Retooling the Environmental Engineering Laboratory Capstone Experience for ABET 2000

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Abstract
The traditional undergraduate environmental engineering laboratory experience is well designed and provides students with appropriate hands on activities relating to data collection and analysis. Students learn the appropriate procedures to perform analytical tests on water, wastewater and sludge samples in accordance with **Standard Methods**.[1]

The Mercer University School of Engineering (MUSE) environmental engineering capstone laboratory experience has historically provided students with proficient content in wet chemistry and soil and air analysis as well as data interpretation. Prior to individual lab exercises, students were provided necessary background information as well as details of the laboratory procedure(s) to be conducted during the following laboratory period. This format exposed the students to a wide variety of laboratory and data analysis techniques, but limited the amount of experimental design actually conducted by the students.

ABET's EC 2000 criteria specifies that graduates of baccalaureate engineering programs must have an ability to <u>design</u> and conduct experiments, as well as to analyze and interpret data. Based on this criterion, the MUSE environmental engineering lab experience was re-structured to emphasize experimental design by including four open-ended problems in the laboratory experience. These supplementary projects required the design of experiments to evaluate a bench-scale wastewater treatment plant, an adsorption process, a coagulation/flocculation experience and an investigation of the interferences associated with the measurement of chemical oxygen demand (COD). These experimental design experiences were added to the course without eliminating content included in the former format and the workload experienced by the student was not significantly increased. Finally, an innovative grading scheme was developed in an effort to better quantify student performance. This paper details how the MUSE senior environmental engineering laboratory experience was modified to better meet criteria specified by ABET EC 2000.

Background
The Mercer School of Engineering (MUSE) faculty has identified eight outcomes, listed in the appendix of this manuscript, that are used to facilitate assessment activities in accordance with ABET's EC 2000.[2] MUSE outcome #4 states that graduates with a bachelors degree in engineering should be able to "design and conduct experiments and analyze data." Historic offerings of the senior environmental engineering capstone laboratory (EVE 445L) focused primarily on conducting experiments and analyzing and interpreting experimental data. The

fourth skill associated with this outcome, namely the design of experiments, was missing from both course outcomes and content.[3] Prior to the implementation of outcome #4, typical course outcomes and content were as follows:

1. Students will develop a general understanding for laboratory procedures utilized in analyzing water and wastewater samples.
2. Students will be exposed to full-scale environmental engineering facilities such as water and wastewater facilities, and/or landfills and air pollution generation and control facilities.
3. Students will improve their technical communication skills by preparing computer generated laboratory reports.

Upon successful completion of the course, student's fulfilled the above stated requirements. Course content focused on learning analysis techniques that included the following: oxygen uptake rate, solids, determining oxygen transfer coefficient, pH, alkalinity, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, Beer's law, turbidity, hardness, coagulation and flocculation. Students, grouped in teams of three, were required to complete a written laboratory report after conducting each experiment. Students also attended up to three field trips. Final and midterm examinations were required. EVE 445L is scheduled for a three hour period one day per week and student's that successfully complete the course receive one semester hour of credit towards graduation. The popular laboratory manual authored by Jenkins et al.[4] was a required text for the course.

Prior to each laboratory experience, students were assigned a chapter to read from their text or provided with an instructor-generated handout. As a result, student participants were equipped with associated background materials as well as with the experimental methods and goals to be achieved during each laboratory session. In this format, students were only learning laboratory and data analysis techniques. Minimal experimental design was required of the students.

With the adoption of MUSE outcome #4, the environmental engineering faculty recognized the need to incorporate experimental design into EVE 445L without sacrificing traditional course content and without significantly increasing the workload for the students. This paper details the revised course objectives, content, and student report writing and oral communication requirements. The assessment process used to evaluate student performance associated with outcome #4 is also described.

Implementation and Assessment

Course outcomes were rewritten and stated that upon the successful completion of EVE 445L the student will be able to:

1. Apply knowledge of mathematics, science, and engineering to Environmental Engineering measurements.
2. Design laboratory experiments, and to collect, analyze, interpret, present, and discuss data.
3. Discuss/describe full-scale environmental engineering facilities that they have toured during the semester. Students will be exposed to facilities such as water and wastewater plants; and/or landfills and air pollution generation and control facilities.
4. Prepare professional engineering reports.
5. Work effectively in a team.

