Session 3551

Using Research Projects to Enhance Environmental Engineering Laboratory Course

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Abstract

The current paper describes a qualitative research study of an *Environmental Engineering Laboratory Course* taught to a group of graduate students in the Spring of 1999. The course structure was changed from a traditional mode of instruction to a project-based course that allowed students to design and carry out a personal inquiry project related to course topics. Data was collected in the form of videotaped course sections, pre- and post-interviews of the professor and students, and course documents such as lesson plans, syllabus, and student work. After data was analyzed it was found there were benefits to both students and instructor in terms of knowledge gained and objectives being met for both research and teaching. Challenges to using the project-based method were also identified. A call for future research could be helping professors more easily transition to the use of the project-based method.

I. Introduction

Environmental Engineering Laboratory is a traditional part of the curriculum for graduate programs in environmental engineering. The traditional goal of the course is to teach specific environmental measurement techniques that can be used by full-time graduate students to conduct their research. The course studied was one semester long with the first author as the instructor. The instructor additionally had one lab technician to help with the course.

Washington State University, Tri-Cities (WSUTC) is a branch campus that offers a M.S. in Environmental Engineering. Most of the students in the program are part-time, and already work in the environmental field. Laboratory work is generally not a part of their careers, as environmental samples are generally sent to contract laboratories for analyses. Projects are required for the students to graduate, but because of the work schedules, few projects incorporate laboratory research. Skills in designing and implementing projects would greatly benefit the students.

WSUTC is also a research campus. Scholarly production in the form of refereed journal publications and research funding are expected for retention and promotion. Juggling the limited resource of time to do well in both teaching and research has been a major challenge for beginning faculty members in a research university.[1,2] Many new, and even experienced faculty, have little or no teaching experience prior to the start of their university positions.[3,4,5] Further, methods university instructors use to teach their students appear to be a mismatch with what students actually need to develop strong understandings of the content.[6,7,8,9,10] Coupling research and teaching would provide advantages for the instructor's promotion and tenure review.

Because of the different needs of the students and the desire to create addition research opportunities, the instructor decided to change the focus of the course to focus on project development skills as opposed to learning analytical techniques.

II. Methods

Description of the Project

The students worked on four projects throughout the semester. Laboratory techniques were taught as part of the projects. The first three projects were assigned. Students developed skills in project design, error analysis and interpretation of data. Each student wrote a report on their work, thereby improving writing skills. The students also presented their project orally at the end of the course.

The study spanned the spring semester. The class was comprised of seven students. Six were obtaining a Master of Science degree in Environmental Engineering. The seventh student was taking the course as an upper division Civil Engineering elective. Their ages ranged between 27 and 50, with a mean of 32 years.

Assigned Projects

Three assigned laboratory projects were given:

1. An irrigation water quality project relating water quality parameters to the type of irrigation canal tested.
2. A contaminated soil project focussing on the relationship of biological activity to soil contamination and other soil properties
3. A groundwater quality project focussing on charge balance of cations and anions in the groundwater.

Student-Designed Projects

The fourth project gave each student the opportunity to study anything that interested them. The students first cleared the project with the instructor, then each prepared a scope of work for their projects. The students were given the opportunity to work alone, or as a team. The projects chosen by the students were:

- The measurement of ammonia solubility in high ionic strength solutions and it's impact on Hanford Waste Tank Issues.
- The water quality associated with an irrigation outfall in the Yakima River.
- The transformation of trichloroethylene (TCE) by zero-valent iron (team project).
- Water quality associated with golf courses.
- Water quality of the Touchet River and analysis of impacts on trout.

Change in Course Structure

The structure of the course was changed to meet the new goals. Fewer laboratory techniques were covered overall in the class and less emphasis was placed on the chemistry involved with the analytical techniques. More emphasis was placed on designing experiments, data analysis and on sample collection methods.

Data Collection

The investigation was qualitative[11, 12] in nature. Data collection spanned the entire spring semester during which the study was conducted. Several data sources were used to answer the question of interest. The third author viewing and videotaping each class session for the second author's transcription developed an initial baseline of teaching strategies. Additionally, teaching notes, the course syllabus, and other course materials were collected for analysis. Four of the seven students were interviewed for their perceptions of the Assistant Professor's instruction. The Assistant Professor was interviewed to determine his current planning and delivery methods, and to discover his goals for his instruction. The course Lab Technician, a former high school science teacher, was interviewed for her impressions of the Assistant Professor's teaching. The Program Coordinator who was the Assistant Professor's supervisor, was interviewed to determine the amount of support new faculty receive in their teaching, and for department teaching goals. A similar sample of students and the Assistant Professor were interviewed post-instruction for their views at the conclusion of the semester. (See Appendix for copies of interview protocols).

