Development of a course on environmental sustainability, ethical decision-making and communication skills in engineering

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***Abstract* - Sustainability and ethics are taught in different forms in engineering degrees. No assessment has been made in the literature of the rationale for teaching them within a common decision-making framework. Following a re-organisation of the Civil Engineering curriculum at the University of Sydney in 2003, a new third-year unit of study entitled "Engineering and Society" has been added to the core program. The course introduces students to issues of environmental and social sustainability and ethics in civil engineering practice. We draw on our experience in designing and delivering the course to evaluate the way in which ethics and sustainability can be integrated in the syllabus. We describe, and reflect on, some of the obstacles encountered in achieving learning outcomes and engaging students in the learning process. We make a number of recommendations, especially in relation to syllabus structure and teaching social sustainability.**

Index Terms – sustainability, ethics, environmental engineering, civil engineering

INTRODUCTION

Engineering graduates apply their technical skills in a wide variety of legal, institutional, and environmental settings, acting as agents of technology-driven social change. While problem-solving has been a much-lauded hallmark of engineering education and practice, decision-making is an equally necessary, if less publicized, skill that engineers are expected to possess. Decision-making is made all the more complex by a number of technical, economic, environmental, social and ethical constraints. In particular, environmental sustainability has given rise to a new framework of engineering analysis that is now an essential part of the work of engineers.

Engineering curricula, like those of many applied sciences, typically start with foundation courses in mathematics, physics and chemistry and quickly move to applied engineering subjects, focussing on the analysis of technical problems and the design of engineering solutions. Little time or space has traditionally been allocated in engineering degrees to the wider social, political and environmental setting of engineering practice. The engineering community has been aware of the limitations of an exclusively-technological focus for some time. Over the last decade or so, many engineering departments around the world have modified their curricula to cater for the increasing importance of environmental and social concerns in the wider community [1-3]. Questions therefore arise about the best way to teach environmental sustainability, ethical decision-making and social responsibility. For example, Boyle [4] lists a number of obstacles in teaching sustainability to engineering students including lack of time in the degree, lack of student maturity and lack of available examples, among others. No single framework or template appears to have emerged from the literature. Some departments have introduced new environmental components in their degrees [e.g., 5] while others have focussed on the developmental aspect of engineering in poorer countries [e.g., 6]. More ambitiously, some new curricula have attempted to introduce engineering-related environmental and social issues from within existing technical courses in analysis and design [e.g., 2]. However, while the literature is relatively rich in discussions of different philosophies of, and approaches to, teaching sustainability and ethics to engineering students, far fewer papers have discussed practical problems of teaching sustainability and ways of overcoming them. Fewer still have considered the merits and drawbacks of incorporating sustainability and ethics in the same learning framework. In this paper, we describe the development of a new course on sustainability and ethics to civil engineering students. We present the objectives of the course and discuss the way it is structured, including the incorporation of both sustainability and ethics. In particular, we evaluate the effects of introducing fundamental environmental engineering material and sustainable building design practice on the second delivery of the course.

CONTEXT

In 2003, the Civil Engineering program at the University of Sydney in 2003 was re-organized [7]. A new third-year unit of study entitled "Engineering and Society" has been added to the core program. This course, now delivered twice, introduces students to issues of environmental sustainability and ethics in civil engineering practice. In addition, it aims to improve students' skills in written and oral communication and team work. The course was designed in order to achieve two sets of objectives: primary and secondary. The primary objectives are:

a. to introduce students to important ecological, social and ethical issues deriving from technology-driven change, including new paradigms of environmental sustainability, and the way they affect engineering decision-making.

b. to develop students' skills at sustainable design and the use of design tools relevant to the development process in New South Wales, Australia.

c. to improve the capacity of students at identifying the impacts of engineering projects on the social and natural environments, and developing alternative solutions to problems.

d. to develop students decision-making skills under environmental and ethical constraints.

e. to develop the students' understanding of the influence of organizational, ethical and legal factors on engineering practice.

The secondary objectives of the unit of study are:

a. to improve the communication skills of students, through verbal and written media.

b. to improve the team-work ability of students.

c. to improve students skills in research and use of library resources.

Decision-making scenarios such as those shown in the appendix were presented to students on the first week of classes to illustrate the objectives of the course, and referred to throughout the semester. It is important to note that third-year engineering classes at the school of civil engineering of the University of Sydney typically include 120 students. Therefore, course management and organization issues are important.

