for later analysis.

The later analysis was in the form of four homework questions. These were:
1. Estimate the total flow into McCormacks Bay per incoming or outgoing tide.
2. Divide McCormacks Bay into three ecological regions. Make the regions as distinct as possible.
3. Identify five pairs of water quality variables with notable correlations in space or time.
4. From the survey results, recommend three future initiatives to the Christchurch City Council to further improve McCormacks Bay.

The homework forced students to use the results of many students, and thereby appreciate the value of good data report writing. It also forced the students to face practical issues of making clear definitions, and of analysing and interpreting data that were in error or difficult to classify. The first question required the students to adjust time for tide stage, and to numerically integrate under the tide stage versus flow curve. This proved to be a useful application of mathematical concepts the students were learning at the time. As another example, the last question led to the conclusion that residents would be most receptive to initiatives that 1) improved the wildlife values of the bay, 2) improved the recreational values of the bay’s park, or 3) improved the management of traffic around the bay. The latter was an issue that the course instructors had not considered initially. The students were later told of their lecturers’ surprise at finding this new issue in the area and it was emphasised to the students that environmental analyses often will bring out issues that otherwise would be overlooked.

Building on the Field Exercise

In addition to the exercises above, the field exercise provided a common experience for lecture examples. Lectures on ecology, indigenous peoples, mass balance calculations, and influence diagrams used the field exercise in this way. Most usefully, the field exercise provided an anchor in common experience for the fuzzier topics of system types and definitions. For example, the course tried to teach that a system must have a purpose. This point was made by discussing how different management objectives for McCormacks Bay could lead to different system representations of the same bay, and that each representation was equally valid.

Test and examination questions also followed on this case-study experience. For the tests, the focus of the question moved from the specific case of McCormacks Bay to the broader issue of the management of the estuary as a whole. As examples, the students were asked to discuss how water flow rates and/or water quality affected the ecology of the estuary, and they were asked to discuss how the tragedy of the commons would apply to the estuary. By building up from the local scale to the regional scale in this way, it is hoped that students will be able to take the next step of analysing national and global environmental issues-- although this was not done in our course.
System Examples

To match the lecture discussion of systems analyses as a management tool, the students were asked to provide an influence (or causal-loop) diagram for an environmental problem. The object of the exercise was to make students wrestle with the difficult tasks of clearly defining the objective of an analysis, setting the boundaries of a system, and identifying the issues that would need to be included in a management exercise (through “scoping” the problem).

The students were asked to provide an influence diagram for one of the following topics:

A. The Christchurch City Council is concerned about the effects of sea-level rise over the next fifty years. Draw an influence (causal-loop) diagram to help them see the likely, inter-related effects of sea-level rise on McCormack’s Bay.

B. The Christchurch City Council is considering a ban on dogs in McCormack’s Bay park. Draw an influence (causal-loop) diagram to help them see the likely, inter-related effects of the policy on the bay.

C. The Christchurch City Council is considering requests for new housing in the hills above McCormack’s Bay. Draw an influence (causal-loop) diagram to help them see the likely, inter-related effects of the request on the bay.

D. The Christchurch City Council is considering a proposal to construct additional culverts under the causeway at McCormack’s Bay. Draw an influence (causal-loop) diagram to help them see the likely, inter-related effects of the proposal on the bay.

The students needed to present their results in a 10 minute oral presentation. Before the presentation, time was available for tutorials to give them advice on their analysis and on oral presentation techniques. The systems exercise showed the students had a strong ability to “scope” environmental problems and to identify feedback loops.

An example of the students’ results is provided as Figure 2, and is in response to problem B above. The systems analysis problem served to show how the data collected in field exercise could be put to use in addressing management problems. In the case of the proposed dog ban, the data on the ecology, water quality, and survey results would be of use. The students were forced to see that non-quantifiable variables were as much a part of the system as quantifiable variables. For example in Figure 2, “bird numbers” (a quantifiable variable) affects the “happiness of society” (a non-quantifiable variable), which in turn affects the “number of people using the bay” (a quantifiable variable).