At midterm the Assistant Professor was interviewed using a stimulated recall protocol to gain insight on his thinking in instruction. One of his videotaped course sessions was played for him and stopping points were selected at which to ask him questions regarding instructional decisions he was making. Additionally, he was asked to stop the video at any point in the interview to share information regarding his instruction. He did not choose to stop the video.

An additional source of data was a research log. The research log noted the interventions taken at each step of the study, and perceptions of how the professor may or may not be changing his instruction.

III. Data Analysis

The second and third authors analyzed the data. This approach was taken because the second author may have perceived the results as partially evaluative. The interviews, course syllabus and any plans, classroom observations and teaching videotapes prior to any interventions were analyzed to develop a profile of the assistant professor's general teaching approach. Following the interventions the stimulated recall interview, post-instruction interviews, and classroom observations and videotapes, and research log, were analyzed to determine any changes in teaching approach that may be attributed to the interventions. Though the classroom observations were the primary data source, the research log and interviews provided additional information and allowed the author's to triangulate data sources, protecting the validity of the study.

After all data sources were reviewed categories were generated from the data. The categories were checked against confirmatory or otherwise contradictory evidence in the data and modified accordingly. Several rounds of category generation, confirmation, and modification were conducted to satisfactorily reduce and organize the data. Finally, pre- and post-intervention teaching approaches were compared to assess changes in the assistant professor's general approach to instruction.

IV. Results and Discussion

Benefits for the Students

Students learned a wide range of laboratory techniques, including:

- Probe measurement techniques including pH, conductivity, nitrate, and dissolved oxygen.
- Spectrophotometer measurements of nitrate, ammonia, nitrite, phosphates and sulfates.
- Volumetric titration techniques such as alkalinity and Winkler titration for dissolved oxygen and biological oxygen demand.
- Gravimetric measurement methods for total & dissolved solids in water.
- Gravimetric measurement methods for water content and volatile matter in soils
- Ion chromatography for various anions
- Inductively coupled plasma spectrophotometry for a wide range of metals and cations.
- Gas chromatography for hydrocarbons and chlorinated solvents.

These laboratory techniques were taught as inquiry because students raised their own questions and designed their own studies. Inquiry methods are in line with national reforms.[13, 14] Additionally, inquiry labs are the most effective in helping students understand content and develop positive attitudes toward science and engineering.[15,16, 17, 18]

Students improved their writing skills. Each student wrote four project reports and a scope of work for their final project. Student grades, on average, increased for each report. For the first report, the average grade was 85%. By the last report, the average grade increased to 93%.

Students developed problem solving skills & an appreciation of the challenges of research. The students learned much about the challenges of research, and in the process, demonstrated clever solutions to problems. One common challenge the students learned was the need to keep their project within a useful, but limited scope. Many projects were simply too ambitious. The students learned that modest projects can yield effective results.

In many courses, students are taught the need and value of statistical tools. In this course, the students learned the challenges of designing a project to be statistically significant while keeping the number of samples within a reasonable amount. The students took different approaches. Some discarded statistics in their projects. Others chose to do a lot of replicates and got bogged down. Still, others determined effective statistical designes.

The students demonstrated ingenuity in solving problems for their projects. For example, a student team wanted to determine the effect of depth on water quality in ponds at golf courses. They designed an effective depth sampler for this task. Another student wanted to determine the ratio of ammonia in high ionic strength solutions to that in the gas phase. This presented the challenge of analyzing ammonia concentrations in the gas phase. He solved this problem by putting the high ionic strength solution in equilibrium with a deionized water (DI) trap. By analyzing the ammonia concentration in the DI trap, he could then determine the ammonia concentration in the gas phase using Henry's law.

Students participated in a campus-wide research symposium. Five of the students in the course participated in a campus-wide student research project. Furthermore, one of the students won the award for the best graduate level research.