DISCUSSION

The course clearly carries three components: a. environmental and social impacts of engineering, b. ethical decision-making in engineering and c. communication and research skills of engineers. The rationale for grouping these components in one course is based on the ethical dimension of environmental and social sustainability, and the multi-stakeholder nature of the decision-making processes in this field. The latter requires engineers to develop the ability to communicate with partners from a wide range of disciplinary and social backgrounds. However, the connection between these three components does not, in itself, tell us how the course should be structured. For example, while many environmental sustainability issues carry a strong ethical dimension, some issues in engineering practice (bidding process, personnel management, construction safety) are essentially ethical problems with no obvious environmental sustainability dimension. Another question was how to make the course attractive to students who usually view technical subjects as the only essential part of their curricula? The perceived 'qualitative' nature of the course is bound to devalue it in the eyes of applied science students who often equate 'usefulness' with numerically-based design and analysis skills, rather than conceptual re-thinking, multi-stakeholders communications and complex decision-making where technical knowledge is only one among many considerations. The problem, in other words, is not only how to change thinking habits and get the students to think outside the 'technical box.. It is also to redefine with students what is significant in their curriculum and future careers.

Timeline

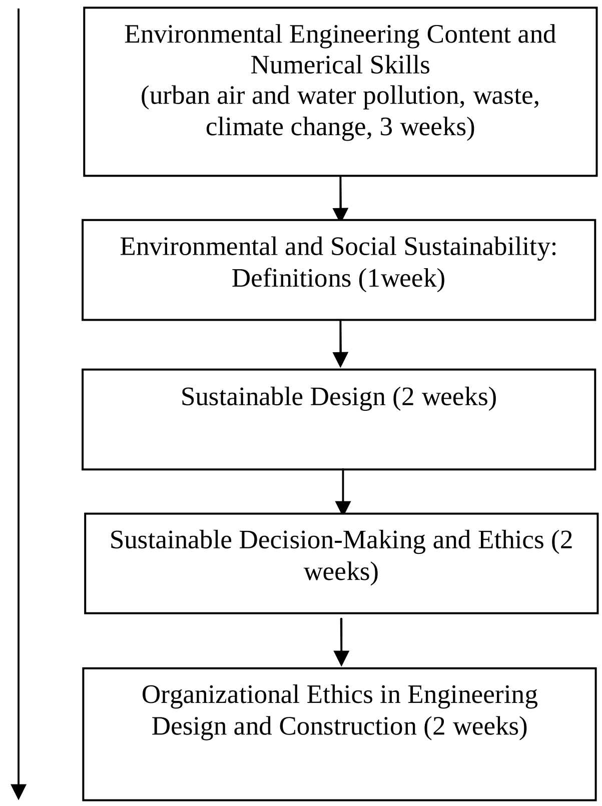

FIGURE 1
COURSE LAYOUT

The course layout, shown in figure 1, was developed with these questions in mind. The course started with a set of lectures and group workshops on environmental engineering topics, with particular emphasis on the way civil engineering projects impact physical and social ecosystems. Examples were drawn from mining, dams and urban planning issues such as housing and transport. Some numerical skills, such as interpretation of air pollution records and standards, and assessment and quantification of greenhouse emissions, were taught. The workshops were designed to get students to read a specific decision-making scenario, perform some data calculations then engage with policy issues, identifying and analyzing stakeholder positions and making recommendations. Building on this material, students were then introduced to concepts of sustainability. Next, the concept was put in practice through lectures on sustainable design, including practical exercise related to the development process in the state of New South Wales where the University of Sydney is located. Finally, the students were deemed ready at that stage to tackle more complex, and less technical, questions of multi-stakeholder decisions of sustainability and ethics, in a more systematic way. Lectures and group workshops on decision-making processes, such as the formal-case analysis and organizational ethics, were delivered. Some workshops were constructed by expanding specific decision-making scenarios shown in the appendix.

This structure provided in effect a set of answers to the questions raised earlier. Starting with environmental engineering content performed three functions. First, it allowed students to start on a relatively familiar note with technical material, including numerical skills. Second, it provided a building block which can then lead to policy and decision-making questions of sustainability and ethics. Third, it allowed us to introduce ethics as a more systematic way of thinking about some decisions in engineering which include, but are not limited to, sustainability. Hence, all theoretical and policy questions and discussions were strongly rooted in engineering perspectives. This was reinforced through weekly group workshops, mirroring current lecture topics. In addition, the workshops allowed students to practice written and oral communications skills.

