



Sampling in the Field: A Case Study of Connecting Theory to Practice

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Abstract

The connection between practice and theory is essential in promoting student engagement, perception, and understanding, yet in lab exercises students are often given an artificial sample lacking in any real world connections. Although experimental procedures performed in the lab may provide cognitive benefits for students, the theory behind the methods might be lost when no connection is made to real world scenarios. One way to overcome these limitations is through applications and experiences for students at the undergraduate level through field work. This paper presents an effort to introduce junior and senior civil engineering students to real world based problems through the use of developed field studies, redefining the current pedagogy of lab studies. Students from three different lab sections of an introduction to environmental engineering lab course visited different locations along the Canyon Lakes system located in Lubbock, Texas that acts as a final cleaning step for discharged wastewater, and they were tasked to sample the lake water and take in field test results for certain water quality parameters. The locations along the lake were chosen in order for students to see a contrast in water quality parameters along the flow of the system. Samples were taken at the site of discharge, one section in the middle of the system, and one section towards the end of the lake system. Students were given background information and asked to develop a study question to be used across all three lab sections. Students over the semester analyzed their field sample for different water quality parameters and determined whether the lake system's water quality parameters were affected as you traveled down the watershed. Data collected from their sample was then gathered into a larger data set representing data from all three lab sections and the three lake sites. Students were then given the task of analyzing and reporting the data throughout the semester. To examine the relationship between field work and student attitudes and perception on field studies, students in an environmental engineering laboratory course were assigned a reflection paper before and after performing the field work exercise. Further reflection was given by the instructor of the lab course on student's performance, attitudes, and the instructor's perception of the field study. Final results revealed a positive response by both students and instructors in regard to field studies being implemented in lab courses.

Introduction

Engineering is an applied science that relates the theory of science to real world applications. Today's society expects graduating engineering students to be able to connect theory to practice in real world scenarios. However, in today's traditional lab settings students are given artificial samples that will produce reasonable results without much effort and lack any real world simulation. Real world sampling and samples contain variation between samples, where as traditional labs use samples formulated to fabricate a desirable result that has no real meaning. This "one sample fits all" traditional lab setup is unlike real world scenarios and in the end,

students learn to mimic experimental setups but the connection to theory and practice is lost. It has been suggested that relevant, real-world applications can promote student motivation, engagement, and comprehension¹. Another study demonstrated that students are more likely to choose engineering and stick with their choice if provided real world, authentic learning experiences². One suggestion to overcome the limits of traditional labs is to use field studies as a practical project-based learning that connects theory to practice.

Project based learning has been stated to be the “application of knowledge” with tasks that are more realistic and comparable to what practicing engineers execute³. Numerous cases have demonstrated that project based learning in labs are more advantageous over problem based learning in the classroom^{3,4} but little research demonstrating the nature of project based learning in labs has been conducted. One study investigated students in geography, earth science, and environmental science and their perception of fieldwork⁵. The study revealed that fieldwork when used, regardless of age, gender, or social impacts, encouraged learning and had positive responses on students’ affective domain⁵. This study further concluded that due to the positive affective responses from the students, a positive perception of field studies would lead to a greater level of motivation and effectiveness when applied to learning outcomes⁵.

The purpose of this paper is to offer a qualitative study on the application of field studies based on real world scenarios in an environmental engineering lab. This paper offers insight to the initial and final perceptive and attitude of students who have completed a course with this curriculum implemented. Further insight pertaining to personal thoughts on the field study and on students’ perspective and attitudes is offered by the two main instructors of the course.

Methods and Design

Population

Students from 3 different sections of the same laboratory course were surveyed throughout the semester. Students included both men and women. Approximately 16 students were enrolled in each of the 3 different environmental engineering lab sections, with a total of students 47 overall. The surveyed course is a 1 hour credit, junior/senior level Introduction to Environmental Engineering laboratory (CE 3171) course taken concurrently with the 3 hour credit Introduction to Environmental Engineering lecture (CE 3309) course. Students in the laboratory are junior or seniors in the civil engineering degree program who are concentrating their studies in structural, geotechnical, construction or transportation engineering. Students concentrating in environmental engineering are not required to take the Introduction to Environmental Engineering laboratory as similar, more advanced lab courses are taken later in their curriculum.

