AC 2008-2617: DESIGNING AND DELIVERING AN ENVIRONMENTAL MANAGEMENT COURSE FOR ENGINEERING AND SCIENCE STUDENTS

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Designing and Delivering an Environmental Management Course for Engineering and Sciences Students

Abstract

Environmental education for engineers and scientists is becoming increasingly important and popular throughout the world. There is a need to develop courses which introduce students to interdisciplinary environmental management principles and tools, and expose them to various real world problems. To promote interdisciplinary environmental education and research, North Dakota State University (NDSU) has introduced a graduate program in Environmental and Conservation Sciences (ECS) in 2003. As part of this interdisciplinary program, a course in environmental management for ECS and civil engineering students was introduced. The course was designed as a graduate level course and was made available to civil engineering undergraduates as a technical elective. The challenge was to address a widely diverse student group with different academic backgrounds. The course has been taught twice since its introduction in 2006. The course is intended to give students an understanding of current environmental issues and tools for environmental management. The issues are examined from the worldwide perspectives of science, engineering, business and society. At the end of the course students are expected to have a comprehensive knowledge of integrated environmental management with a global perspective. It is designed to help them in environmental decision-making from a socio-economic-environmental standpoint. Case studies are undertaken to bring clarity to the concepts introduced.

There is no recommended text book for this course, and publications from various nonprofit and governmental organizations including the United States Environmental Protection Agency (US EPA) are used. Various models used for environmental analysis and decision making are introduced. The instructor's knowledge gap is filled by inviting guest speakers to cover various topics. Students extensively use the Blackboard, a software system designed to facilitate the management of and access to educational information delivered via the Internet, for group discussion and course materials transfer. A discussion forum is kept open on the course Blackboard allowing students post course assessments anonymously as the course progresses. Student inputs are used to decide on the nature of assignments and projects. Two projects are taken up during the semester and the learning process centers around these projects. Typically students work on an environmental management (EM) project and a life-cycle assessment (LCA) project. Inductive teaching techniques have been used with a 'revise your course as you go' policy. The apparent disadvantage of an academically diverse student population has been used as an advantage through the introduction of inductive project based teaching. The students in the course are from different countries and that helps them to have real global perspectives on various issues through class interactions. The culturally diverse student population and their efforts to relate the course to the global context make the class discussion lively and educative.

Introduction

Environmental education for engineers and scientists is becoming increasingly important and popular throughout the world[1]. There is a need to develop courses which introduce students to

interdisciplinary environmental management principles and tools, and expose them to various real world problems. To promote interdisciplinary environmental education and research, North Dakota State University (NDSU) has introduced a program in Environmental and Conservation Sciences (ECS) in 2003. The new program is built on established research strengths across four colleges in the university and is expected to provide the collaborative framework to integrate research and education across disciplines to resolve complex resource issues[2]. The ECS program has successfully enrolled students for the last four years in Environmental Sciences and Conservation Biology tracks. The philosophy of the ECS courses is to emphasize and develop the common ground shared by all sciences such environmental problems can be addressed with a multi-disciplinary approach. The Environmental Science track deals with the abiotic environmental issues such as water, air, and land pollution, while the Conservation Biology track focuses issues like preservation of biodiversity and ecosystem function. The colleges of Agriculture; Arts, Humanities and Social Sciences; Engineering and Architecture; and Science and Mathematics participate in the ECS program making it a real interdisciplinary program. Civil Engineering Department faculty members are actively engaged in the ECS program. As part of this interdisciplinary collaboration, a course in environmental management catering to ECS and civil engineering students was introduced. The course was designed as a graduate level course and was made available to civil engineering undergraduates as a technical elective. The challenge was to address a widely diverse student group with different academic backgrounds. The course has been taught by the first author (course instructor) twice since its introduction in 2006. This paper outlines the development process and delivery of the course to NDSU students.

Overview of the Course

The course, ECS 740 Environmental Management, is intended to give students an understanding of current environmental issues and tools for environmental management. The issues are examined from the worldwide perspectives of science, engineering, business and society. At the end of the course students are expected to have a comprehensive knowledge of integrated environmental management with a global perspective. It is designed to help them in environmental decision-making from a socio-economic-environmental standpoint. The conceptual framework used to develop the course content is shown in Figure 1. The course content developed and offered in Fall of 2006 is presented in Table 1. The course objectives and grading policy are presented in Table 2.

