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Integrating Project-Based Service-Learning into an Advanced Environmental Chemistry Course

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Service-learning is an approach that contributes to student learning and is particularly applicable to environmental chemistry. The American Chemical Society (ACS) is interested in this approach; ACS members reported recently on a meeting held to develop goals that ACS should consider to encourage service-learning in chemistry departments *(1)*. The participants explained that chemistry is well-suited for the promotion of service-learning because of its potential role in supporting K–12 education, improving science literacy in the general public, and investigating scientific issues that affect society. Further, they suggested that chemists follow the lead of the ACS student affiliates, many of which are already involved in outreach efforts *(1)*. Service-learning has been used successfully in many science settings. For example, students in general chemistry conducted a lead paint analysis for the community as part of the laboratory portion of their class *(2)*; biology students developed a game called "Plant Bingo" for local nursing home residents as a method to learn and teach about different species of plants *(3)*; and a four-week laboratory module was developed to study xenoestrogens in drinking water, in which the results were shared with the local water commissioner *(4)*. In summary, instructors report that students are more committed to the work and learn more as a result of engaging in service-learning *(2–4)*.

There is evidence for the observed increase in student learning with an active approach. When learning is measured not only by the quantity of information students gain, but by how much of their learning they can transfer to new problems in new situations, evidence is mounting that more active approaches, particularly involving projects that can benefit others, are especially effective as an approach to teaching. In addition, learning in different contexts, such as in the classroom, from a textbook, and through project-based learning, is also shown to increase student learning, again, as measured by the ability of students to transfer knowledge to a new problem *(5)*. Many practitioners have found success in increased student learning using service-learning as their active approach. For example, in a large political science class, service-learning discussion sections were randomly assigned and outcomes were carefully assessed. As a result of service-learning, students learned to transfer their knowledge; they could better apply principles and developed a greater awareness of societal problems than students in the non-service-learning sections. In addition, student learning and course grades increased and there were significant effects on students' personal values and orientations *(6)*.

One challenge of service-learning is to provide a meaningful student experience in a short period of time. Particularly when addressing scientific issues that affect society, time is needed to plan projects, read background material, carry out the project, and prepare and execute a final report. A single semester does not provide much time for all these components, and although some have found alternate approaches, such as combining the efforts of a semester with a summer internship *(7)*, most service-learning experiences utilize a single semester *(1–4)*. In addition to the time constraint, a service-learning approach can demand more resources than a traditional approach. While some instructors have a whole class engaged in one activity *(3, 4)*, others have students working individually *(6)* or in smaller groups *(2)* to complete projects.

The course discussed in this article is Advanced Environmental Chemistry, a course that was added to the regular offering of this department in 1999. It is an advanced course intended for junior- and senior-level chemistry majors, although chemistry master's students and biology and environmental studies majors who have the appropriate background in chemistry are also eligible. The course is taught in a seminar style, has no required laboratory component, and is limited to 15 students. The textbook required is *Environmental Toxicology and Chemistry* by Donald G. Crosby *(8)*. Having taught the course with a more traditional approach, I was interested in following the science educational reform and trying a more active approach. Educators have suggested that involving students in the discovery process, facilitating independent student learning, and encouraging the development of lifelong learning skills are important goals *(9)*. In environmental chemistry, service-learning projects seemed to fulfill all these goals. Single-semester projects focused on community environmental health were used.

Project Descriptions

A variety of service-learning projects were suggested in a handout that was distributed on the first day of class. Although students were encouraged to pursue ideas outside those suggested, none did. Students were also allowed to work in pairs if they chose. Out of eight students, two did individual projects, while the other six worked in three pairs. The project titles are given in Table 1. The project ideas stemmed from community requests that I had received over the last two years. For example, a local neighborhood had a history of environmental contamination and had a number of projects that could be done (Pair 1 and Students A and B). Also, students had been concerned about their exposure to environmental tobacco smoke in local restaurants and bars. Finally, a student organization, the Bucknell Brigade, has been involved in relief work outside Managua, Nicaragua since Hurricane Mitch in 1999. The group has raised the money to build a medical clinic in the Nueva Vida resettlement community, and engineering students have designed water-holding systems because the city water supply is not continuous.

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Table 1. Project Titles and Number of Students Involved

Number of Student(s)	Project Title
2	Analysis for gasoline contamination in soil in a local neighborhood
2	Exposure to environmental tobacco smoke in local restaurants and bars
2	Assessment of water quality in the Nueva Vida, Nicaragua medical clinic
1	Analysis of drinking water quality in a local neighborhood
1	Assessment of particulate matter sources in a local neighborhood

Table 2. Example of Course Schedule

Week	Assignment
1	Project proposal
2	Project plan
4	Ethics paper
6	Sampling and analysis protocols
8	Introduction draft
9	Abstract draft
9	Final abstract—electronic
10	Analysis report
11	Poster figures
12	Poster draft
13	Final poster

There was a concern that holding water in a tank overnight may lead to contamination, so an assessment of water quality was requested. Students selected projects and research partners based on their own interests.

Each project involved environmental sampling and analysis. Students researched standard methods found in the literature to determine sampling and analysis protocols. Because the University owns all the standard sampling equipment (air samplers, filters, soil samplers, and water grab samplers) students were not restricted in the methods that they used for sampling. For analysis, however, instrumentation may provide a more significant barrier. Again, we took advantage of the University's gas chromatograph–mass spectrometer, inductively coupled plasma–atomic absorption, spectrophotometers, and commercially available test-strip methods. In providing project ideas, the available sampling and instrumentation was considered, and later in the course, when students chose analytical methods, University holdings were considered. In a university with no advanced analytical instrumentation, commercially available test strip methods (for example, like those available from Carolina Biological Supply Co.) may provide sufficient information for the projects.

