Evaluation of the Impact of Multi-Educational Methods in an Environmental Engineering Class

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Abstract

The Cooper Union School of Engineering belongs to a NSF supported group of Universities, the Gateway Coalition. Working in collaboration with the Coalition, various projects have been implemented in order to improve and enhance education in different areas. One such area has been the environmental engineering classes. Various projects have been alpha- and beta- tested and subsequently implemented in the relevant environmental courses at Cooper Union in the past five years. These environmental projects and curriculum modules included new computer software uses, computer aided design projects, virtual laboratory, and virtual wastewater treatment plant fieldtrips, applications of GIS, use of the Internet for access to information and databases, etc. An important dimension of all these projects has been the feedback from the students and the evaluation of the implementations and curriculum modules through questionnaires, performance scales, semi-structured interviews, and other relevant assessment methods. The thorough assessment of projects and courses goes hand in hand with a careful planning of Departmental and program objectives, outcomes, and educational strategies and actions.

In the present paper, we present a particular implementation to the introductory environmental engineering class and the conclusions from the evaluations through questionnaires in two consecutive years. The specific implementation involved the introduction of biological and physicochemical wastewater treatment units to students through multi-educational methods and their evaluations/opinions regarding their effectiveness. The multi-educational methods included: 1) class lecture, 2) reading textbook, 3) fieldtrip to one of NYC's Water Pollution Control Plants, and 4) virtual fieldtrip with multi-media presentation in CU's Driscoll Auditorium. Additionally, the students' evaluations and opinions about various aspects of the overall class experience (through a more extensive questionnaire) are also presented. Students positively appreciated exposure to different educational methods, regardless of their own personal preferences. Their self-awareness of progress in learning throughout the course was also enhanced. A discussion follows on the benefits of using the results of what was mainly a summative assessment for developing a formative, CQI strategy for environmental engineering at Cooper Union, consistent with ABET 2000 and the educational objectives of the Civil Engineering Department.

I. Introduction

The Cooper Union School of Engineering is part of the Gateway Coalition, a group of currently seven schools working together for changing and improving engineering education in the face of the radical and overwhelming structural changes affecting the engineering profession today. The Coalition is a NSF-funded program with the philosophy of preparing the engineering student for the new situation, marked by the rapid spread of information technologies, and an increased international competition among engineering firms. The attributes of the student as an emerging professional, well presented in the new ABET criteria 2000, reflect these changes and require new attitudes and practices in the educational community (1).

Cooper Union has a nationally renowned School of Art, an internationally famous School of Architecture, and a top-flight undergraduate School of Engineering. Our small size, culture of intellectual curiosity, and tradition of integrating research and practical experience with education provide an excellent backdrop for adapting exemplary educational materials in innovative ways.

Cooper Union offers bachelors degrees in art and architecture, and bachelors and masters degrees in engineering. Admitted on merit alone, all 900 students receive full-tuition scholarships. About 40% of our students were born outside the U.S., and a similar percentage needs financial aid beyond the full-tuition scholarships. For 140 years, Cooper Union has been a means of social mobility for a multicultural, largely urban student population whose members are often first in their family to attend college.

The School of Engineering offers chemical, civil, electrical, and mechanical engineering degrees, plus a general engineering BS degree and studies in cross-disciplinary fields such as biomedical, environmental, materials, and manufacturing engineering. Eleanor Baum, the nation’s first woman dean of engineering, leads the school’s 31 full-time and 53 adjunct faculty. In 1997, *U.S. News & World Report* ranked the School of Engineering first among U.S. undergraduate engineering schools; and *Time Magazine/Princeton Review* ranks it as the nation’s third most selective school, tied with West Point.