The course had to be designed to cater to students with backgrounds in humanities, science and engineering and, hence, deviated a lot from a 'conventional' environmental management course offered in engineering discipline. Deviation from the convention brought in issue of text book into focus. Most of the available environmental management text books are written for students with engineering background. After scanning a number of textbooks it was realized that it would be an injustice to recommend a single textbook for this course. It has been decided to provide a series of reference books[3-9] instead. To make the course more relevant and time appropriate journal papers are extensively used as study materials. Manuals and reports available with US EPA and some websites are used as reference for specific topics. For example, for life-cycle assessment (LCA) a US EPA publication[10] is used. For integrated environmental management, best management practices, and risk assessment the US EPA resources[11-13] are used. Web-based

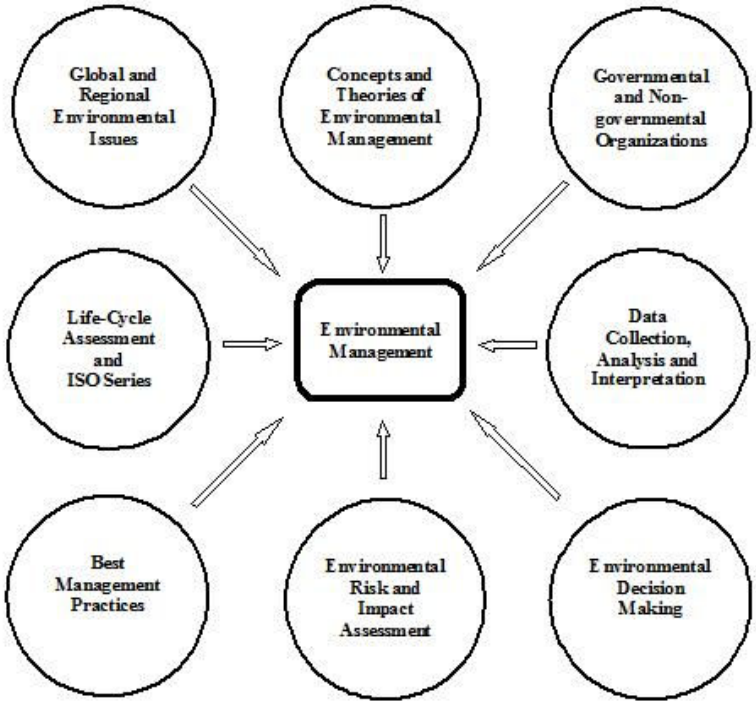

Figure 1. Framework for Course Content in ECS 740: Environmental Management

Table 1. Environmental Management Course Content for Fall 2006

Lecture 1: Introduction and overview; world and regional environmental issues (population and poverty; world economic order and the environment)
Lecture 2: Environmental degradation (biodiversity and ecological destruction; global warming; natural resources depletion and contamination)
Lecture 3: National and international perspectives of environmental management
Lecture 4: Evolution of environmental policies, regulations, and management
Lecture 5: Role of regulatory agencies and non-profits in environmental management (USEPA; state agencies; United Nations; World Bank; NGOs)
Lectures 6-7: ISO 14000; Life-Cycle Assessment (LCA)
Lectures 8-10: Integrated environmental management (socio-economic and environmental perspective; case studies)
Lecture 11: Class Test 1
Lectures 12-14: Prevention and control of environmental degradation (Scientific principles and techniques; case studies)
Lectures 15-16: Best Management Practices (BMP) (Principles; case studies; manifestations of BMPs to the environment)
Lectures 17-18: Environmental modeling (Purpose of models; types of models; use of GIS and remote sensing in models; models as decision making tool; model demonstration)
Lectures 19-20: Environmental assessment (General framework; ecological risk assessment)
Lecture 21: Class Test 2
Lecture 22: Environmental feasibility study (General framework; case studies)
Lectures 23-24: Environmental decision making (Frameworks under which decisions are made; models and processes for decision making; decision communication)
Lectures 25-27: Collection, analysis, and management of environmental data
Lecture 28: Transfer of research findings/technology to the field
Lectures 29-30: Student Presentations
Lecture 31: Final Examination (2-3 hours)

Table 2. Course Objectives and Grading Policy

Course Objectives:

- The students will understand current environmental issues of concern
- The students will use tools for analysis of data for environmental management
- The students will have a broad knowledge of integrated environmental management issues and methodologies with a global perspective
- The Students will learn techniques for environmental assessment and feasibility studies
- The will be able to make environmental decisions based on socio-economic and environmental considerations

Course Grading: Grades will be based on the following:

Assignments	30%
Class Tests/Quizzes/Exams	20%
Final Examination	10%
Project(s)	40%

Grades: A (90^+ to 100%), B (80^+ to 90%), C (70^+ to 80%), D (60^+ to 70%), F (0 to 60%)

resources[14-17] have been extensively used.