Measurement and assessment of the outcomes were made by:

1. Student preparation of 10 professional engineering reports; 9 abbreviated reports and 1 complete laboratory report. The abbreviated and complete laboratory reports are described later in this manuscript.
2. Student preparation of one or more field trip reports.
3. One student oral presentation.
4. One mid-term and one final exam to provide feedback on the individual comprehension of environmental engineering experiments.
5. Primary instructor evaluation and student feedback on the perceived quality of the course and effectiveness of the instructors.

The number of laboratory periods devoted to learning specific analysis techniques was reduced (from ten to six sessions) compared to previous offerings of EVE 445L. To accomplish this task without eliminating content, multiple analyses were conducted each period. In order for students to complete all necessary tasks in the allotted three-hour time slot, the instructor completed a variety of setup activities prior to class beginning. Students were given detailed information describing the tasks completed by the instructor prior to the class. Each student was required to keep a laboratory notebook and class attendance was mandatory.

During the first class meeting, laboratory safety rules were reviewed and each student was assigned to a group of three or four students. Each group was instructed that they were responsible for conducting all experiments, analyzing the data, and producing a laboratory report. Ideally, this was a cooperative effort, with each member of the group contributing equally. The second laboratory period was devoted to a review lecture focused on design of experiments and statistical analysis. Six class periods were then utilized to introducing students to a variety of standard analytical and laboratory procedures. Students were required to read appropriate experimental descriptions in the text and/or handouts prior to class. During the class period, the instructor, aided by students, demonstrated or conducted the techniques. Laboratory exercises required students to operate lab equipment, collect data, analyze and interpret data, and effectively summarize lab procedures, data collected and results in a written report. Each team submitted an abbreviated lab report for these illustrative experiments. Instructions for the abbreviated lab report follow.

In an effort to satisfy the course experimental design requirement, each team was responsible for the complete design of one experiment during the semester. Design activities occurred after students had been introduced to all standard laboratory analysis techniques. The specific team assignments are shown in Table 1. The team responsible for the specified laboratory topic was required to design and prepare all materials for the lab. Specifically, students were responsible for the following:

1. Design the required lab experiments for assigned topic.
2. Prepare the lab materials for the assigned topic.
3. Investigate one of the know interferences to the measurements required for their lab.
4. Run the entire class through the lab experience. Assign each group a laboratory task to perform (i.e., each group was involved in some part of the experimentation each week).
5. Perform any required tests needed to investigate their assigned phenomenon.

6. Prepare a complete lab report for their assigned topic (Instructions for complete report follow).
7. Develop a detailed experimental design that was due to the instructor four days prior to the class. Experimental design was approved by instructor prior to proceeding in the laboratory.
8. Make a 20 to 30-min oral presentation regarding the assigned laboratory topic. All presentations were made on the last day of class.

Teams not responsible for that week's lab were required to submit an abbreviated lab report. Details of both the abbreviated and complete laboratory report styles are given in Table 2.

Table 1. Abbreviated student laboratory design projects.

Team 1 – Activated Sludge Kinetics and Settling Characteristics. Conduct a treatability study for determining the major biokinetic coefficients and parameters used in designing completely-mixed activated sludge systems and for designing secondary clarifiers.
Team 2 – Adsorption. Investigate the properties of activated carbon as an adsorbent. Define the systemic parameters that are required for design of a continuous flow system.
Team 3 – Coagulation and Flocculation. Conduct appropriate jar tests on samples from the Ocmulgee River in order to estimate an optimum dosage of aluminum sulfate or ferric sulfate for the removal of suspended matter or color. Observe the rate of floc formation and sedimentation. Consider coagulant dosage, pH and mixing.
Team 4 – COD Interference. Use laboratory experiments to quantify the extent of the interference of nitrite on the measurement of COD and the effect of the technique used to address the interference.

A rubric, shown in Table 3, was developed to facilitate assessing student performance in all four skill areas (designing and conducting experiments and analyzing and interpreting experimental data) addressed in MUSE outcome 4. Additionally, the rubric enabled the various instructors of EVE 445L to grade in a consistent manner and it also provided feedback to students allowing them to easily determine where points were lost.

Conclusions

Through the implementation of the course modifications described, students were introduced to a variety of standard laboratory techniques and were then charged with using this knowledge to design and perform an experiment to solve an assigned problem. By implementing the abbreviated and complete laboratory reports, the burdened placed on students was minimally increased as compared to previous course offerings. Assessment of the four skill areas associated with MUSE outcome 4 was easily performed using the developed grading rubric.

Table 2. Abridged guidelines for both the abbreviated and complete laboratory reports.