Course Structure

The CE 3171 lab meets once weekly for 3 hours and is structure to rotate weekly between lectures and labs with the exception of the first two weeks of lab which are both lectures consisting of background material and an introduction in the field project. During the second lecture, students are given historical information, but not past water quality data, on the Canyon Lakes system and the structure, objectives, and tasks for the field project are determined. The 3rd or 4th week of class is usually the designated sampling field trip and students are tasked with obtaining field measurement and a grab sample that they will use throughout the course of the semester. The field study was approximately 8 weeks of the 13 week semester with 3 of the 4 labs revolving around the field study. The course grade is weighted among reports, quizzes, homework, and a final exam. The total weight of the student's grade that is influenced by the field project is 45%. Students typically spend on average 1-3 hours weekly on assignments and class material.

Field measurement taken consist of pH, dissolved oxygen (DO), and total dissolved solids (TDS) using probes designed to measure one of the parameters. These initial field measurements offered an introduction into future concepts that the students would study; students used these initial field observations to write the first lab report, while the final 3 lab reports were written using data collected from lab experiments. Lab measurements that are used in the field project include pH, total alkalinity, hardness, solids fractions (total solids, total dissolved solids, total suspended solids, total fixed solids, and total volatile solids), and COD. A final lab demonstrating coagulation and flocculation was completed towards the end of the semester but was not included in the field project. No freedom was given to students in the designing of the laboratory experiments or which parameters were tested, as these topics are required by the department and must be included in the curriculum.

Instructors of Lab Course

Two of the 3 lab sections were taught by the main instructor (MI) of the environmental engineering labs while the final section was taught by a side instructor (SI). The MI was also the principal investigator of this project. The MI has been teaching the environmental engineering course for 4 years and has been given the role of lead instructor for the environmental engineering labs while the SI has been teaching the environmental engineering lab for 2 years. Until the fall semester of 2014, both instructors were teaching assistants (TAs) under the guidance of the instructor of the environmental engineering lecture course. In fall of 2014, both TAs were named the instructor on record for their respected sections. Both instructors are PhD students within the environmental engineering department whose dissertation topics are unrelated to engineering education. The MI developed the field studies project without the aid of the SI, but later gave instruction and direction to the SI pertaining to the project. The SI

implemented the project in their lab section independent of the MI but came to the MI with questions or concerns during the project period.

Field Studies Project

Development of the field studies project began initially with determination of an appropriate field site and development of a study question. The field study took place in Lubbock, Texas with a population of approximately 230,000. The city is a semi-rural area and as such, site locations are limited as the city is remote and isolated from other large cities with industry. However, a unique opportunity is present at the Canyon Lakes system located in the city. The Canyon Lakes system is a series of 6 lakes that are interconnected, with a flow that runs from north to south along the watershed. At the beginning of the system, treated effluent from the local wastewater treatment plant is discharged. The discharged effluent meets state water quality standards but contains a high concentration of nutrients. The Canyon Lakes system acts as a final, natural, polishing step for the discharged effluent. As water flows down the watershed, nutrients and solids are removed through natural attenuation, until the end of the system where stream quality water is released. Each of the 3 lab sections was given a different location along the watershed in order to take individual samples for water quality analysis. Samples were taken at the site of discharge, one section in the middle of the system, and one section towards the end of the lake system. The locations along the lake were chosen in order for students to see a contrast in water quality parameters along the flow of the system.

The development of the field study question was adapted from previous site evaluations. Previous site evaluations had been completed prior by private engineering firms and the city's engineers with full water quality analysis. Students were not privy to prior water quality results but rather were promoted to develop a real world scenario objective to be completed throughout the semester. Students were given the role of "city engineer" in the project and worked as a class to develop an objective and sampling plan before going into the field. Students then later reported their findings in 4 lab reports that were submitted throughout the semester. The project was designed to allow for an infinite amount of semesters to use a similar, if not the same project depending on the instructor's preference.

Responsibilities of Instructors and Students

The student's responsibilities included development of the overall project objective, collection of field samples, the analyses of the field samples using lab techniques taught to them by the instructors, giving their lab instructor their data from their collected data, and reporting of the data obtained across all 3 lab sections through lab reports. Students worked individually when collecting their samples and during the analyses of the samples, but were given data from all 3 lab sections to be used in their individual reports.