Use of guest speakers to fill the knowledge gap of the instructor has proven to be effective. Typical list of guest speakers include faculty from Industrial Engineering, Economics, Political Science, environmental managers from local industries, and representative of nonprofit environmental organizations. Presentation by a guest lecturer also breaks the 'monotony' of the class and brings in news ideas towards problem solving. Guest lecturers are encouraged to be informal in their presentations and allow student participations during and at the end of their presentations. Presentation by guest lecturers and associated handouts served as another resource base for the course.

The present course is interdisciplinary in nature given the fact that students from civil engineering, biology, natural resources management, geology, and other branches of science and engineering work to together on projects and assignments. Each student brings in his/her expertise and fills in the knowledge gap of others. Nine graduate students took this course in 2006 and six students took this course in 2007. In both years students were from six different countries representing different socio-cultural, political, and environmental settings. This diversity provided a unique opportunity for exchange of ideas and making the class discussion more global. This course uses inductive teaching techniques throughout the course. Inductive nature of teaching is more prominent in the project works and assignments. Abstract theories are introduced while assigning a project and homework assignment. Detailed theories are taught or the students are helped to learn them when they discover the need for the theories.

In addition to printed books and papers, computer models were introduced with hands-on demonstration to solve specific field based problems.

Course Modification through Student Participation

The course syllabus and other materials are posted on the course Blackboard at the beginning of the session, and a 'welcome mail' is sent to the participating students. The mail enumerates the course details, objectives, and expectations from the students during the semester. Students are encouraged to suggest modifications to the course contents and delivery methods such that they are better served. One or two students would normally reply back. Also 'revise your course as you go' policy has been tried and found to be partially successful. However, when students are asked again to go through the same process at the end of the semester, they are more forthcoming. Typical student suggestions include inclusion of new topics for discussion, provision for more guest speakers, more extensive project work, and change of emphasis on certain discussion topics and delivery methods. Most students like the inductive teaching technique and interactive nature of the course. Based on student feedbacks the course syllabus from the first year was modified and the new syllabus and delivery methods (Table 3) were found to be more effective. The basic pedagogical structure of the course has been maintained as the same with an emphasis on inductive teaching.

In the first year the class met two times a week for 75-minute sessions. However, it was felt that the discussions are not complete due to the short duration of the class and case studies (projects) did not get adequate attention. The class now meets only once a week for 150 minutes. The first two hours of the class is for topic introduction or invited presentations with a brief 'coffee break'. The last thirty minutes of the class is exclusively devoted to the case study discussion done in a 'round table conference' style. Teleconferences with stakeholders and resource persons in the USA and aboard (India) are held either during class hours or on a specially arranged time. The 150-minute class has so far proved to be more effective and popular among students.

Modeling through Role Playing

To develop interpersonal skills and teamwork spirit among the students, role playing is made a part of course. Role playing has been proven to be effective in promoting perspective taking[18] and interpersonal skills[19-20]. Teamwork development and team member relationship reinforcement are also catalyzed by role playing[19-20]. Students are asked to play the roles of the stakeholders from the live environmental management project chosen for study. In 2006 and 2007, Deepor Beel wetland in India was selected for study. Role playing helps student in understanding the complexities and subjectivity involved in environmental decision making and helps them in learning conflict resolution. Students are asked to select their role based on their individual background and liking. Because of limited number of enrollments in the course, each student plays the role of a different stakeholder. However, once the course starts getting more enrollments, each role will have to be played by a group of students. Each role player does enough background work on the role s/he plays and even gets emotionally involved. That helps in simulating the real or near-real field situation. Each student posts his/her views (as a stakeholder) on Blackboard Discussion Board on the issues in hand and how s/he wants them addressed to best serve to stakeholder s/he is representing. Other students (stakeholders) respond to this post indicating how they are going to be affected by what are being proposed. Here they suggest compromises keeping the interests of their own stakeholders in mind. This blackboard discussion is followed by in-class role playing with the instructor as the moderator. Two to three

role playing sessions are organized to come up with some 'agreed' solutions and identify works that need to done.

