2006-114: USING ENVIRONMENTAL IMPACT ASSESSMENT TO INTRODUCE ENVIRONMENTAL ENGINEERING TO TRADITIONAL CIVIL ENGINEERING UNDERGRADUATE STUDENTS

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Using environmental impact assessment to introduce environmental engineering to traditional Civil Engineering undergraduate students

Introduction

The City College of New York undergraduate Civil Engineering (CE) program has a well rounded curriculum which develops proficiency in structural, transportation, and environmental engineering. The 134 credit program is fairly traditional in that it requires statics, dynamics, mechanics of deformable bodies, structural analysis, finite element analysis, soil mechanics, transportation systems and engineering, fluid dynamics, hydraulics and hydrology, and environmental engineering of all undergraduate students.

The program serves a diverse student population, a majority of whom elect to specialize in structural engineering. For example, in Fall of 2004 and Fall of 2005, 52% of the undergraduate students taking the environmental course specialized in structural engineering, and 30% specialized in transportation engineering. Only 18% of the undergraduate students actually specialized in environmental engineering. Since a majority of the students taking the course did not specialize in environmental engineering, the required environmental engineering course was considered to be irrelevant by many of the students.

In response to these factors, a required course called Environmental Impact Assessment (EIA) has been introduced into the curriculum, just before the required Environmental Engineering (EnvE) course. The EIA course introduces environmental concepts as a means to perform environmental assessment, a practice employed by engineers of all specializations to develop more sustainable engineering designs. As such, the EIA course focuses on the environmental media of greatest relevance to EIA, namely air, water, soil, and sound; the physical and chemical descriptions of these media; and the transport and transformation of pollutants in and across these media. Environmental engineering practices to reduce these pollutant concentrations at the source or in the environment are only introduced, and only to make students aware of conventional means to mitigate environmental impact. Conventional methods of drinking water, waste water, and air pollution treatment are now the focus of attention in the revised EnvE course. The primary goals of the EIA course are to engage all CE students regardless of their specialization, and create an interdisciplinary forum to discuss and evaluate some of the social, economic, and environmental issues associated with CE projects. The secondary goals of the course are to prepare students for two higher level required courses, and promote the utility and importance of environmental engineering and thus recruit more students into the field of study.

Structure of the New Course

The course is open to engineering students who have completed sophomore level calculus, computer assisted data analysis and chemistry, and who are in the process of completing or who have already completed fluid mechanics.

The course draws upon references for both impact assessment and environmental engineering. The formal national, state, and local environmental policy acts and relevant regulations are distributed as handouts to students.[1,2] Handouts from environmental assessment textbooks reveal the motivation and basic methodology of EIA, provide guidance on how to describe the "environment" [3], and exemplify environmental impacts that can result from typical structural, transportation, and water resources engineering projects.[4] The environmental engineering textbook introduces and illustrates the environmental engineering concepts used to characterize the environment, describe pollutant transport and transformation in the environment, and mitigate pollutants.[5]

<u>Difference between Objectives of the New and Old Courses</u>

The former EnvE course was traditional, and included basic descriptions of the air and water environments and typical pollutants in these environments, and conventional industrial methods to mitigate them. The course objectives are detailed below.

1. Analyze water and wastewater for specific contaminants
2. Size a treatment process to achieve removal of pollutants
3. Perform and design experiments to test water quality and evaluate treatment dose
4. Understand the fundamentals of air quality and air pollution
5. Appreciate the need to minimize contamination of the environment
6. Learn to write an engineering report

The sequence of new EIA and EnvE courses has fundamentally different course objectives from the former EnvE course. Together, they cover a broader range of topics, spanning from environmental assessment, environmental modeling, and environmental engineering, as well as a broader range of environmental media, spanning from air, water, soil, and sound. However, each topic is covered in great depth, allowing students to become truly proficient in the concepts.

While the new sequence of courses is able to cover more concepts and at greater depth because of the increase in contact hours (i.e., one course was replaced by two courses), the arrangement of the material in the new sequence also helps to motivate the concepts introduced in both courses. They motivate eachother, since the need for pollutant mitigation and the broad sources of these pollutants is now well understood, and specifically in relation to CE projects across the specializations.

