TITLE:

Integrating Primary Scientific Literature into a Graduate Course on Environmental Engineering

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PROJECT SUMMARY:

To address gaps in students' backgrounds, an environmental engineering professor changes her instruction in a graduate course and focuses on three aspects of student learning: reading scientific literature, using basic scientific principles as the basis for scientific inquiry, and synthesizing scientific literature and concepts in written reports.

Background

CE 573 / 773, Biological Principles of Environmental Engineering, is one of three required principles classes that all graduate students in environmental engineering or environmental science take (the other two are chemical and physical principles). Many of the students enrolled in this course are professional engineers pursuing their master's degree part-time. Most students have basic science courses in their background, although the breadth of exposure varies among students. During spring 2008, the course was scheduled for evenings from 6—10 pm; 13 students were enrolled. Because the class met only once a week and for such a long time period, I typically structured the class by lecturing for about one hour and 15 minutes, then devoted the rest of class time to discussion and laboratory exercises.

The major goal of the course was to provide graduate students the basic biological background necessary to further their studies in engineering and environmental science. Upon completing the course, students should be able to use basic biological principles as a means to understand and discuss current topics in environmental science and engineering. In addition, by the end of the course students are expected to communicate effectively (both in written and oral forms), to conduct literature reviews, and to analyze and interpret experimental data (see CE 733 Sylabus).

Last time I taught the course (spring 2007), I found that when I assigned scientific articles to stimulate discussion, students either did not read the assigned articles, and/or did not feel comfortable participating in discussion about the science reported in the articles. I initially attempted to hold students accountable for the reading by calling on them randomly to answer my questions. Even then, the students did not respond with the level of thoughtfulness or depth I anticipated, and classroom time dwindled away from us in a series of painful silences. Moreover, when students completed literature reviews for their final projects, their work lacked synthesis and novel insights based on their understanding of the literature.

Although graduate students were enrolled in this course, it seemed as though most students had not been taught to question published research results or to analyze whether the methods and results properly supported the conclusions. Rather, students tended to believe that anything published is absolutely true. This suggested to me that they did not comprehend the process of scientific synthesis. I believe that students demonstrate a true understanding of fundamental scientific principles when they are able to critically analyze and question scientific results, as well as synthesize their own research questions. When I presented these expectations to students as "critical thinking" and "problem synthesis," they sounded like ambiguous, lofty concepts; in previous semesters, students commented that they were unsure of what my expectations were and how to fulfill them.

I think students can be energized once they understand that "the state of the art" in science is constantly changing and that progress is made in small experimental increments. Teaching students to critically read scientific literature allows them to appreciate the role of individual studies in the accumulation of knowledge, but it is also important because scientific writing and publishing rely on critical peer review. Consequently, my ultimate goals are for students: 1. to be able to synthesize scientific literature by thinking critically about the content, and 2. to improve in their ability to communicate their understanding of primary literature in their own writing.

In response to these observations, during spring 2008, I made changes in my teaching approach that addressed three aspects of student learning:

1. Reading scientific literature
2. Using basic scientific principles as the basis for scientific inquiry
3. Synthesizing scientific literature (and concepts therein) in written reports.

By integrating primary scientific literature into my teaching, I aimed to reinforce to students the fundamental scientific principles and to enable students to synthesize research questions. In essence, I wanted to document that taking class time to teach reading and writing does not "cheat" students from the material they may have obtained in a lecture.

Level II Implementation

Overall, my goal was to teach students to read and critically analyze research articles and ultimately to synthesize the ideas contained within the literature in their own laboratory project and paper. I made several changes in my course to achieve this goal:

1. I incorporated primary literature earlier in the semester than I had during the previous semester. Specifically, I assigned scientific literature as reading assignments each week, which we discussed as a large group during the next class period. I also had students incorporate literature in their laboratory reports right from the beginning of the semester.

Each week, I found articles that related directly to the unit lesson and the basic principles I was teaching. My goal was to show how these principles were incorporated into more complex scientific questions and were integral to the scientific process as a whole. These articles also related directly to the lab work students were performing. We discussed the papers as a class. Initially, discussions were slow, so I started having students bring in written summaries of the papers (see Questions for Responses to Scientific Papers), with the goal of encouraging deeper reading and therefore more stimulating discussions.

2. I established clear standards and tried to better prepare students for incorporating literature as a context for their own laboratory experiment (see Lab Report Format). students with a rubric was a key component for setting their expectations and preparing them for lab write-ups. The rubric included items related to the critical analysis of data; for instance, students were assessed on their ability to incorporate tables, graphs, and statistical analysis in their reports. I also included as a trait the effective use of primary literature. Throughout the semester, my goal was to get students to internalize the rubric, and ultimately enable students to edit their own work by recognizing when a high quality product had been produced.

3. Before their first lab write-up, I provided three examples of a lab report from a previous semester (see Exercise 1, Exercise 2, and Exercise 3) and asked students to evaluate them using my assessment rubric My goal was for them to internalize the rubric criteria, making it easier for them to produce higher quality work. As a class, we then discussed the grades they had assigned each lab report (see Grading Rubric Example).