Table 3. Modified Environmental Management Course Content for Fall 2007

Lecture 1: Introduction to Environmental Management; National and international perspectives of environmental management; world and regional environmental issues (population and poverty; world economic order, and the environment)
Lecture 2: Environmental degradation (biodiversity and ecological destruction; global warming; natural resources depletion and contamination); Role of regulatory agencies and non-profits in environmental management (USEPA; state agencies; United Nations; World Bank; NGOs); Prevention and control of environmental degradation (Scientific principles and techniques; case studies); Evolution of environmental policies, regulations, and management
Lecture 3: Life-Cycle Assessment (LCA)
Lecture 4: ISO 14000 Series; ISO 9000 Series (Guest Lecturer); LCA (continued); Test 1
Lecture 5: Economic values of biodiversity and scenery (Guest Lecturer); Possible LCA Projects (Guest Lecturer)
Lecture 6: Integrated environmental management (socio-economic and environmental perspective; case studies); Best Management Practices (Principles; case studies; manifestations of BMPs to the environment)
Lecture 7: Environmental Management at an industry (Guest Lecturer); Test 2
Lecture 8: Environmental assessment (General framework; ecological risk assessment)
Lecture 9: Environmental assessment (continued). Modeling Ecosystem Services Using the Mallard Model (Guest Lecturer)
Lecture 10: Environmental modeling (Purpose of models; types of models; use of GIS and remote sensing in models; models as decision making tool; model demonstration) (Guest Lecturers)
Lecture 11: Governing the International Commons with special focus on biodiversity, whaling, Antarctica and toxic trade (Guest Lecturer); Environmental feasibility study (General framework; case studies); Test 3
Lecture 12: Concept of reliability for management applications (Guest Lecturer)
Lecture 13: Environmental decision making (Frameworks under which decisions are made; models and processes for decision making; decision communication)
Lecture 14: Collection, analysis, and management of environmental data. Transfer of research findings/technology to the field
Lecture 15: Class Presentation; Final Examination

Concepts Applied to Case Studies

Two projects are taken up during the semester and the learning process centers around these projects. Typically students work on an environmental management (EM) project and a life cycle assessment (LCA) project. Projects on EM and LCA are felt important keeping in view their relevance in project evaluation and management[21]. Concepts learnt in the class or through reading are applied to the cases in hand. For example, the concepts of environmental impact assessment, risk assessment and decision making are applied to address the EM problem. Life-cycle impact and decision making tools are used in the LCA project. Again, the concept of LCA is applied in the EM project. Computer software available for LCA is used. The EM project is typically a 'live' project and students work on this project as 'consultants'. The EM project involves networking with stakeholders, data collection and analysis, environmental risk and impact assessment, and preparation of a 'comprehensive' management plan.

In the last two years students worked on Deepor Beel wetland in India as their EM project. LCA was performed on corn ethanol fuel production with specific reference to North Dakota and on paper disposer and hot air hand dryer used in the NDSU restrooms. The two projects are so selected that one addresses a problem at home (North Dakota) and other has a global appeal. The course website (www.ndsu.edu/ndsuem) is specifically maintained such that actual stakeholders

can look at the analysis and solutions being suggested. In all the case studies, students interact with the actual stakeholders through personal visits, e-mails, phone calls and teleconferences. Such communication techniques help in developing their public relation and interpersonal communication skills much needed for an environmental manager.

Assignments, Tests, and Hands-on Model Demonstrations

Five to seven homework assignments and three to four tests are planned during a semester. Student inputs are being used to decide on the nature of assignments and tests. Assignments are designed to help the students learn additional topics not extensively covered in the class and to develop the ability for critical analysis and problem solving. In-class tests were done away with after the first year based on student feedback and instructor's own evaluation. It was felt that the class time spend on in-class tests can be better utilized for course discussion. Presently all tests are take-home and more extensive than the conventional in-class ones. The questions in such a take-home test are both closed ended quantitative and open ended qualitative ones. Similar 'no in-class test' technique has been used by other and reported positive results[22]. The students were encouraged to submit all completed tests and assignments electronically to show their commitment towards a better environment. Some of the assignments and test questions challenge students to use various conventional computer tools (e.g., Excel spreadsheet) beyond the convention. It is felt that there is a very thin boundary, if any, between the type and nature of homework assignments and take-home tests.