Responsibilities for the instructors differed for the MI and SI. Responsibilities of the MI included development of the field study project, obtaining permission from the chair of the department, determining a useful site location for the field study, and development of survey and reflection papers. The MI was also responsible for making sure that all students had transportation to the site on the day of the student's lab section (Monday, Tuesday, or Wednesday).

The SI was responsible for the implementation of the field study project within their classroom and attending all 3 sections on field study day. Both instructors guided their students in the development of the overall semester project goal and were responsible for collection of the students' lab data from their lab sections. The SI was charged with giving her students' data to the MI who would then combine the data into one larger data set representing data from all three lab sections and the three lake sites and send out the collected data to all students across the 3 lab sections. Each instructor was responsible for the grading of their student's lab reports.

Evaluation of Instructors and Students

A survey was given to students at the beginning of the semester, prior to the students going on the field study. General questions consisted of whether the student had previous experience using field studies in their lecture and/or lab classrooms, their age, gender, and ethnicity. The following two open ended questions were given at the end of the survey in order to investigate student's initial perception on using field studies in the classroom:

- (1) What is your initial perception of using a field studies project in a lab setting?
- (2) How do you think adding a field study component to the lab will impact the outcomes (grades, understanding, etc.) for the semester?

Towards the end of the course, students were assigned a post reflection paper to assess their final attitudes and perception of field studies using the following two questions. Students were prompted by the following two questions and asked to write 3 - 5 sentences for each question:

- (1) Describe the impact of using real world water quality samples gathered from your sampling experience at the Canyon Lakes system. What is your general perception of its use in the lab classroom and its impact on your performance in lab?
- (2) Would you recommend using field studies/sampling practices in future labs? Why or why not?

Students' responses for the post reflection paper were not viewed or read until after final grades for the course had been submitted in order to eliminate bias. The pre-survey and final reflection paper accounted for a total of 2% of the students' final grades and all 47 students surveyed completed both the pre-survey and final reflection paper.

Since the MI was also the principal investigator of this study, a reflection paper was completed after the end of the semester. The MI also kept notes throughout the semester on developing attitudes, perception, and thoughts from the students. The SI completed a similar reflection paper at the end of the semester. The following questions were used in the reflection paper:

- (1) What is your overall opinion about using field trips and field studies in the lab classroom?
- (2) How did you think this benefit or hurt the students throughout the course (better grades, was there a lack of understanding or was greater knowledge obtained, more or less participation, etc)?
- (3) What are some of the challenges that you faced when implementing the Canyon Lakes Project?
- (4) What are some ways to improve the overall project, classroom design, etc.?

Results and Discussion

Students' Perception

Comments from students' initial reflection were following the line of a lack of experience with field studies rather than a lack of interest. A majority of the students (~ 93%) had never participated in a laboratory that had a field studies component. Students expressed interest in a field studies component being added to the course, but many expressed concern that the required work load for the course would increase if field studies were included. Another common theme among the responses was *"it would be great to do a project that had real world applications"* and that collecting a sample from the field would give them the sense of being a *"real engineer"*. Overall, initial perception and comments were positive and students were excited to implement field studies into the lab.

The final reflection paper given to students offered a final overview of students' perception and how they felt field studies impacted their performance in the lab. The common themes of students' response were that 1) field sampling helped them apply real world application to the lab and they felt they were more prepared for real world scenarios, 2) the field study was fun and

not tedious like most traditional labs and 3) understanding of environmental concepts was easier and they were able to apply knowledge learned in the lab to the co-requisite environmental course. The final breakdown of number of times students reported each theme is shown in Table 1.

Table 1. Results from Students' Final Reflection Papers

Comments	n
(1) Field sampling helped them apply real world application to the lab	34
(2) The field study was fun	35
(3) Understanding of environmental concepts was easier	40

n, Number of students. Total number of students = 47.

The majority of students expressed that sampling in the field helped them learn the environmental concepts better as the project offered a common topic that they could utilize to connect abstract concepts to real world scenarios. Students also really enjoyed using a real world scenario because they felt it would benefit them in the future job markets and gave them a sense of one possible scenario a practicing engineer might face. The following comments are taken directly from students' final reflection paper and offer insight into students' attitude and perception.

