



PROJECT BASED LEARNING OF ENVIRONMENTAL ENGINEERING PRINCIPLES

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Abstract

In this paper, the importance of project based learning to teach environmental engineering concepts and train emerging civil and environmental engineers is presented. One of the project based learning exercises was the water treatment laboratory experiment. Coagulation, flocculation, sedimentation and filtration concepts and design principles were taught through practical demonstrations for junior and senior civil engineering students in the environmental engineering laboratory. The source water was collected from the algae contaminated ponds on the campus. The student learning was greatly enhanced by the practical and hands-on, project based laboratory experiments. This paper discusses the integration of project based learning activities into environmental engineering courses and the enrichment of student learning experiences.

Keywords

Environmental engineering, research based instruction, higher order of learning, cognitive skills, project-based learning

Introduction

Project based learning can be described as a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to a complex question, problem, or challenge. This type of learning includes in-depth inquiry of the subject matter, curiosity (question) driven exploration, selection of appropriate solution which will be subjected to critique and revision and acceptance from broader audience (as commonly practiced in environmental engineering). This learning exercise requires the students to think beyond the textbook knowledge, research for various information sources, looking beyond existing solutions to develop new and creative solutions for the problem of study. All of this together compounded by the nature and complexity of environmental engineering problems presents a challenging task to environmental engineering educators.

Generally, teaching engineering courses is a challenging task. The process of understanding scientific principles and applying them in engineering design demands higher order learning and thinking skills from the students. A widely-used classification scheme for different levels of learning, Bloom's Taxonomy¹ defines higher levels of learning as "*synthesis* - to create, design, develop, formulate...; and *evaluation* - to evaluate, rate, defend, predict". To promote higher levels of learning (or taxonomies), proper instructional strategies should be implemented. These instructional strategies should include learning elements that provide authentic contexts, critical thinking, authentic activities, multiple roles and perspectives, coaching and scaffolding, access to expert performances and modeling, promote reflection to enable abstraction and articulation. These elements should support collaborative construction of knowledge and the use of authentic assessment techniques². The courses should provide actual and real world exercises that create a context for activities to promote higher levels of learning.

The students should be allowed to assume multiple roles and share various perspectives that come from basic intuitive (gut) feelings and coach, be coached by others, research expert performances on the given topic and reflect over the content and improve articulation. Laboratory class exercises provide excellent opportunities to implement these elements^{3,4}. Laboratory course instruction provides opportunities for teaching various engineering design principles that could not be covered effectively in a traditional classroom teaching environment. Laboratory instruction can be used as a tool to promote cooperative (team learning) learning to teach engineering design. In cooperative learning, students work in teams toward the attainment of some superordinate goal where the labor is divided between team members, such that each individual takes responsibility for a different sub-goal and individual contributions are pooled into a composite product to ensure that the goal is reached. To be successful, five factors are paramount to the cooperative learning process: 1) Positive interdependence, 2) Face-to-face interaction, 3) Individual accountability, 4) Small group and interpersonal skills, and 5) Group self-evaluation⁵.

In this paper, we discuss the research-based laboratory teaching exercises that were implemented in a civil and environmental engineering course. The goal of this laboratory course is to introduce some unit operations and processes and analysis commonly applied in water and wastewater engineering. In addition, the ABET general engineering criteria also target the social aspects of engineering education at several levels. For example, criterion 3(c), “an ability to design a system, component, or process to meet desired needs,” and criterion 3(d) addresses the need to function on multidisciplinary teams, criterion, and 3(f) social and ethical responsibilities, criterion 3(g) communication skills, and criterion 3(h) addresses global and social impact. Constructivist theories of learning also recognize that learning is a social activity⁶. This means that the laboratory instruction and project-based design courses can be identified as opportunities to improve students’ ability to work in teams, as well as their communication skills. As a result, many civil engineering programs now incorporate many of these dimensions in their design classes, ranging from cornerstone to capstone design courses⁷.

Illustrations

The civil and environmental engineering department has implemented project (cooperative learning) based exercises in the CE 3801 Environmental Engineering Laboratory course (junior level civil engineering course). In this course, student groups (three to four) were formed to facilitate team-based cooperative learning. The laboratory exercises included: “Adsorption”, “Aeration”, “Coagulation-Flocculation-Sedimentation-Filtration”, “Chemical Oxygen Demand (COD) and Total Solids measurement”, and “Tracer Analysis”. In these laboratory exercises, environmental samples from authentic sources were analyzed where possible. For example, the water treatment (coagulation-flocculation-sedimentation-filtration) exercise was conducted using algae contaminated pond water from two different lakes on the campus. Similarly, the wastewater COD and Total Solids measurement characterization exercise used samples of wastewater from various designated process points of the local municipal wastewater treatment plant. Other experiments were conducted using synthetic chemicals such as a dye (i.e., methylene blue) to simulate the environmental pollutants. The students were required to participate in the following assignments.