Keeping in view the objective of creating environmental managers with a comprehensive knowledge about various decision making tools available, various commuter models are introduced in the class. The hands-on-demonstrations for computer models are held in Civil Engineering computer room. The password protected computers in this room are only open to Civil Engineering students. To accommodate students from other branches of engineering and science, temporary passwords are created for the students for the semester. One desktop computer is normally available for each student during class hours and they are provided with access to the computer cluster at any other time throughout the semester. MODFLOW[23], QUAL2K[24], SWMM[25], GaBi[26] and Mallard[27] models are introduced and students work on small assignments to have a feel on the usability of the models for decision making. Students are also introduced to some commercial versions of the models and how they are used by the industry and consulting firms. Visual MODFLOW (11-user license) has been installed in the computers for student use. Students normally use the free trial version of GaBi 4.0 even though a licensed full version is available with the instructor.

Diversity Used to Advantage

The class derived advantage of having students from different academic backgrounds and they being from different countries. In 2006, all students but four were from different countries. The four students from the United States also had different backgrounds in terms of their education and work experience. The group also contained three women. In 2007, all the students were from different countries and there were two women. The cultural, academic, and gender diversities among the students and views generated because of that helped in understanding the complexities involved in managing environmental issues and how to bring consensus. The

apparent disadvantage of an academically diversified student population has been used as an advantage through the introduction of inductive project based teaching. The students introduced a real global perspective through interaction amongst themselves. The culturally diverse student population and their efforts to relate the course to the global context make the class discussions lively and educative.

Course Assessment and Student Feedback

NDSU has an anonymous course assessment process in place. The evaluation form has a scanable part where students rate various aspects of the course from poor to very good. The form also has a provision for students to provide written evaluation. ECS 740 has been offered only two times and it is too early to compare and evaluate the data generated from student assessment. To get real time feedbacks from students, a discussion forum is kept open on the course blackboard allowing students assessment the course anonymously as it progresses. The instructor reviews these comments on a regular basis and makes adjustments and modifications to the course and delivery techniques as needed. Having a say in the way they are being taught, students realize that they are playing important roles in the course. They feel happy being able to voice their opinion, which may be unpleasant to instructor at times, and seeing the instructor taking them seriously. The instructor of this course feels that maintaining such a feedback forum positively impacts the instructor's course delivery and students' learning processes.

Summary and Conclusions

Inductive teaching technique has been tried in the course and found to be effective. Past students' active interactions with the course instructor and participation in class in the next semester on selected events are indicators of positive influence of the course on students. The course, however, needs a number of improvements to make it more effective and to attract more student enrollment. It should, however, be noted that the authors have not done any specific quantitative survey among the students to evaluate the effectiveness of this course. Preparation for such a survey is underway.

ECS 740 is presently offered as a core course in Environmental Conservation Sciences program and as an undergraduate technical elective in Civil Engineering. The course, however, is open to all graduate students at NDSU. The course instructor sends out e-mail to all faculty members and graduate students informing about the course. Despite these efforts the student number has so far remained small. Co-listing of the course in other programs should help in increasing enrollment. Despite co-listing the course as a civil engineering technical elective no undergraduate student has so far opted for this course. This may because of lack of design credits with this three credit course. Civil engineering undergraduate juniors and seniors typically look for 0.5 to 1.5 design credits to fulfill their 6.0 design credit requirement. Modifying the course syllabus to incorporate some design credits should bring in engineering undergraduate students. However, a global change in the syllabus for civil engineering students may dissuade other students to take the course. Keeping this in view some changes can be made to the LCA project or offering more than one LCA projects to incorporate some design credits.

The present course website needs further improvement to make it a better educational tool not only for the students taking the course but for others interested in environmental management. Links to various environment management tools need to be provided.

Case studies from across the world are planned for the course. The Deepor Beel wetland case was taken up in the first two years because of involvement and familiarity of the instructor with the wetland. The instructor is presently working with a Boulder (Colorado) based nonprofit, Global Response, to identify and lay groundwork for an environmental management project for Fall of 2009. The involvement of a nonprofit is expected to bring in a new perspective to the learning process.

Based on student feedback more invited lectures are felt necessary. The geographic location of NDSU come in way of getting speakers physically on campus but available new technologies should make it possible to have speakers from across the world. The instructor plans to bring in more speakers into the classroom through the use of interactive video network, podcasting, streaming video and teleconference.

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