Table 1. The Cooper Union at a glance

Cooper Union Demographics	Enrollment	Women	African American & Latino-American, and Native American	Asian-American
Engineering	470	30%*	10%	34%
Art	280	45%	25%	16%
Architecture	155	43%	15%	21%

**Almost double the national average for schools of engineering.*

Since its inception in 1992, the Gateway Coalition has promoted innovative educational techniques and methodologies and the implementation of quality measurements in the educational process that are contributing to a better awareness and achievement of results. More than 20 new modules have been implemented into courses at The Cooper Union for the past 6 years. An ongoing and expanding process of assessment helps to keep track of the specific achievements with the new experiences. Student feedback is routinely gathered, and the careful documentation of the process serves the purpose of changing and improving the delivery format of new editions of courses and programs. Overall we have learned that, when treated as "emerging professionals" students behave very professionally indeed: their participation in the educational process becomes more active, their confidence in their own skills and abilities increases, and their learning is more successful (2).

For the past few years, the Environmental Engineering Curriculum Innovation and development group within the Coalition has undertaken various educational initiatives with the following goals:

. Develop teaching/example modules in various courses taught by various professors;
. Exchange these class-tested modules among professors in other colleges, who then could beta-test them in similar classes;
. Introduce computer-aided demonstration and example modules in classes, with the use of case studies (3).

II. The Environmental Courses

Among the above-mentioned modules developed at The Cooper Union School of Engineering there was a virtual environmental laboratory coupled with a field trip, with the intent of emphasizing biological treatment processes for municipal wastewater treatment plants. This module was introduced in Cooper Union both in CE 141 -Introduction to Environmental Engineering (during the junior year) and in CE 441 Wastewater Treatment Plant Design (senior year and elective for graduate students). A description of the subject matter of the two courses follows.

The junior year course, CE 141 -Introduction to Environmental Engineering, is the first course where Cooper Union students have some exposure to environmental engineering concepts and practices --it is, in addition, the only required one. The course introduces and reviews the pertinent physical, chemical and biological theory and principles, and then looks at the design concepts and hydraulics of water supply systems and wastewater collection systems. Finally, this information is brought together through the engineering applications of physicochemical water treatment unit processes as well as the biological unit processes applied to wastewater treatment. The course is enhanced by an environmental laboratory period where parameter determination is used to bench-scale unit operations modeling. A prominent feature of the course, and a very effective one in terms of learning (according to the students' opinion) is the fieldtrips to facilities in the New York City area.

The senior year or graduate elective course, CE 441 -Wastewater Treatment Plant Design, combines lecture with design to teach the various hydraulic concepts, physicochemical unit processes, and biological unit processes that are typically used for municipal and industrial wastewater treatment plant design. The course includes four separate design case study projects, each introducing different concepts, principles, and aspects of hydraulic and treatment processes to students. One of those projects is design with the aid of software and example modules, which were developed in a previous Gateway project.

Students in both courses were exposed to the following multi-educational methods:
1) class lecture, 2) reading textbook, 3) fieldtrip to one of NYC's Water Pollution Control Plants, and 4) virtual fieldtrip with multi-media presentation in CU's Driscoll Auditorium.

Class lecture
The lecture is conducted in a traditional manner, with frequent use of the blackboard and overhead projector or slides. The students are encouraged to ask questions at any point, be it for clarification purposes of the material being discussed, or to bring up background knowledge in other areas. On occasion, guest speakers are invited to the class to address environmental issues of common concern. The students do homework and computer projects, as well as fieldtrip report and take a midterm and final exam consisting of a closed book questions section and an open book problems section.

Environmental Lab
The environmental lab has a small lecture section and a hands-on lab major part. The students work in small teams on hands-on bench-scale testing experiments where they determine the parameters and measurements for the entire class. All students participate in the work that each team develops thoroughly, and all the data from several days of lab work are utilized to write one report per series of related experiments. The samples utilized are collected by students in a fieldtrip, either on their own or by canvassing the school neighborhood.

Virtual Lab and Fieldtrip Presentation
The virtual lab and field trip presentations are being conducted in the Driscoll Multimedia auditorium with the use of videos, relevant computer software, and multi-media CD-ROMS. The instructor acquired these instructional materials from various industries and consulting firms or from the Water Environment Federation either with partial funding from the Gateway Coalition.

Fieldtrip
Each semester, the environmental class and/or the environmental student lab organize at least one or two fieldtrips to a sewage treatment plant, pumping station, water treatment plant or pilot treatment facility of the NYC Department of Environmental Protection. The students are given a talk and a tour of the facility and most times also collect some samples to be used in the lab.