Approach

Using engaged learning concepts to design and instruct the CE 3801 Environmental Engineering Laboratory class still required a formal process as a framework of operation and to ensure productivity. The activities employed to manage the course involved:

- **A problem set assignment**– Students were collectively instructed on issues of laboratory operation and safety. This was followed by a presentation and classical homework design to provide students with a background in experimental statistics, data regression, and experimental design. All work was completed during the first week. This was followed by establishing teams and assigning teams experiments for which they would be responsible.
- **Laboratory exercises** – these were conducted on a number of selected topics, as outline above. Student were assigned to teams to work together on each lab exercise. Each student was also assigned a specific experiment in which to serve as *team leader*. The team leaders assumed the responsibility for all aspects of setup and performance of the experiment by their team and, if necessary, coordinate with other team leaders and the instructor or teaching assistant. Student performance as team leader as well as individual participation were considered in assigning final grades. An evaluation rubric was used to evaluate the performance of team leader as well as the team members in the student groups. Teams were formed with careful arrangement to match student strengths of the subject matter. The teams were assigned at the beginning of the semester. The laboratory exercises were provided as a problem statement and the students were asked to come up with the procedures and pre-lab calculations.
- **Pre-lab calculations** were submitted on an individual basis and are due at the beginning of each lab session. The calculations involved quantitative parameters to be used during the lab exercises, and as such are designed to facilitate execution of the exercise.
- **Lab reports** presenting experimental results and data analysis were prepared and submitted on an individual basis. Reports should comply with the mini-report format provided, and were due at the beginning of the lab period one week after the exercise was conducted.
- **Group reports and presentations** were prepared after completion of the lab exercises. Each group was assigned to write a full report and make a presentation on one of the lab exercises performed. Reports were submitted prior to the presentations.
- **Site visits** were conducted at nearby public works facilities to provide students with the opportunity to view equipment and operations. Site visit reports complying with the provided format were due one week after the visit is conducted.
- A **final exam** was conducted during the last week of the semester. The exam was administered online and may be taken at the individual students' schedule.

Student Experiences

The water treatment (coagulation-flocculation-sedimentation-filtration) experiments were conducted using actual water samples from two algae contaminated ponds. The students were asked to prepare the samples and plan the experimental procedures to determine the optimum dosage for treating the raw water. In designing these experiments, to maximize the learning potential, the following were addressed: students must take responsibility for their own learning;

problems should be ill-defined and allow for free inquiry by the student; student collaboration should be encouraged in both group- and self-directed work; students must constantly re-analyze problems as individuals and as a group; students must reflect on what they have learned from the problem; students must take part in self and peer assessment; and problems must have value in the real world.

Fig. 1 shows the images of coagulation-flocculation-sedimentation-filtration experiments (A) and sludge volume observations (B) by the students in the laboratory during a laboratory session. For this experiment, the students were asked to prepare the experimental plan, collect the actual environmental samples from two different ponds on the campus, followed by experimental setup and execution. The students were asked to collect the samples from the ponds on the campus. But they were not provided any other information on the water quality or turbidity. This was determined as part of the laboratory experiment. The student experiences and opinions from the evaluation survey are presented below. The students were asked to respond to the following simple questions and reflect over their experiences in the laboratory session activities:

As a result of the team based laboratory exercises,

- Q1. My understanding of the environmental relevance of the subject matter is:
- Q2. My interest in environmental engineering discipline and confidence in the subject matter is:
- Q3. My analytical and experimental skills are:
- Q4. My leadership and management skills are:

Response options:

- A. Worse (W);
- B. The same (T);
- C. Better (B);
- D. Significantly better (S);
- E. N/A no opinion (N)