Students developed ideas and preliminary research for their master's projects. At least two of the students are pursuing their projects as their M.S. research project, which is required for all M.S. students at WSUTC. The data they have collected in the class will contribute to their projects. Since both students work full time, their efforts in the class will be a major part of their M.S. projects.

Students Enjoyed the Course. Post-course interviews indicated overwhelmingly positive responses to the overall experience of the class. "We learned a lot from the class" was the general response from all five students interviewed. Additionally, students found the professor personable, which aligns with prior research indicating effective methods of college science and engineering instruction. The average score on student evaluations were higher than the departmental average.

Benefits for the Professor

Information was gained on an existing research project. One of the projects involved irrigation water quality, which was a subject of an irrigation water quality study conducted by the instructor. The data analyzed by the class was used in the project. This provided key data during the winter period when the project staffing was at a low point.

Preliminary research was performed, opening new research opportunities. New research areas developed from the project. One project involved the use of zero-valent iron for the removal of TCE from water. This provided information on zero-valent iron techniques and has allowed the instructor the opportunity to pursue project in this area. A second project involved water quality at golf courses and has opened the door for further research in this area. An ammonia solubility project investigated changes in ammonia solubility in high ionic strength liquids, such as those found in waste tanks at the Hanford Reservation.[20] This project proved to be of great value to waste tank transfers at the Hanford Reservation and resulted in a funded research project at the University.

Challenges of the Project Approach

The traditional material covered in the laboratory course included in-depth chemistry involved with the analytical methods. Although covered, the material was not treated in as much depth as in the past. This may present challenges for the students, particularly when performing their oral examinations during the M.S. defense. To some degree, this was mitigated by requiring the students to discuss methodology in their written reports. The effect of the change in curriculum cannot be assessed until the students undergo their M.S. defenses.

To perform the analyses required for the projects, particularly those in the early part of the course, it was necessary for the students to do them before the theory of the analysis was discussed in the lecture portion of the class. This required some discussion during the laboratory portion and some independent study by the students to read and understand the methods.

Some projects did not succeed as intended. The irrigation project was hampered by circumstances outside the control of the students. The idea was that the students would analyze samples collected from the same sites each class. Unfortunately, sample collection for the project was not consistent, and therefore, it was difficult for the students to properly analyze the data.

Course organization must be improved. Projects required more analyses to be performed during each laboratory compared to the traditional approach. A laboratory technician set up the labs and the new project approach was a challenge for the technician and the instructor. Consequently, several laboratory sessions suffered from disorganization and time was wasted when supplies and reagents were not readily available.

Rapid feedback on experimental designs is necessary. The students designed their projects and prepared a scope of work for them. Unfortunately, the instructor did not provide timely feedback on these work scopes. Therefore, improvements in design could not be implemented effectively by the students. Project oriented courses require step by step assignments. Instructors must provide rapid feedback for this approach to work effectively.

The projects were a challenge for the undergraduate student in the course. The laboratory course is a cross-listed course, meaning it can be taken for graduate or upper-division undergraduate credit. There is no undergraduate civil engineering program at WSUTC. However, undergraduates may take the course at WSUTC and transfer it to the main campus of Washington State University at Pullman. One undergraduate took the course. His performance was generally satisfactory, but he struggled with the more open-ended approach that the project presented. He particularly struggled with the challenge of designing his own research project. In fact, he eventually worked on a team with a graduate student. Using the project approach with undergraduates must consider their need for guidance.

The independent project required the purchasing of special supplies of each student group involved. This required additional expenditures of approximately $1,000 for the course.

V. Conclusions

In conclusion, the project approach worked well. Students learned how to design effective research studies and produced high quality work. The projects contributed to the sense of relevancy and camaraderie expressed by the students. Learning outcomes were directly tied to the projects. And the projects spurred the intellectual curiosity of the students, creating research opportunities beyond the scope of the course. The instructor was able to gain important research benefits from the course, as well.

Improving organization of the course and the laboratories, and providing rapid feedback, are necessary to realize the full potential of the project approach. Nevertheless, the study indicated that the use of projects is an effective means of teaching Environmental Engineering Laboratory courses. Future research should explore how professors can more easily transition to the use of project based methods.