Textbook (4, 5)
The textbook used in the class makes emphasis on the civil engineering, hydraulic, and process design approach since most of the students taking the CE 141 course are majoring in Civil Engineering. The textbook has been changed a number of times for the past years, but the thrust has remained the same. The students also deal with additional material, such as recent articles on related subjects from newspapers and magazines, as well as additional information and data in table and graphical form.

III. Evaluation

The questionnaire discussed in the present paper was developed by Prof. C. Yapijakis, responsible of the environmental engineering area at The Cooper Union and instructor of the courses mentioned above. The purpose of the questionnaire was to gather student feedback on the educational effectiveness of the new teaching and information-delivery formats used in CE 141, and in general to provide the instructor with better knowledge about the study preferences and learning modes of his students. It is not, therefore, an assessment instrument designed to measure achievement in learning outcomes, although the context-knowledge of the instructor could lead to some sound hypotheses on this matter.

The questionnaire was first handed in the fall of 1998 and then one year later, in 1999, to the students of CE 141 --Introduction to Environmental Engineering. A set of four basic questions was included in both years. In 1999 some new questions were added as a result of the assessment conducted in 1998, and also with the purpose of documenting other concerns, such as the studying habits of the students, and their learning preferences.

In 1998 the CE 141 students were asked the following questions:

Based on your personal perception (if no opinion, or if you were not there, you can answer: N/A) and your way of learning and studying, please answer the following briefly:

1. Did you understand better about biological wastewater treatment processes from Professor's lecture, environmental lab, virtual environmental lab, field trip presentation (Driscoll room), the actual NYC Red Hook WPCP presentation/field trip, or from reading your textbook? Rank in order 1 (most effective) to 5 (less effective).
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2. Which one or two of the above you want to do more of, to increase your understanding of class material?

3. Do you learn better from hands-on experiences or from reading material at home?

4. Do you learn better on your own (doing homework or projects or studying by yourself) or do you think you benefit exchanging ideas and cooperating in a team effort --even if you have to turn in an individual project at the end?

In the fall of 1999, the questionnaire included also the following questions:

5. Did you write your fieldtrip report and lab reports
a. on your own entirely
b. after discussing with classmates
c. in collaboration with classmates

6. Was your textbook (only) adequate to supplement your understanding of the lecture information, or you used other library books sometimes or you also used the Internet sometimes?

7. Did you change your style of learning (on your own or working with friends), comparing junior year at Cooper Union vs. high school? YES/NO

8. What is your usual preferable style of learning?
On your own
Studying with friends
Combining the above always

9. Before taking the intro to Environmental Engineering course, were you encouraged by other professors to work in teams (as engineers do) even for individual projects/homework? YES/NO

Some of these new questions reflect a new emphasis on teamwork, a feature strongly encouraged by the instructor of CE 141. Students in this course work routinely in teams in the lab section, where each team is responsible for a different part of an experiment. Teamwork is similarly recommended for students in preparation for exams and for completing homework assignments and even individual projects. Other questions try to measure variations in modes of learning among students since high school, given the fact that Cooper Union students were top high school students who nevertheless tend to be somehow isolated and individualistic in their learning habits.

IV. Discussion of results

As we see in Table 2, a significant number of students in both years rank "field trip" and "textbook" on top of the scale in educational methods. They show a clear preference for using these methods for understanding the class material. Each method reflects two contrasting approaches to learning: one (the textbook) is usually perceived as a fundamental source of knowledge, and requires individual and mental work -although it can be used in teamwork sessions- and the other (the field trip) is frequently used as a supplementary method, one that allows visual learning and hands-on experience in a real situation. Both methods combined seem to be an appropriate way for learning, according to the students.

As a supporting learning method (and one only occasionally used in CE 141), the virtual lab presentation is not ranked #1 by any student in 1998 or 1999. However, a noticeable number of the students (7 in 1998) rank it second among their preferences. Yet for equal number the virtual lab seems not to have been very helpful for learning: 7 students place it last in that year. Results in 1999 show a somewhat more balanced distribution, with more than half of the class ranking the virtual lab as the second or third preferred learning method.

