Incorporating a Research Project and a Water Chemistry Laboratory into the Water Quality Engineering Course at the University of Hartford

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Abstract

The Civil Engineering program at the University of Hartford requires students to take a four-credit Water Quality Engineering course that includes an environmental research project and a one credit Water Chemistry Laboratory taught by the Chemistry Department. Collaboration between the environmental engineering and chemistry faculty has further strengthened the program by having students learn analytical techniques on samples collected from local water and wastewater treatment plants. The data collected by the students is then used in the Water Quality Engineering course for analyzing the physical, chemical, and/or biological performance of each unit process. By using their own data, the students also gain a better understanding of the uncertainty in the water quality measurements. The Water Quality Engineering course also includes a laboratory. This laboratory is designed so that students work on a semester long group research project that is sponsored by a local utility, muncipality, or consulting firm. These projects require students to do fieldwork, laboratory work, design, and data analysis. At the end of the semester, students make an oral presentation and submit a final report to the sponsors. Student surveys and feedback from the sponsors of the research projects have been used to assess the effectiveness of this approach in teaching water and wastewater treatment.

I. Introduction

At the University of Hartford, civil engineering students are required to take a four-credit Water Quality Engineering course and a one credit Water Chemistry Laboratory in the first semester of their senior year. Physical, chemical, and biological treatment of water and wastewater are the primary topics covered in the water quality engineering course. In 1999, the course was revised to include a water research project that is sponsored by a local utility, municipality, or engineering firm. The research project provides students a hands-on experience with a current environmental engineering issue and in-depth knowledge of a topic that would otherwise be difficult to attain in an introductory water treatment course.

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The Water Chemistry Laboratory course is taught by the Chemistry Department and was designed to support the Water Quality Engineering course. Students are taught various analytical methods used in assessing the quality of a water sample. Review of the environmental engineering curriculum showed that the courses were not well integrated. In summer 2001, shared activities were developed to improve the integration of the courses.

This paper describes how externally sponsored water research projects and the integration of the Water Chemistry Laboratory and Water Quality Engineering courses has strengthened the environmental program. Student surveys, sponsor feedback, and comments from independent reviewers have been used to continually improve the program.

II. Environmental Research Projects

With funding from the National Science Foundation (Grant No. 9850673), an environmental laboratory based on collaborative and active learning was incorporated into the civil engineering curriculum. The laboratory was designed to provide undergraduate engineering students practical, hands on experience with topics and concepts typically not covered in undergraduate environmental laboratories. Students work in teams for the entire semester on a "real" environmental problem posed by either a water utility, municipality, or consulting firm. This approach stresses the practical aspects of project engineering that students are likely to encounter on the job. In contrast, most environmental engineering laboratory exercises follow a simple one-two-three approach that neither stimulates critical thinking nor enhances learning.

The laboratory is based on and incorporates the "Seven Principles for Good Practice in Undergraduate Education," including student-faculty contact, cooperation among students, active learning, prompt feedback, emphasis of time on task, communication of high expectations, and the respect of diverse talents and ways of learning[1]. Recent research has also shown that the retention of material by students is much higher when the student is directly involved in the learning process. This involves engaging the students in the learning process rather than just transferring facts. In other words, students learn by doing, not by merely listening. Astin investigated and monitored eighty-eight environmental factors to determine their relationship to student's academic achievement and personal satisfaction with post-secondary education[2]. The two environmental factors found to be most influential were interaction between students and students, and interaction between students and faculty. These two characteristics are especially stressed in the environmental engineering laboratory.

Groups of four or five students work under close supervision and guidance of the instructor and project sponsors. For each project, teams of students are presented with a practical engineering problem. The students propose a plan to solve the particular engineering problem at hand. The advantages and disadvantages of their proposed plan are discussed with the instructor and project sponsor and modifications are made, if necessary. Student teams carry out their plan while maintaining a dialogue with the instructor and project sponsor. The final product of each project is a professional report submitted to the sponsor that states the experimental design, results,

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discussion, conclusions, and recommendations. The students also make a formal oral presentation of their results to the sponsors and to local environmental professionals.