"We could have just as easily used artificially created dirty water, or a random samples collected from some unknown site, but I really like that the water used in our experiments was collected by us from a system designed with an objective we could test. Conducting experiments on chemicals and materials that were acquired for us from the "cabinet of mystery" isn't personal. Collecting samples first-hand helped me to connect with the results, which enhanced the overall learning experience."

"It was actually great to see where the water sample came from to get a sense of why it contains the things it does in the experiments. Not only are we getting our sample from our location, while the other lab groups are getting their samples from other locations that makes it even nicer for comparisons of each location in lab. It makes the lab a lot more interesting compared to when we would just get samples in the boring chemistry labs. I would recommend using the field studies for sure! It was a great experience for us to actually see something other than a

laboratory. It keeps you interested throughout the semester to see how terrible the water is before it gets treated. Definitely should keep the grab sampling lab field trip in future labs.”



Figures. (a) Students using pH, TDS, and DO probes to take real time field measurements. (b) Students collecting field samples to be processed later in the lab.

“The impact on my performance in the lab was that it helped in giving me something to compare to and helped in writing the labs. I personally enjoyed the real world sample because it helped me in understanding in what we were studying. It was one of my favorite parts of any lab here at school because it uses real world samples. Also, the sampling was enjoyable because we got to see where the sample came from.”

“It helped me to understand the lab better and it helped when interpreting the sample results. I think this method should continue to be used in future labs because it is interactive and it causes students to pay more attention. It helped me to understand our experimental results better because it is data that I went out and got and was therefore my responsibility.”

“Using the samples from the Canyon Lakes we were able to also compare out results. You could also compare the results from our real world water samples with other real world results.”

Few students had negative comments about using field studies in the lab and even fewer would not suggest the use of field studies. Only ~10% of the 47 students surveyed had negative comments about field studies, but only 2 student said that they would not recommend the further use of field studies in the lab. Most “negative” comments made were less critical about the use of field studies in a lab setting and more that it did not help them overall one way or another by having the project added into the course. For example, one student commented on how the source of their sample made no difference in the overall scheme of the class:

“To me personally, the source of water makes absolutely no difference in regards to where the sample came from. If you grabbed several different samples of water from a lake, faucet, or toilet, it would not matter in the long run.”

Other comments expressed frustration with using data collected from other students because they were not able to verify the data and it was difficult to interpret data with errors:

“I would not recommend using field samples in the future labs. When individual samples were taken, there is too much variation in the data points and you can't accurately determine if the error is from sampling or in the actual testing procedure. With a controlled sample the data numbers from the lab can be controlled...so students can easily identify the error and correct it.”

Overall, students found the use of field studies to be very helpful. Students enjoyed the added “real world scenario” to the classroom and saw benefits in not only their understanding of course concepts but real world applications.

Main Instructor's Perception

The general opinion of the MI is that field studies included in lab practices benefits not only students but the instructors as well. The MI reported observations in four different categories: 1) how did the field studies help with teaching environmental concepts, 2) how did it benefit students grades and performance in the labs, 3) how did the MI perceive students' attitudes to field studies, and 4) what were some of the negative aspects of fields studies observed by the MI. Students appear to be able to grasp concepts more easily as there was a common theme with the lectures.

The lab reports written by students were largely improved from previous semesters taught by the MI, possibly due to the directional guidance that the project offered. Students had an overall objective for the class, and by using this theme, students were able to be more concise and thorough with their reports. Average test scores between sections within a semester were also seen to improve with non-field study semesters (n=6) averaging 79.6 ± 3.5 between 3 lab sections from 2 previous semesters and the field study semesters (n=3) averaging 89.5 ± 3.75 between the 3 lab sections. The test scores were determined to be significantly different ($p=0.02$) using a t-test with statistical significance set at a $p < 0.05$. Short answers given by students during test questions showed a tendency towards a higher level of thinking and a more thorough understanding of course content. For example, during semesters when the field study was not implemented students', when prompted to write a sampling plan for a given scenario would commonly responded with the following answer: “collect sample, test sample, and report data”. Frequent students' response from the field study semester for a similar prompt would give more detailed responses and cover more course content in their answers. For example, one student

gave the following response: *“In order to make an appropriate sampling plan an overall objective would need to be made that would help you determine the question that needs to be answered. Secondly, what parameters you would need to help to answer your main objective (pH, solids, etc.) would need to be decided and what type of sampling (grab, composite, or continuous) and how many samples you would want to take. Environmental factors and timing would also need to be considered.”* This possible increase in performance by the students could be that the field study project offers a much more focused “realistic and applied” topics compared to more traditional “theory-only” topics.