Table 2. Educational efficiency of multi-educational methods in CE 141
Ranks of educational methods; figures express number of students.

	RANKINGS 1998 (N=19)					**RANKINGS 1999 (N=16)**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Lecture	3	5	7	1	3	2	4	7	1	2
Environmental lab	1	1	4	9	4	3	3	4	5	1
Virtual lab presentation	0	7	2	3	7	0	5	5	4	2
Field trip	7	3	1	2	3	7	3	2	2	2
Textbook	7	2	3	2	5	6	2	2	1	5

Question 1: Did you understand better about biological wastewater treatment processes from Professor's lecture, environmental lab, virtual environmental lab, field trip presentation (Driscoll room), the actual NYC Red Hook WPCP presentation/field trip, or from reading your textbook? Rank in order 1 (more effective) to 5 (less effective).

A similar interpretation can be made of the environmental lab, that portion of the course that fully exposes students to hands-on experiences and work. Consistent with its relative importance and time devoted to it in the course, the lab is ranked first or second by a few students (2) in 1998 and by many more (6) in 1999. However, a troubling proportion of the students seem not to be very satisfied with this method, as almost half of the class in 1998 put it in fourth place (9 students). Improvements in the organization of teams effected during the fall of 1999 seem to have had a positive effect, as results show.

Finally, the lecture mode is ranked third by most students in both years, although many students qualified their responses with suggestions about specific aspect of this traditional teaching format. Some students would like to see more discussion of specific examples of the material during the lecture time, and some others suggest including a lecture only after exposure to experimentation or after the field trip.

These results are consistent with results in Table 3 below. Students in both years respond similarly to a number of issues. In both years students consider that more field trip experiences and more use of the virtual lab mode would be beneficial to their learning. Seventeen students say they would like to spend more time outside the classroom and fifteen say they would like to see more virtual lab presentations. Eleven students in both years say they would like more exposure to experimentation in the virtual lab.

There are also some differences between 1998 and 1999 that are worth mentioning. The most important ones in our opinion are those concerning the lecture format. Students in 1998 did not consider this educational method very efficient for their learning and many expressed a desire to see some changes effected in the lecture format. A change in the organization and delivery of lectures was first implemented in the fall of 1999. The timing of the lectures was adjusted to the exposure to material in the lab and the presentations. The overall time devoted to lecture was reduced significantly, and students were also frequently challenged by the instructor to participate during the lectures. Students seem to be satisfied with this shift to a more hands-on learning format and a reduced lecture time, as reflected in results for 1999.

Table 3. Changes suggested

Figures express the number of students who would like to do in class more of each item

	1998 (N=19)	1999 (N=16)*
Lecture	**6**	**2**
Environmental lab	**5**	**6**
Virtual lab presentation	**6**	**9**
Field trip	**8**	**9**
Textbook	**2**	**3**

Question 2. Which one or two of the above you want to do more of, to increase your understanding of class material?

*In 1999 students were asked to list only two educational methods.

This decrease in the number of students who favor the lecture mode is consistent with the data about learning habits (Table 4). The percentage of students who declare to learn better from hands-on experience (which is the preferred mode of learning, rather than from reading material at home, or from a combination of both) is higher in 1999 than in 1998. In 1999 more than half of the class expressed a clear preference for hands-on experience.

There is also an increase in the proportion of students who prefer to learn in collaboration with classmates, from 21% in 1998 to 31.25% in 1999. In addition, a lower percentage of students seem to prefer the individual mode alone. However, students do not use team learning alone in order to prepare and learn the class material. Most (about half of the class in both years) use a combination of individual and collaborative strategies. When asked specifically about their usual learning habits, students respond consistently. About half of them declare to usually combine individual and team learning, and the rest are equally divided among those who study and learn on their own (25%) and those who usually do it with others (25%). Some of the comments by students were:

"Studying by myself. Group efforts are rewarding in someway, but only if the people you are working with understand how to work in groups."
"Homework and projects are better in a group; studying for tests is better alone with an option to call classmates for specific questions."