I believe that these systems concepts had been much more difficult for our students to grasp before the introduction of the field exercise and its use as a case study for systems analyses.

Discussion

The site selected for our case-study was crucial to its success. We were fortunate that the bay was large enough to have a set of inter-related facets to its management, and yet small enough for students to appreciate in an afternoon visit. Many sites would have too few management issues and so would be less suitable for teaching; there would not be an opportunity to teach students about how environmental aspects of problem become tied into other aspects and require an integrated
approach to management. In the previous year, we tried to use the whole of the Avon-Heathcote Estuary for the case study; however, this proved to be too large to adequately visit, and to have too many facets for effective analysis. Because the survey could be a burden on residents if repeated, the case study must be located somewhere else next year, and again a careful selection process will be needed. If others would like to try our approach of using a case study, I suggest that the choice of a suitable location be made carefully, and that alternate sites be available for use in succeeding years.

A disadvantage of the case-study approach is that, because of the extra time spent on the field exercise, less content will be covered in the course. For entry-level engineering students, I do not regret this sacrifice. It is hoped that in the first year of Engineering School students will improve their learning skills so that in later years they will have a better ability to effectively learn content. The Environmental Analysis course has an emphasis on improving learning skills, and the use of a case study in the course seems to help greatly to improve these.

Another disadvantage is the fact that the emphasis on local and regional viewpoints means that the course does not adequately address important national and global environmental sustainability issues. Although there does seem a need to teach these in a more advanced undergraduate engineering course, these are not taught now at the University of Canterbury. In the meantime, we hope that students can see that the skills they have gained in analysing the sustainability of local and regional environments would also apply at the larger scale.

As a final disadvantage, the case study approach requires more work for educators. A great deal of work is needed to organise the field exercise and to conduct it in small groups. The need to shift the location of the field exercise from year to year means that the organisation work remains high from year to year. My experience is that technical staff and post-graduate students perform well and enthusiastically in organising and conducting the field exercise. Much of this must be due to the uniqueness and practicality of each year’s field exercise. In this sense, the disadvantage of extra work also comes with the advantage of increasing the interest and enthusiasm of teaching staff, which can only help increase the students’ enthusiasm for the topic.

From my experience, the main benefit of the case-study approach described here is the deeper understanding reached by the students. This seems to result because more students see the relevance of environmental sustainability issues when they are taught in relation to local problems. Perhaps more than liberal arts students, engineering students need to see the practical relevance of their education at all times. General discussion of environmental philosophy, environmental regulation, public consultation, and systems’ analyses might seem useful to educators who have a great deal of experience to rely on; however, to young students who have received a heavy dose of technical subjects in university, the general discussion can too often make no connection with students’ experiences, and so not be learnt. Forcing students to talk to residents about their environmental concerns regarding McCormacks Bay seemed to open the eyes of many students to the fact that engineers act to serve their community, a fact too easily lost in the deluge of equations of first-year engineering study.

A final advantage of the case study approach deserves mention. I believe the McCormacks Bay experience has helped show our city that we are training engineers to solve real-world problems. The results of our students’ work were provided and explained to the Christchurch City Council Parks Department. More importantly, residents who were surveyed saw that university engineering students were genuinely interested in their opinions. Surely, this experience will raise the residents’ opinion of the value of university education and of the engineering profession.
Acknowledgements

Much of the co-ordination and conceptual work for the field trip is due to the effort of Professor David Wilkinson, and many ideas expressed here resulted from fruitful discussions with Drs. Dave Wareham, Hugh Thorpe, David Elms, and Bob Spigel— all of the Department of Civil Engineering, University of Canterbury. I would also like to thank the University of Canterbury’s Erskine Fund that allowed me to take leave to present this paper.

Figure 2  Sample Student Assignment for an Influence Diagram Applied to McCormacks Bay.