The objectives of the new EIA course are as follows:
1. Develop knowledge of soil, water, air, and noise pollution, their sources, and why they are regulated
2. Predict the transport and transformation of pollutants in and across the environment
3. Recommend and apply environmental engineering practices to reduce the impact of a potential activity on the environment
4. Apply the National Environmental Policy Act (NEPA) and the New York State Environmental Quality Review Act (SEQRA) to determine the extent of assessment required of a particular project based on the project actions and its location

5. Apply the New York City Environmental Quality Review (CEQR) policy to qualitatively assess the impact of a potential engineering activity on the environment
6. Develop a repertoire of local examples of impact assessments on real engineering projects
7. Learn to professionally communicate technical findings and develop ability to work effectively in a group

The objectives of the new EnvE course are as follows:
1. Develop understanding of water quality parameters used in characterizing water and wastewater pollution (augmented by laboratory experiments)
2. Motivate the need for water and domestic wastewater treatment
3. Develop knowledge of commonly used technologies in water and wastewater treatment (augmented by laboratory experiments)
4. Given raw water quality and effluent requirements, recommend and justify a train of treatment of processes
5. Develop knowledge of commonly used technologies in air pollution treatment (augmented by laboratory experiments)
6. Given input air quality and exhaust requirements, recommend and justify a train of treatment processes
7. Learn to professionally communicate technical findings and develop ability to work effectively in a group

Lecture and Discussion Topics

The remaining sections of the paper focus on the EIA course, since the new EnvE course has yet to be taught. The previously mentioned objectives are to be achieved within 2.5 hours of contact time per week over a 14 week semester, by discussion of the following topics.

1. *Introduction:* - Air, water, sound, and land resources

2. *Environmental impact assessment:* - National / NY environmental policy and regulations
   - Federal and state recommended methods project classification and environmental review
   - NYC recommended methods to describe environment and evaluate impact
   - Introduction to the Belleayre Resort project revisited at the end of each media

3. *Review of chemistry:* - Chemical classes and physical phases
   - Units of measure (e.g., atoms, molecules, moles, concentration)
   - Chemical reactions (e.g., reaction types, stoichiometry, kinetics, chemical equilibrium)
   - Examples of reactions in and across water, soil, and air environments

4. *Review of materials balances:* - Unsteady and steady mass balances
   - Idealized models of flow (e.g., batch, continuous stirred tank, plug flow) and efficiency
   - Examples of mass balances applied to water, soil, and air environments

5. *Human impact:* Health risk perception; exposure assessment; risk characterization

6. *Soil impact:* - Properties (e.g., soil classifications and properties, soils in NYC)
   - Transport of soil (e.g., soil loss by erosion using Universal soil loss equation)
   - Transport and transformation of pollutants (e.g., infiltration of water and water pollutants into unsaturated soil using Horton and across saturated soils using Darcy)
   - Pollutant mitigation (e.g., erosion minimization, well extraction)
   - EIA description of land attributes (e.g., soil stability, resistance to natural hazards, land-use patterns) and example of soil EIA using Belleayre Resort project

7. *Water impact:* - Properties (e.g., hydrologic cycle, aquatic environment, NYC watershed)
   - Pollutants (e.g., pollutants, sources of water pollutants nationally and in NY, water quality of surface and ground waters and rate of fishkill in NY)
   - Transport and transformation of pollutants (e.g., pollutants in surface water using mass balances and Streeter Phelps equation, and in ground water using soil methods)
   - Pollutant mitigation (e.g., overview of treatment of drinking water and waste water)
   - EIA description of water attributes (e.g., aquifer safe yield, flow variations, aquatic life, various chemical components, fecal coliform) and example of water EIA using Belleayre Resort project

8. *Air impact:* - Properties (e.g., meteorology, stability and terrain effects, NYC airshed)
   - Pollutants (e.g., criteria and hazardous air pollutants, sources of air pollutants nationally and in New York, violations of NAAQS and releases of HAPs in NY)
   - Pollutant transport and transformation (e.g., pollutant concentrations predicted using steady and unsteady box models and Gaussian plume model)
   - Pollutant mitigation (e.g., overview of industrial and mobile removal of gases or PM)
   - EIA description of air attributes (e.g., diffusion factor, various chemical components) and example of air EIA using Belleayre Resort project