"I prefer to study myself on the concepts, then ask questions and discuss with a study group." "The team effort stuff taught me more, but you still have to be careful of who is in your group." "Learn on my own for tests, but also group thinking helps a great deal on homework."

It is not surprising, therefore, that most students do not rely exclusively on the textbook for obtaining information, although the portion of the class who consider the text adequate is noticeable. Further evidence of this pattern in learning and working habits is the distribution of responses to the question about the field trip report. Most students (56.25%) say they wrote it individually, after discussion with classmates. One quarter of the class wrote it individually and the rest (3 students) wrote it in collaboration with classmates.

Table 4. Learning habits and preferences

	1998 (N=19)	**1999 (N=16)**
% of students who learn better from hands-on experience [number of students between brackets]	**42 (8)**	**56.25 (9)**
% who learn better from reading material at home	**21 (4)**	**18.75 (3)**
% who learn equally from both	**37 (7)**	**25 (4)**
% who learn better on their own	**21 (4)**	**18.75 (3)**
% who prefer collaborative learning	**21 (4)**	**31.25 (5)**
% who use a combination of individual and collaborative learning methods	**58 (11)**	**50 (8)**
% who wrote fieldtrip report on their own	**N/A**	**25 (4)**
% who discussed field trip report with classmates but wrote it individually	**N/A**	**56.25 (9)**
% who wrote field trip report in collaboration with classmates	**N/A**	**18.75 (3)**
% who think textbook is adequate and enough	**N/A**	**31.25 (5)**
% who use additional information sources	**N/A**	**68.75 (11)**
% who has changed style of learning since high school	**N/A**	**87 (14)**
% who usually learn/study on their own	**N/A**	**25 (4)**

% who usually learn/study in teams	**N/A**	**25 (4)**
% who usually combine individual and team learning	**N/A**	**50 (8)**
% who were encouraged to work in teams before CE 141	**N/A**	**68.75 (11)**

Questions:
3. Do you learn better from hands-on experiences or from reading material at home?
4. Do you learn better on your own (doing homework or projects or studying by yourself) or do you think you benefit exchanging ideas and cooperating in a team effort --even if you have to turn in an individual project at the end?
5. Did you write your fieldtrip report and lab reports
a. on your own entirely
b. after discussing with classmates
c. in collaboration with classmates
6. Was your textbook (only) adequate to supplement your understanding of the lecture information, or you used other library books sometimes or you also used the Internet sometimes?
7. Did you change your style of learning (on your own or working with friends), comparing junior year at Cooper Union vs. high school? YES/NO
8. What is your usual preferable style of learning?
On your own
Studying with friends
Combining the above always
9. Before taking the intro to Environmental Engineering course, were you encouraged by other professors to work in teams (as engineers do) even for individual projects/homework? YES/NO

V. Assessment

The results discussed above show evidence that students in the CE 141 class felt overall satisfied with their exposure to a variety of educational methods, regardless of their own individual preferences. We have now evidence that students generally favor a more experimental approach to learning environmental engineering, one in which they are able to construct their own understanding of the subject matter, provided a common panoply of concepts and principles. Also very importantly, we have learned about their own learning methods and habits (which also warrant a shift to experiential learning) and can use this information both as baseline for future comparisons and also as grounds for a way of tracking learning outcomes which accords individual learning styles.

Although the evaluation instrument was not designed to measure learning *outcomes*, the process implemented and the information obtained contributes to the learning process in two fundamental ways: 1) it contributes to enhancing student awareness of their own learning process, and 2) it helps the instructor to not lose touch with his students' learning process. These are commendable achievements in their own right, but do not tell us much about the results of the learning process. In order to measure learning progress we need to know to what extent have students achieved the outcomes expected in the course.