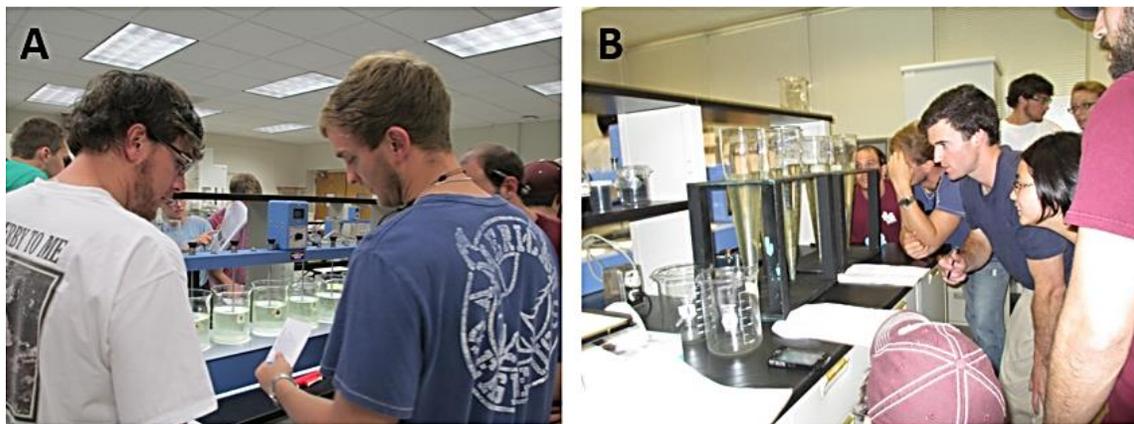


Fig.1. Civil and environmental engineering students performing water treatment experiment: A. coagulation-flocculation-sedimentation-filtration techniques; B. sludge volume measurements.

The summary of the students' responses is shown in **Fig.2**. Among the 50 respondents, 84% of the students (42 out of 50 respondents) responded that the laboratory exercises have improved or significantly improved their understanding of environmental relevance of the subject matter being taught in the associated classroom and the laboratory classes. About 58% of the students (29 out of 50 respondents) answered that the laboratory exercises improved or significantly improved their interest in environmental engineering discipline and confidence in the subject matter while 34% (17 out of 50 respondents) of the students mentioned that their interest in environmental engineering discipline and the subject matter were the same after the exercises. Majority of the students (60% - 30 out of 50 respondents) agreed that these exercises have improved their analytical and experimental skills, and team work and communication skills. Again, 50% (25 out of 50 respondents) of the students responded that this exercise has improved or significantly improved their leadership and management skills which were the main goals of this assignment.

A few students responded that the cooperative learning methods were not effective in enhancing their learning experience. These students represented less than 10% of the total student population. It should be noted that some students would like to learn independently and are less inclined to work in teams. Typically, these students do not perform in a team-based and research-based learning environment. However, the above team-based and research-based laboratory exercises can be very instrumental in improving the student learning of the subject matter. Especially, the engineering design courses are increasingly being recognized and taught as a team process with multi-faceted socio-technological dimensions.

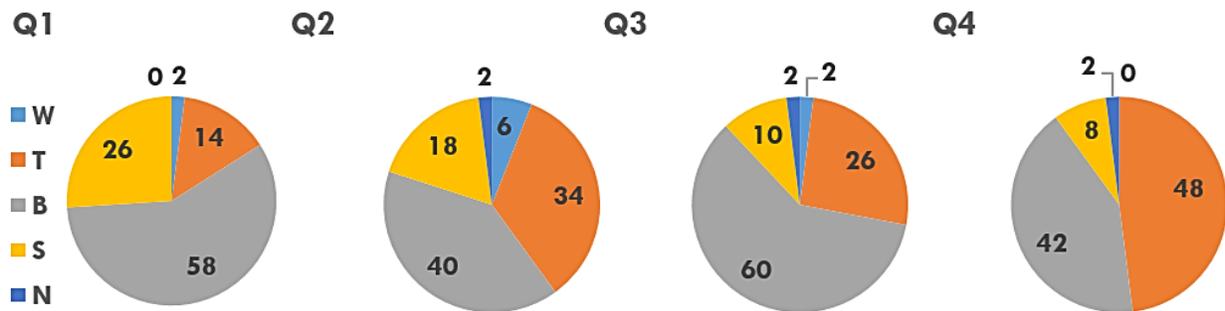


Fig. 2. Assessment of laboratory activities - numbers represent percentages (As a result of the team based laboratory exercises, Q1- Understanding of the environmental relevance of the subject matter; Q2 - My interest in environmental engineering discipline and confidence in the subject matter; Q3 - My analytical and experimental skills; Q4 - My leadership and management skills are: Worse (W); The same (T); Better (B); Significantly better (S); and N/A no opinion (N)).

Conclusion

In addition to the survey data, anecdotal information from students collected outside of class, either as part of the annual departmental exit survey of seniors or in conversations with students engaged in social settings, it is obvious that the typical student finds creative engagement as

provided by this instructional approach as stimulating and rewarding. The instructors involved are perceived as being supportive of the educational process, for which students are appreciative. They also find that their backgrounds are generally superior to other students based on their conversations while at co-operative education work semesters or summer internships. They feel being participants on the learning process makes them stakeholders in the process and they become vested in class content beyond simply doing laboratory reports and getting a grade. On the instructional side, this process is rewarding to those willing to invest themselves into the educator role. Time commitment is somewhat greater and it takes a person with a broader understanding of the unit operations and processes, experience with design and analysis, and an interest in student success to make this approach work effectively.

Acknowledgements

This work was supported by the Department of Civil and Environmental Engineering, the Bagley College of Engineering, and the Office of Research and Economic Development (ORED) of Mississippi State University (MSU).

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