How I assessed whether these changes were effective

Writing**:** I used a rubric presented to document performance in areas that I felt reflected critical thinking, writing ability, and effective use of scientific literature in students' lab reports and final project. I could not make direct comparisons to previous classes because I had never before used a rubric, and also because I changed the nature of the final assignment. However, I could compare rubrics over time within a single semester to gauge improvement in each category of the rubric, as well as improvement in overall performance.

Reading: Informally, I used in-class questions and discussion prompts to track students' understanding of the course material. Formally, I used a grading rubric to ascertain the level of critical thinking and analysis performed from the reading assignment response. Since I have not used this in previous classes, I looked for improvement over the course of the semester as evidence of learning.

STUDENT WORK

Overall, students performed well in the course, with the majority of students earning A grades (see Final Grade Distribution).

For many students, incorporation of literature improved over time. Specifically, students improved in citing literature within the text where it was appropriate. Even though I did not specify where in the paper citations needed to occur (i.e. students could cite all five of them in the methods section if they chose to), most students found papers in the literature that helped them understand their data and support their interpretations and arguments.

For example, in Lab 2, one student included the required number of references (five), but it was unclear what statement the references were meant to support in the Introduction of the paper. In Lab 3, the same student more clearly and correctly used references in the Discussion. Although his work on the entire lab earned him only a C grade, he demonstrated that he had learned how to incorporate references into his writing (see Comparisons Across Time Student 1 Labs 2 and 3). For other students, too, the improvements were most evident in the Discussion. For instance, between Labs #2 and #3, two students improved their grades from D's to B's, largely because of better synthesis of concepts and literature in the Discussion (see Comparisons Across Time Student 2 Labs 2 and 3, and Student 3 Labs 2 and 3).

Thus, overall, students improved between Lab #2 and Lab #3, particularly the lowest-performing students: those who earned D's on Lab #2 earned either C's or B's on lab #3. However, for several students, their grades dropped again for Lab #4, due to lower scores on the Results and Discussion sections. Lab #4 required data analysis of kinetics, which many students did not perform accurately. Students generally did incorporate literature into the Discussion.

For the final project, students worked in self-selected groups to choose a topic to study, isolate the questions and formulate hypotheses in a proposal, design an experiment, then execute the project and write it up in a formal lab report. Students also prepared PowerPoint presentations that they shared with the class.

All students in a group received the same grade, but I had them sign pledges reporting what percentage of the work they did. Students didn't have trouble developing a research question and designing an experiment, and they appeared to have fun conducting the experiments. As a class, their performance on the final project was very good (see Lab Project Graded Rubrics). Topics they chose included: comparing the disinfectant efficiency of ethanol, bleach, and anti-bacterial soap; fluoride inhibition of nitrogenous biofiltering activity of *Pseudomonas fluorescens* in a simulated aquifer system; microbial contribution to pH change and biofilm formation in biodiesel; and the impact of variable loading on a fixed-film reactor versus a suspended growth reactor.

REFLECTIONS

Having students read scientific papers early in the course appeared to help them incorporate literature into their writing. Although the papers were often more comprehensive than necessary, they served the purpose of exposing students to the application of basic biological principles, as well as introducing them to the cumulative fashion in which individual research projects contribute to a larger body of knowledge.

Performance on the final projects improved for virtually all students. Group dynamics may have contributed to the marked improvement. For example, one group was comprised of three students, each of whom received between 40 and 60 points (out of 100) on their initial (independent) lab projects (labs #2-#4). This group earned an A on the final project. I can be fairly sure that it was not one strong student who carried the weight; rather, I believe that their strong final performance illustrates the value of group interactions.

This course was the first time I ever used rubrics for grading, and I found that I really liked them. They provided explicit expectations and objective scoring criteria, and they equalized my grading effort across individual students. One challenge I faced was that if students technically met the criteria in the rubric, it was hard to give a low grade even if the overall product wasn't as high of quality as I expected. Thus, I will need to modify the rubric so it is used less as a checklist and more as a guide. Regardless, I found using grading rubrics extremely beneficial, and I've shared my rubric with other faculty who expressed interest after I discussed my experiences with them.

Even though I saw improvement in the writing this semester compared to the first semester I taught this course, the quality of lab reports still needs to be improved. In the future, I may allow students to revise their reports for a second grade. This will provide students additional opportunities to improve their writing and analysis skills without increasing the number of labs in the course.

Next year when I teach this course, I am going to follow a similar course format. I will continue to require literature be incorporated into lab reports, but I will increase the number of required references from five to ten. This increase will require students to write a more thorough discussion in order to meet the requirements.

For the reading assignments, the paper summaries ensured that students performed the reading and provided an avenue for assessment. These also seemed to spark discussion. Due to the course structure, the first half of the semester is devoted to learning basic science concepts in microbiology, cell biology, biochemistry, kinetics. For every lesson plan, I already require assigned reading and an online reading quiz. The second half of the semester is devoted to learning various applications of biology in environmental engineering. During this time, I will begin requiring literature reading assignments and required responses in place of the required reading quizzes. I will use a grading rubric to grade students' critical reading responses for the second half of the semester. The incorporation of primary literature during this half of the course should support the overall learning objectives and expose students to a multitude of biological applications in environmental engineering. Discussion of various methods and data will connect the first half of the course (basic science) to the second half (applications).