Undergraduate civil engineering students have worked on the projects listed in Table 1 since the problem-solving laboratory was started in 1999. Five of the seven projects were funded by the sponsors. The sponsors paid for the equipment and supplies needed for the project. In three of the projects, the sponsor also paid for an independent lab to analyze water samples when the sensitivity required was below the detection limit that could be achieved in the environmental laboratory.

Table 1. Externally Sponsored Water Research Projects

Project Year	Project	Sponsor
1999	Clearwell Baffle Design Study	Manchester, CT Water Department
1999	Unit Process Evaluation of the Canton Water Pollution Control Facility	Canton, CT
2000	Globe Hollow Reservoir Study, Phase I	Manchester, CT Water Department
2000	Removal of Boron from a Wastewater Generated by an Optics Polishing Process	Louriero Engineering Associates, Plainville, CT
2000	Polyaluminum Chloride Coagulation Study	Metropolitan District Commission, Hartford, CT
2001	Globe Hollow Reservoir Study, Phase II	Manchester, CT Water Department
2001	Elizabeth Park Pond Study	City of Hartford & Fuss & O'Neill, Manchester, CT

III. Integration of Water Quality Engineering Course and Water Chemistry Laboratory

In the one-credit Water Chemistry Laboratory, students learn how to measure a variety of water quality parameters. The water analyses that were preformed in fall 2001 are listed in Table 2. In previous years, students analyzed water samples from the Park River, which passes through the campus. To connect the laboratory more closely with the Water Quality Engineering course, it was decided that students would analyze water samples collected from a local water or wastewater treatment plant and then discuss their data in the Water Quality Engineering course.

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Furthermore, field trips were taken to the treatment plants so the students could see first-hand the treatment processes and the location where the samples were collected.

Table 2. Water Chemistry Laboratories

Lab Number	Laboratory Description
1	Check in and general description
2	Standard Preparation and Acid – Base Titration
3	*pH and Total Alkalinity**
4	*Measurement of Dissolved Oxygen*
5 (two weeks)	*7-day Biochemical Oxygen Demand*
6	Enteric Indicator Organisms
7	Ion Exchange
8	Sulfate
9	*Total Dissolved and Ortho Phosphate*
10 (3 weeks)	Independent Project

**Italics indicate the labs that were integrated into Water Quality Course*

The four labs that were directly integrated into the Water Quality Engineering course are highlighted in Table 2. For the pH and alkalinity lab, samples were collected at six different locations in a rapid sand filtration plant (influent, aeration, coagulation, sedimentation, filtration, and effluent). The goal was to emphasize that certain processes change the pH and/or alkalinity of the water (e.g., alum coagulation, chlorination, and corrosion control) and that other processes have minimal effect on pH and alkalinity (e.g., aeration of surface water, sedimentation, and filtration).

Dissolved oxygen is an important parameter in both natural and engineered water treatment systems. Students learn to measure dissolved oxygen (DO) in Water Chemistry Laboratory using the Winkler Method. In fall 2001, students also had to use a handheld DO probe to measure the spatial and temporal variation of dissolved oxygen in a reservoir and in an urban pond. To demonstrate the uncertainty in the measured values and that different analytical techniques may give different values, the students performed an experiment where the Winkler Method, handheld DO probe, a laboratory DO electrode meter were used to measure the same samples.

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Grab samples were collected from the influent, primary effluent, and secondary effluent of an activated sludge wastewater treatment plant and analyzed for seven-day biochemical oxygen demand (BOD_7). The measured BOD_7 along with flow and suspended solids data provided by personnel at the wastewater plant were used to analyze the hydraulic, physical, and biological performance of each unit process. Results were then compared to typical design and performance characteristics. In a subsequent lab, samples from the same locations were also analyzed for total dissolved and ortho phosphate. The objective of this lab was to demonstrate that tertiary treatment is required to remove a significant fraction of phosphorous from the wastewater.