9. *Sound impact:* - Properties (e.g., power and power level, rating systems)
   - Pollutants (e.g., noise in NYC)
   - Pollutant transport and transformation (e.g., near field and far field attenuation)
   - Pollutant mitigation (e.g., reduction of vibration, use of physical barriers)
   - EIA description of sound attributes (e.g., physical and psychological effects, communication and performance effects) and example of sound EIA using Belleayre Resort project

10. *EIA case studies:* Student presentations of EIA of structural, transportation, and environmental engineering projects proposed in New York or NYC

<u>Group Project</u>

A major component of the course is the group project, intended to develop associations between concepts learned in class and real engineering projects related to the students' own specializations. At the beginning of the course, students are grouped into teams based on their specialization. Each team is provided a website address for an Environmental Impact Statement (EIS) for a local engineering project related to their specialization. Examples of projects analyzed by the structural engineering students include the construction of the 4-Season

Belleayre Resort in the Catskills, and the construction of the World Trade Center Memorial and the redevelopment of the business complex. Transportation engineering students have analyzed the extension of the NYC 2nd Avenue Subway, and the renovation of the NYC Cross-Bronx Expressway. Environmental engineering students have analyzed the construction of the Croton Filtration Plant, and the construction of NYC Tunnel Number 3 to supply the upper east side of Manhattan and provide redundancy in the existing water distribution system.

In the first third of the semester, they are assigned small components of the project, to complete individually. These assignments task them to summarize the NEPA and SEQRA processes (week 3), describe their project, its alternatives, and any controversy associated with it (week 4), classify their project using SEQRA and detail the project history to date (week 5), and compile a table of the impacted environmental attributes as a function of project alternative (week 6). In the last two thirds of the semester, they work as teams on the project. They choose and refine the best individual assignments of the group members for inclusion in the group report. They also qualify or quantify the baseline and impacted social, economic, and environmental attributes as a function of project alternative, identify data and modeling tools required to evaluate the impact, and discuss the effectiveness of mitigation.

Course Assessment Tools

Short term assessments are used to evaluate whether individual course objectives were met, and whether the primary goals of the new course were met: engage all CE students regardless of their specialization, and create an interdisciplinary forum to discuss and evaluate social, economic, and environmental issues. At the end of the semester, students are assigned a final grade in the course. This grade is used to evaluate student learning from the perspective of the instructor. Students are also asked to complete two end of course surveys. The formal anonymous end of course survey is conducted by the school and is used to evaluate student perception of whether course objectives were satisfactorily met. An informal anonymous survey is conducted by the instructor to reveal student perception of the usefulness of the references and comprehension of course topics, and solicit ideas for demonstrations to be to help clarify unclear concepts.

Long term assessments indicate the retention of the course material and the influence of the course on the professional choices made by the students. As such, long term assessments are used to evaluate whether the secondary goals of the course are met: prepare students for two higher level required courses, and recruit more students into the environmental engineering specialization. Since the EIA course is in its infancy, the first data points needed for long term assessment will not be available until at least three years have passed. EIA serves as a prerequisite course for two other required courses: the new junior level EnvE course and the senior level Capstone Design course. The end of course evaluations for these two courses will document the utility of EIA as a prerequisite for these later courses. Instructors will be interviewed to reveal to what extent students retained concepts introduced in EIA. Since most students select a specialization in their sophomore year (i.e., just after taking EIA), the ability of the course to attract students to environmental engineering will be evaluated by tracking the number of students who elect to specialize in the field. Upon graduation, a final assessment point is collected when the exit interview is conducted. The number of students who acquire jobs in the environmental field or who perform environmental impact assessment for their job will be enumerated.