A number of difficulties arose. Identifying and designing suitable case problems for workshops was a major obstacle. While a wide variety of case problems exist in the literature, very few carry the students through a process of a). scenario description b). background research c). data analysis d). policy analysis. Hence, we designed the ethics case problems ourselves and used off-the-shelf ones for environmental engineering [8]. However, while the latter were very well presented as an electronic package, simulated well engineering decision scenarios and covered a wide range of problems, the policy questions in the environmental engineering problems were sometimes felt to be trivial by the students. A crucial future development is a new design of some case problems to make them more compelling to students and more effective in achieving learning outcomes.

Nevertheless, the student response to the course has been positive, especially on the second delivery, when environmental engineering and sustainable design were introduced, and case problems were somewhat refined.

CONCLUSIONS

The question raised in this paper—how best to teach sustainability and ethics to engineering students—is important and difficult to answer. Our experience has shown that designers of similar courses ought to carefully consider the ratio of theory to applications in course delivery. A focus on theory would obviously be counter-productive, especially when aimed at a population of students in an applied science degree, accustomed to courses with very practical content. Conversely, a course entirely directed towards applications may fail to achieve its purpose, if it aims to change student thinking about engineering decision-making as a process that includes and goes beyond technical knowledge.

APPENDIX

Decision-Making Scenarios

Scenario 1. You are a recent graduate. This is your first week, in your first job. You have been assigned to a team designing a shopping mall, for the third time in the last five years. You are asked to check the specifications for a set of concrete beams in mezzanine level of the mall, and recommend whether to keep them or change them, either because they are unsafe or too conservative.

Scenario 2. You are a recent graduate. You have been working in the design office of your employer for six months. You have been performing brilliantly and are keen to get some construction site experience. One day, your boss calls you from the airport and says he needs you to go to site D for the next three months, and supervise and quality manage on-site concrete-making, including safety issues. He hangs up before you can ask what safety aspects you are responsible for. You go to the site the next day. As soon as you walk in, you are struck by how cavalier with safety rules the workers on the site are. In fact, you can think of three health and safety rules that are being violated. Your boss cannot be reached. Obviously, few people on the site know you and you have little personal authority. You are not even certain of the level of official authority you carry. You are keen on having good personal relationships with the new team you're working with and do not want to lose face. Beside, who are you to change things around on the first day of work. On the other hand, this is quite serious and someone ought to do something about it. What do you do?

Scenario 3. You now have three years experience. You have been headhunted by another, fast-expanding firm. Your salary has skyrocketed. You have been appointed as site engineer for a bridge you have had a big part in designing. The project has been behind schedule and over budget and the client, a government authority has been under immense political pressure to deliver. After joining, you find out that your predecessor was fired because he has been unable to keep to budget and was perceived as lacking problem-solving skills and being too fussy. You check the tender documents and you have a strong suspicion your company had underestimated the cost of the project in trying to win the bid. On site, you discover that the steel used in construction was of lower quality than that specified in the bidding documents—same strength but higher maintenance. All steel material had already been bought by your company and delivered to the site. What do you do?

Scenario 5. Ten years into your career, you are senior manager at a plant manufacturing construction material. A fire at the onsite waste-water treatment plant has shut down the facility. You have a choice of either suspending manufacture for four weeks—the time it will take wastewater processing to restart—or to dump the waste in the adjacent river. You can keep dumping within legal limits. However, a new law, based on recent scientific findings about the susceptibility of local marine flora and fauna to pollution, bans dumping altogether and will come into effect six weeks later. In other words, dumping is legal but definitely harmful and wrong. If you suspend production, three major contracts will be at risk. What do you do?

Scenario 6. You are the Head of Infrastructure Department in your local government. There has been a long-held vision of a bridge across a major bay. Significant economic benefits would arise from such a project. However, the bridge would lead to the demise of two fisheries and some recreational activities that have been a hallmark of this part of the city for a long time. Should you push for the building of the bridge or not? Should it be your own decision?

Scenario 7. You are a City Planning Consultant with twenty-year expertise in infrastructure projects. You have been asked by local government to provide advice on a transport development strategy for your town. The three major options are a. to invest in a major roadway expansion, b. to upgrade the bus fleet and build a new major bus stations and c. to build an subway train network. There are many winners and losers from the different options. How should you develop your recommendations?

ACKNOWLEDGMENTS

We are grateful to Anna Carew, now at the University of Wollongong, for her involvement in the initial design and delivery of the course.

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