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Appendix
Interview Protocols

Professor Pre-Instruction Guiding Questions

1. How long have you taught, and which courses?
2. What topic do you like teaching the best and why? What topic do you like teaching least and why?
3. Describe a typical class session.

Professor Goals and Planning

1. What are your goals for teaching? What do you want your students to know at the end of a lesson? At the end of a unit? At the end of the semester?
2. How do you plan what you will teach each class session?
3. What is the most important factor you consider when planning a class session?
4. How do you think your class should be taught? How do you teach your class?
5. In what ways do you believe you could do better in teaching? How do you feel you could accomplish this? What might be preventing you from accomplishing your goals?

Views of Student Understanding

1. How do you know what your students understand about concepts you are teaching?
2. What is the most effective way for you to know your students' understandings about what they are learning?
3. Do you use students' thinking and ideas when teaching science? How?
4. Do students influence your teaching? How?
5. What else can you tell me about your teaching?

Professor Post-Instruction Guiding Questions

1. How successful do you feel in teaching this course this semester? What were your strongest successes? Your weakest points?
2. What do you believe your students learned? How do you know what they learned? Upon what evidence do you base your views?
3. What impact did student ideas have on your teaching practice?

4. What might you have done differently given more time or resources?
5. What has been the effect of this study on your teaching?
6. What else can you tell me about this semester's class?

Professor—Video Stimulated Recall (VSR) Interview Protocol

Setting the Scene

We are going to be watching a videotape of a lesson from your class. I have some questions to ask you about your teaching, and have some stopping points selected at which to ask those questions. You should also feel free to stop the videotape at any time and discuss your teaching or thoughts about what was happening, especially at points where you were making instructional decisions.

1. What were your goals for this lesson?

2. Stopping Point One: When the student asked for the information, what did you think?

3. Stopping Point Two: What were you thinking when you were explaining the different methods? How were you gauging your students' understandings? What did you think when the student raised the point regarding the Hach kit standards?

4. Stopping Point Three: When you were explaining about the nitrates and molars, what were you thinking? How were you gauging your students' understandings?

5. Stopping Point Four: Data analysis section—what did you want students to know about this section? What do you hope students can do as a result of studying the error analysis section? What did you think when the student asked about the error analysis test? How did you decide your response?

6. Stopping Point Five: When you were describing your irrigation project report, what were you thinking? What were you hoping students would gain from your presentation? How do (will) you understand whether they get that point?

7. Stopping Point Six: When you asked "So does that give you a better idea of what you are going to do?" What were you thinking? Could you tell if students understood? How?

8. Stopping Point Seven: When you brought the map to class, what was your goal? How do you know whether students attained that goal?

9. Stopping Point Eight: When you explained the sections of the map, what were you thinking? Did you think about asking them any questions regarding the purposes prior to explaining them? For instance, Park Pond. Maybe asking them about their ideas for Park Pond might have started them thinking prior to your telling them the information.

10. Have (Will) you use student ideas in your lessons? How?

Student Pre-Instruction Guiding Questions

1. What does your professor like you to do when it is time for class?
2. What does your professor do to help you learn the subject matter?
3. If you do not understand something, what do you do that helps you improve your understanding?
4. Do you believe your professor is an effective teacher? Why or why not?
5. Considering all teachers have strengths and weaknesses, what are some of the strengths your professor has in teaching? What are some of his weaknesses?
6. What could your professor do to help you learn the subject matter even better?
7. What else can you tell me about how your professor helps you learn the subject matter?

Student Post-Instruction Guiding Questions

8. What does your professor like you to do when it is time for class?
9. What does your professor do to help you learn the subject matter?
10. If you do not understand something, what do you do that helps you improve your understanding?
11. Do you believe your professor is an effective teacher? Why or why not?
12. Considering all teachers have strengths and weaknesses, what are some of the strengths your professor has in teaching?
13. What are some of his weaknesses?
14. What could your professor do to help you learn the subject matter even better?
15. Have you noticed any changes in your professor's teaching over the course of the semester? If so, what specific changes have you noticed?
16. Do you feel having an observer in the class changes how your professor teaches?
17. What is your feeling about the class participation?
18. What methods do you think your professor uses in encouraging class participation?
19. What do you think about your class project?
20. How do you like working on a group project?
21. Did you learn more from your group project than your lab assignments?
22. What else can you tell me about how your professor helps you learn the subject matter?