Students’ attitudes towards the field studies were generally positive. Students’ thoroughly enjoyed collecting their own sample and seemed to have fun throughout the semester as they went through and discovered the water quality of their sample. Students appeared to be more engaged in why certain water quality test gave a specific water parameter. They also were a lot more responsive to questions asked to them by the instructor during class and would ask more questions during the class about the water quality topics. Surprisingly, students were possessive of their samples and took great pride in the data collected from their individual samples. It seems to give the students’ a sense of accomplishment when their data correlates with others and when they were able to detect an overall trend in the data.

As with any situation using real world samples, problems arose during data collection. By using samples collected from a real field site, data collected from the students would sometimes contain errors or inconsistencies within the data sets. Students at the beginning of the semester when presented with such problems in their data sets became frustrated and were unsure how to report the problems within the data sets. However by the end of the semester, students were able to confidently able to read and evaluate data sets that include inconsistencies/errors and know how to accurately report the data and offer plausible conclusions. The benefits of including a field study project far out weight the problems that occur during implementation.

Side Instructor’s Perception

The open ended reflection paper given to the SI offered insight to an implementer, rather than a developer, of the field project design. The side instructor’s final perspective on the field studies project was positive. The SI commented how easy it was to incorporate the field studies into the course schedule. Further comments include the usefulness of using field studies to relate environmental topics to the students and how the students’ interest seemed more peaked. From the SI’s reflection paper the following quote was taken:

“Field studies offer the opportunity to invigorate the students’ active minds, for them to ask more questions, and pay more attention when they perform the labs.”

The side instructor offered no further suggestions to improve the project design and was an overall supporter of further implementation of field studies in future labs. The only challenge was the difficulties in transporting the students to the field site, but this was easily overcome with help from the school.

Challenges in Implementing

Implementation of the field study was not without its challenges. Challenges included lack of resources, transportation of students' to the field site, and re-organization of the curriculum in order to fit the project within the required curriculum. Additional monetary cost for the field study, including transportation of MI and SI and supplies for the field study, was supplemented by the department. In order to alleviate the stress of finding transportation for all students, students were asked to take their own vehicles or commute with others to the sampling site as the sampling site was a short distance away from the school. As both instructors are PhD students, who have other obligations, time was a constraint that was taken into consideration when designing the project. To ensure that the work load of the instructors and the time allotted each week for the lab was not exceeded, the field study project was designed on a smaller more, local scale. Only using the time allotted for the lab to teach and implement the field studies also helped to resolve this issue. Time invested during the semester to implement the field study was comparable to the time invested for the traditional lab course. However, prior to the beginning of the semester, the MI was required to spend approximately 20 – 25 hours to ensure that the field study project would be feasible in the required curriculum.

One of the largest constraints that was hardest for the instructors to overcome was not having full control of the course. Until recent semesters, labs curriculum and development was left to the professor who taught the co-requisite environmental engineering lecture. While TAs were allowed to offer suggestions, resistance to implementing field studies occurred. The development of the field studies took time over a few semesters and was not fully implemented until the semester the TAs became the main instructors and had full control of the course.

Conclusions

Generally, implementation of field studies within an environmental engineering lab course demonstrated a positive perception by both students and instructors. Overall, students' perception suggested that the use of field lab studies in environmental engineering labs allowed for more real world application, more than traditional lab settings. Students enjoyed the process of collecting samples from the field and felt more connected to the application of the lab experiments. Students also commented on how designing a project based on field studies helped

them in the classroom because of the common theme of their project being applied throughout the semester.

Instructors also had a positive perception on the application of field studies. Common themes among the instructors' comments included : 1) instructors were able to relate lecture information easier as there was a relevant real world topic the student's could relate back to, 2) field studies brought variety to the lecture making environmental topics more interesting to teach and 3) students' engagement and understanding of course material seem to more evolved. The findings of this paper suggest that use of field studies in an environmental engineering lab course could have positive effects of students' attitudes and perception on lab activities. Further research is needed in order to quantitatively understand the potential effect of field studies on students' performance, attitude and perception.

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