Abbreviated Report[1]

- Cover Page – Organize pertinent information including name, experiment title, group members, date of submission, etc.
- Methodology – Briefly outline the purpose of the laboratory and how the experiments were conducted
- Raw Data – Logical presentation of raw data collected in the laboratory
- Calculations – Reduce data and perform appropriate analysis on data collected. Include calculations, graphs, etc.
- Final Data and Results – Briefly summarize the important findings discovered.

Complete Report[1]

- Cover Page – Organize pertinent information including name, experiment title, group members, date of submission, etc.
- Introduction – Include relevant background information and discuss the importance of the exercise.
- Objective(s) – Clearly state the objectives of the exercise.
- Equipment/Apparatus/Reagents – Provide a list of equipment and chemicals used to carry out the experiment. Figures are required.
- Procedure – Provide a clear and organized presentation of the steps in the experiment(s). Include methods of data analysis.
- Data – Neatly present data collected during the laboratory. Tables and graphs are appropriate.
- Analysis – Conduct appropriate analysis on data collected. Include calculations, etc.
- Results – Present key results determined from the analysis section.
- Discussion and Conclusion – Briefly discuss the practical significance of the experiment and provide a critical discussion and examination of class results.
- Reference – Cite all reference materials
- Appendix – Include raw data and any other information.

[1]The laboratory report should be treated as any other engineering or scientific report. Literate English should be employed. The report should be machine-generated and be well organized to reflect the methodology of the experiment performed towards its conclusions.

Table 3. Laboratory evaluation form for complete reports.

Group member names in alphabetical order, as numbered:

Last	First	Last	First
1.		4.	
2.		5.	
3.		6.	

Laboratory Title	Number	Section Day	No.	Group

Item	Value	Score
Experiment Design	200	
Conduct Experiment	50	
Analyze Data. (g + h + i + j)	100	∴
Interpret Data (k + l)	50	∴
a. Neatness; coherent, professional document	15	
b. Writing: grammar and spelling.	15	
c. Adherence to format	20	
d. Equipment: thorough; clear; suitable figures	10	
e. Procedure explained in students' own words and organization	10	
f. Complete description of procedure with clear steps	10	
g. Description of steps for data analysis	25	
h. Data: complete and clear reporting of results	25	
i. Clear presentation of calculations.	25	
j. Appropriate graphs and tables	25	
k. Results: clear identification of key results	25	
l. Explanation significance of results	25	
m. Discussion of difficulties and their effects.	20	

Business days late		RAW NET SCORE	

∴ This cell not added to Raw Net Score

Total possible score is 500 points

Appendix - MUSE Outcomes

1. Apply mathematics and science principles to the solution of engineering problems.
2. Apply appropriate breadth and depth of skills in identification and analysis of engineering problems.
3. Apply appropriate breadth and depth of skills in engineering design and analysis of engineering problems.
4. Design and conduct experiments and analyze data.
5. Function effectively on interdisciplinary teams.
6. Communicate effectively to both specialized and public audiences in a variety of modes, i.e., writing, presentation, etc.
7. Relate the practice of engineering to global contemporary issues, to professional ethics, and to the need for lifelong learning.
8. Provide leadership to and contribute to sustaining and improving community.

Bibliographic Information

1. Standard Methods for the Examination of Water and Wastewater 18th edition (1992) Greenberg, A.E., L.S. Clesceri, and A.D. Eaton, eds., American Public Health Association, Washington, DC.

2. Engineering Accreditation Commission, Criteria for Accrediting Engineering Programs: Effective for Evaluations During the 2000-2001 Accreditation Cycle. Accreditation Board for Engineering and Technology, Inc. 111 Market Place, Suite 1050, Baltimore, MD 21202, March 18, 2000.

3. McCreanor, Philip T., 2001. Quantitatively assessing an outcome on designing and conducting experiments and analyzing data for ABET 2000. ASEE/IEEE Frontiers in Education Conference, October 10-13, 2001 Reno, NV.

4. Water Chemistry, Jenkins, Snoeyink, Ferguson, Leckie, 3rd Edition, John Wiley & Sons, 1980.

Biographical Information

LAURA W. LACKEY has four years of experience as an assistant professor of Environmental Engineering at Mercer University. She has six years of industrial experience at the Tennessee Valley Authority as research Environmental/Chemical Engineer. She earned a BS, MS, and Ph.D. in Chemical Engineering from the University of Tennessee. The terminal degree was awarded in 1992. She is a registered professional engineer.

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