Course Timeline

The assignment schedule is outlined in Table 2. In addition to assignments, substantial class time was devoted to discussion of the projects. Of 26 class meetings in the semester, 11 were devoted entirely to the discussion of the projects. In these discussions, students shared discoveries and problems and offered suggestions to one another. Later in the project, drafts of poster sections were exchanged and critiqued during class time.

On the first day of class, the concept of a service-learning project was discussed. I had prepared a lengthy handout that justified the use of projects in the course to guide class discussion. Workload is a common concern for students, so I discussed in detail the work that would be required, and went over the schedule of assignments. I was careful to establish contingency plans for projects that did not work out, so that students would not be penalized. This was particularly important because the course culminated in a professional poster presentation (at the annual meeting of the Hudson–Delaware Chapter of the Society of Environmental Toxicology and Chemistry) and students needed to be reassured that effort would count towards their grade, more than final results.

In the first couple of weeks of the semester, students were choosing research partners, projects, and writing project proposals. In the project proposals, students were required to show that they had searched the literature related to their project choices. Additionally, students were asked to provide a justification for why they wanted to work on their particular project. Finally, some consideration had to be given to what background information was going to be necessary. Most students chose to provide a list of questions that they would answer from the literature. To get the class started on literature searches, a meeting was arranged with the science librarian during which students were shown the available references and given a lesson in searching databases for relevant information. Two weeks after the start of the semester, students were required to submit a project plan, which outlined their activities and timeline for the semester.

Three weeks into the semester, the class began to discuss ethical issues involved in community-based research, and an expert colleague facilitated a workshop on ethics in research. At about the same time, sampling plans were developed. Students were encouraged to derive methods from published studies, and to carefully consider the number of samples that they could analyze in the time provided. Students consulted with the instructor to determine the available analysis methods. About halfway through the semester, students were required to submit a 3–5 page summary of the background information that they found in the literature. This paper was used as the basis for the introduction section in their final poster. Shortly thereafter, abstracts were submitted. In most cases, students had not yet completed the analysis phase of their projects, but an abstract deadline had to be met, so most abstracts included incomplete descriptions of the final results. As the end of the semester neared, students were required to submit raw analysis results, and then a week later, a rough draft of figures for their poster. As they were starting to think about poster design, a session with an information technology specialist was arranged during which students learned how to design professional posters using pre-

Success of the Approach

One of the greatest successes of using service-learning projects in this course was the fact that students presented their findings at a professional meeting at the end of the semester. In preparation for the meeting, students worked hard to be sure that they knew the literature on their project so that they would be able to answer questions effectively. Unfortunately, professional meetings are sometimes unavailable or impractical. Other instructors have used Web-based publication of student projects and in-house presentations effectively. Working with community groups was also a positive aspect of the experience. Students reported back to their communities at the end of the semester, and worked deliberately throughout the project so that they would be able to report back to community members with confidence that they had carried out the project correctly.

The major advantage of the service-learning approach was the increase observed in student learning. Clearly, this is a subjective measure, and because no exams were given in the service-learning class, no objective measure of increased student learning can be provided. However, students developed confidence in their abilities as scientists, and gained an intimate understanding of how the profession works. Having the projects to complete and a community group that they were responsible to provided ample motivation for learning related material. Students saw that textbook reading, by providing a context, helped them to do a better job on their projects.

Limitations of Approach

Clearly, this approach to teaching environmental chemistry would not work for all classes, at all institutions, and for all instructors. Class size has to be small to provide the individual assistance needed to help students through, particularly, the analysis phase of each project. Appropriate project ideas have to be readily available, and instructors have to learn about areas of research potentially unrelated to their own. The institution has to have the analytical resources to carry out analysis of samples. The time commitment is high for both students and faculty, although for students, the end product seemed to justify the means. The time dedicated to the service-learning projects meant that there could only be limited coverage of textbook material; approximately one-third of the textbook material covered in the traditional approach was removed to make time for the service-learning projects. In this offering, the basic concepts of environmental chemistry and toxicology were covered (e.g., environmental chemodynamics, transformation, quantitative toxicology, biotransformation, and mechanisms of toxicity, covered in Crosby, Chapter 1–10), but study of specific environmental contaminants and toxicants (e.g., inorganic toxicants, biotoxins, and common pollutants) was omitted. Additionally, in the previous offering of the course, prediction of environmental transport and fate through physical chemical properties of molecules was emphasized, but in the service-learning course, this topic was omitted in the interest of time. However, environmental sampling, which was so central to all the service-learning projects, was covered in much greater depth with this new approach.

Changes To Institute

Despite the general success of this approach, there are a few changes that I will institute when teaching with this approach again. First, I will emphasize more the community service aspect of the projects. Although students were aware throughout the semester that they were working for a community, during class discussions, we tended to focus more on the technical aspects of the projects and less on the implications of various findings on the community groups. In addition, because of time constraints, students reported back to their community groups via a written report. A presentation might have been more effective. In balance, students did not do enough reflection while they were engaged in the projects or afterwards. On the semester timeline (Table 2), I will move the sampling and analysis protocol due date up by one or two weeks. Because there was so much time given for that assignment, actual sampling and analysis were not done until mid-semester. Although everything worked fine this time, if our GC–MS had broken down, for example, many of the projects would not have been so easily completed. Advancing the initial phases of the project would also allow more time in the end for reflective assignments and for community presentations.

Summary

In summary, the service-learning approach in environmental chemistry was a success. Students learned more than they did with a traditional approach and gained insight into how environmental chemists work. In the end, students were proud of their work, and presented expertly at a professional meeting.

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