Challenges to the EIA Course

Most of the challenges to this course relate to the availability of appropriate resources. Many EIA textbooks and references were surveyed to identify those that would complement and supplement the intended lecture topics. However, the authors found no single book that both possessed the technical rigor or numerical basis required for an engineering course, and was comprehensive in its coverage of environmental policy, environmental assessment, and environmental engineering practices. As a result, environmental policy concepts are addressed using a reader compiled from various sources and a technical guidance manual produced by the City of New York, environmental engineering concepts are addressed using an environmental engineering textbook,[5] and environmental assessment concepts are addressed using a combination of the sources.

Another challenge to the course is the voluminous nature of most environmental assessments. An ideal project for this course would assemble students into teams and ask them to assess a real project. However, this process requires extensive data to describe the environment, as well as extensive data to describe the impacts caused by the engineering project. Such data require a large amount of effort for each different environment and for each new project. After conducting the course for two semesters, a reasonable alternative to producing an EIS has been identified: future sections of the course will also include a mini-design project during which students identify environmental attributes, impacted in construction or in use by a project on campus. This project will be assigned after the final group project has been submitted, so students can draw upon both the lecture/discussion material and their group projects.

A final challenge to this course is how to balance time spent introducing and reinforcing the concept of EIA, relative to time spent addressing conventional methods of water, air, and noise treatment. Our solution to this challenge is to require two environmental courses of our students. As previously mentioned, the new EIA course is the first one and focuses on the environment and the impact of engineering activities on it, and only provides an overview of treatment methods. The revised EnvE course is the second one and focuses on treatment methods and has a weekly laboratory component. This course differs from the former EnvE course in that students learn to design and not just apply treatment concepts.

Assessment of the Course

The EIA course has been conducted twice thus far, in Fall of 2004 and Fall of 2005. Although both short term and long term assessment tools are in place, this discussion does not address long term assessments of the new course since the data are not yet available. Instead the discussion focuses on data collected using the formal anonymous end of course survey administered by the school, and the grades earned by students in the course.

Student Evaluation of Course

The average grade given to all CE courses by our students was 81-82% during the period from Spring 2003 to Fall 2005. The grade given to the "environmental" course, whether it was the new EIA course or the former EnvE course, varied each semester, as illustrated in Figure 1. On average the instructor grade of the student was 12% higher for the new EIA course than for the former EnvE course. The course grade fell below the departmental average only during the semesters when the former EnvE course was taught.

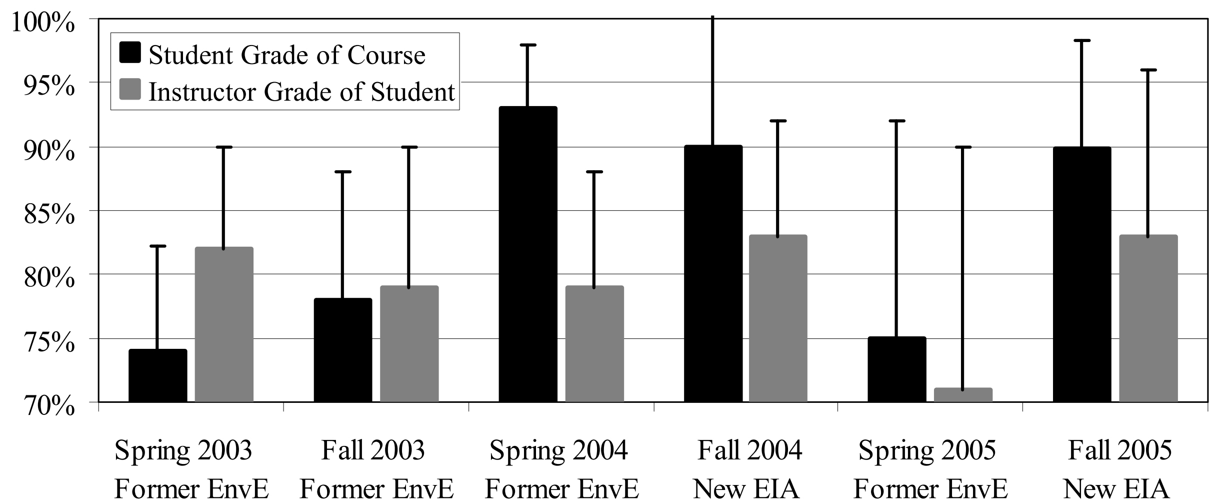

Figure 1. Average student grade and perception of course improved when environmental engineering subjects were taught using EIA than when taught in a traditional EnvE format.