Some of this work is currently developing in CE 141. We are designing a consistent assessment procedure for tracking student learning during future editions of the course. Part of this process is the assessment plan for the course. The assessment of CE 141 was planned through a series of one-to-one meetings between the course instructor and the Director of Assessment. During these meetings it was agreed upon the need to specify objectives (instructor-centered goals) and a set of specific and measurable outcomes (knowledge and skills acquired by the students) for the course. A series of strategies and actions required to achieve the objectives and the outcomes were discussed, including the multi-educational methods overviewed in this paper. Finally, we spent some time cross-referencing the particulars of the course and the overall objectives of the Civil Engineering Department. We also selected the ABET criteria 2000 (a-k) which are covered in the course. The results of these discussions are tabulated below (Table 5).

The educational objectives of the Cooper Union Civil Engineering Department, not listed in the table, are:

1. To provide a rigorous educational experience in the sciences, mathematics and humanities to serve as a foundation for civil engineering knowledge as well as lifelong learning for our students
2. To provide a broad-based educational experience in the fundamentals of the various civil engineering disciplines (structural, environmental, geotechnical, water resources, transportation, infrastructure and construction management).
3. To promote teamwork, interdisciplinary concepts, organizational and communication skills, and problem solving methodologies in the curriculum.
4. To provide future graduates with a comprehensive professional design experience ranging from the feasibility assessments of geotechnical, environmental and economic issues to the analysis and design of components/systems of a real-world civil engineering project.
5. To instill in our students a sense of commitment to excellence, independent thinking, research, innovation and the use of the latest technologies and modern professional practices throughout their careers.

Table 5. CE 141 COURSE ASSESSMENT PLAN

Course Name and Code____CE 141 INTRODUCTION TO ENVIRONMENTAL ENGINEERING
Department______CIVIL ENGINEERING____

COURSE OBJECTIVES	STRATEGIES AND ACTIONS	OUTCOMES	DEPT. OBJECTIVES COVERED	ABET CRITERIA a-k	ASSESSMENT METHODS/METRICS
Expose students to teamwork, hands-on activities, and experimentation, both in the lab portion and in class projects.	Tasks are organized in teams of 3-4 students with a documented division of responsibilities, in each of the two sections (class and lab) of the course.	Students learn to be effective teamworkers in producing a finished product. They will learn collaborative work habits and to produce work for the group.	3, 4	a, e, g, k	1. Grades for lab reports (common part, individual discussion, and conclusions). 2. Discuss lab results and methods of data analysis with students.
Promote the Project Management and Leadership skills in the students.	Each student is expected to lead the team in one of the lab experiments. The team leader has to set priorities, establish timetables, and lead the group's discussions.	Students are exposed for the first time to leadership positions and become familiar with the usual leadership responsibilities.	2, 3, 5	b, d, f, g, k	Instructor and lab assistant reviews students individual performance in the lab.
Promote the use of the latest computer technologies in the field of environmental engineering.	Students use commercial software package or write their own for specific projects, homework or the lab reports.	Students learn to use computers for problem analysis and design, data analysis, evaluation and visual presentation.	5	i, j	1. Grades for lab reports. 2. 2. Grades for class computer projects.
Increase the students' awareness of visual communication.	Preparation of graphs and visual aids for presentation in reports and presentations to students.	Students understand and apply various methods of visual communication.	2, 3, 5	d, g, h, k	1. Grades for lab reports. 2. Grades for computer projects. 3. Presentation of information to students.
Enhance students' creativity and independent thinking through laboratory projects and class computer projects.	Laboratory projects in teams of 3-4 encourage students to explore innovative solutions that may lead to patents, promote creative, independent thinking and solutions to open-ended problems. Class computer projects encourage students to use this tool in analysis and solution of problems.	Students must be able to apply their talents to seek innovative solutions to challenging engineering problems.	4, 5	b, e	1. Performance of students in class presentations. 2. Student/faculty collaboration in professional publications, or in multimedia presentations.
Expose students to experimentation in the field of environmental engineering.	Teams in lab learn through the development of experimental skills and an awareness of results beforehand through theory.	Students are able to set up an experiment, determine before hand parameters to be measured and collect information for development of design parameters.	2, 3, 5	b, d, f, g, k	1. Performance of students in laboratory experiments. 2. Grades in lab reports. 3. Questions to the instructor or lab assistant.

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