In addition to numerically rating how well course objectives were met, students were asked to comment on the course. Comments that were in common with both the former EnvE and new EIA course related most often to the "practical" nature of the course and the opportunity to apply concepts learned in prerequisite classes to a new subject.

> *"The class addressed my concern of not having enough practical classes that deal with real world practices."*

> *"The class showed me how to use material from fluid mechanics and hydraulics, such as mass balances, to answer many problems."*

When taught as a traditional EnvE course, particular students voiced a frustration and lack of interest in a course that they felt had "little relationship to other CE courses" or to their specialization.

> *"To be honest I didn't like the course at all. My field of specialization is structures so I don't care at all about this class."*

"The class, in general, was very boring."

When taught using EIA, many transportation engineering and structural engineering students voiced a support of the course. Particular students appreciated the introduction of EIA at the beginning of the course, the consistent coverage of environmental media throughout the course, and the reinforcement of the EIA and environmental concepts during the group project.

"The study of the impact of engineering projects on the environment along with the study of environmental engineering of air, water, and noise ... is a great way to introduce environmental engineering to students."

"I liked how the class was taught. It was organized into four main groups (air, water, soil, and noise) that helped me to absorb environmental impact from four perspectives."

"I am a senior specializing in structural engineering. Before this class, environmental engineering was just an ambiguous topic. Because of this class, I am a well-rounded engineer who can walk into an interview with more confidence and have a better awareness of the environmental aspects in any civil engineering project."

"The group project was informative. It added perspective to the rest of the class"

<u>Instructor Evaluation of Students</u>

The student grades of the course and their comments indicate that the new course met its primary goals: engage all CE students regardless of their specialization, and create an interdisciplinary forum to discuss and evaluate social, economic, and environmental issues.

The short term assessment of student performance in the course indicated how well the students met the instructor's expectations. As indicated in Figure 1, the average grade earned by students was also variable each semester. On average the instructor grade of the student was 5% higher when the course was taught as EIA than when it was taught in a traditional EnvE format.

<u>Limitations of Short Term Assessments</u>

The short term assessments presented thus far do not account for differences in teaching style of the two instructors responsible for the course during the assessment period. Instructor A was responsible for the course in Spring 2003 and 2005. Instructor B was responsible for the course in Fall 2004 and 2005. The two instructors taught as a team in Fall 2003 and Spring 2004.

Student grades of the course and student grades achieved in the course, as a function of the instructor and the course format, are shown in Table 1. The difference in grades by instructor are notable. Since the student grade of the course indicates how well course objectives were met and given particular anecdotal student comments, difference in grades may be at least partially explained by differences in teaching style.

Table 1. Differences in teaching style do not fully explain improvement in grades.					
Average	**Instructor A**	**Instructor B**	**Instructors A and B**	**Former EnvE Course**	**New EIA Course**
Student Grade of Course	74%	90%	86%	78%	90%
Instructor Grade of Student	77%	83%	79%	78%	83%

Conclusions

To meet the perceived needs of our CE undergraduate students, a new required course on environmental impact assessment has been introduced into the curriculum, just before the required environmental engineering course. The new EIA course introduces environmental concepts as a means to perform environmental assessment, and focuses on the description of and transport and transformation of pollutants in and across the environmental media of greatest relevance to EIA, namely air, water, soil, and sound. Environmental engineering practices to reduce these pollutant concentrations at the source or in the environment are only introduced, leaving this to be the focus of attention in the revised EnvE course.

The primary goals of the new course were to engage all the CE students, create a forum to discuss and evaluate social, economic, and environmental issues, and recruit more students into the environmental engineering specialization. The short term assessment of the new course indicated that its first two primary goals were reasonably met. The new course was perceived to be engaging and relevant, even to students whose specialization was not environmental engineering. Further, the average student performance in and perception of the course dramatically increased.

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