The enteric indicator organism, sulfate, and ion exchange laboratories could also been integrated into the Water Quality Engineering Course. The plan is for these labs to be integrated into the water quality course in fall 2002. The independent project has been an effective learning experience and will not be changed. Students work in pairs to analyze a water source of their choice using the analytical methods learned during the semester.

IV. Assessment of Environmental Program

The tools used to assess the water research project were student questionnaires, sponsor feedback, and external reviewer comments. Overall, forty students have participated in the water research projects over the last three years. Questionnaires were developed after the first year to provide specific feedback on the student's learning experience. Responses from twenty-seven students who completed the survey in the last two years are presented in Figures 1 – 4.

The environmental laboratory was developed to promote active learning from a variety of sources. Students were asked how much they learned from seven different sources while working on their project. The results are presented in Figure 1. Students felt that the instructor was the most useful source of information with 63% of the students indicating that the instructor was an excellent source of information and an additional 22% of the students found the instructor to be an above average source of information. The success of the instructor – student interaction was most likely related to the instructor meeting with small groups of students once a week to discuss their progress. Interaction between project team members was also an effective source of information. Fifty-five percent of the students found this to be an above average or excellent source of information. Interestingly, about half of the students did not discuss their project with students from the other groups even though the majority of students found students in their group a good source of information. The usefulness of the sponsor as a source of information was highly dependent on the project. In about a third of the projects, the sponsor was an excellent source of information.

The next set of questions asked the students to compare the research laboratory experience to the more typical lab manual approach used in their other engineering and science courses. The results are presented in Figure 2. Greater than 75% of the students felt that the research project approach was better or much better than the lab manual approach in learning about a current engineering problem, promoting team work, improving project management skills, and making

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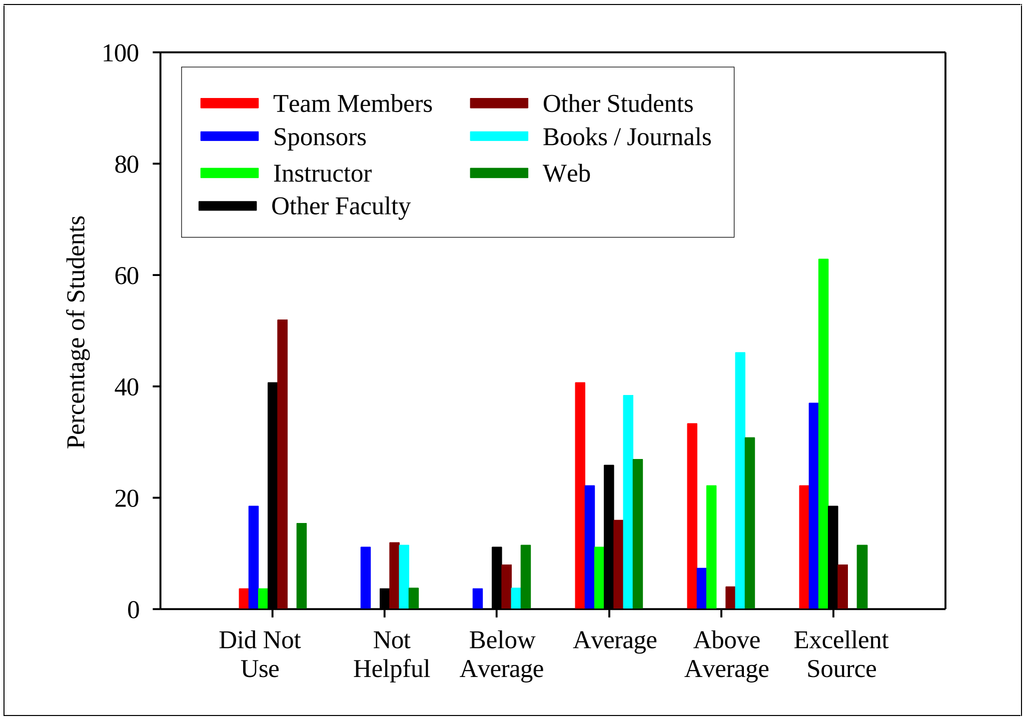

Figure 1. Sources of Information Used by Students in Water Research Projects.

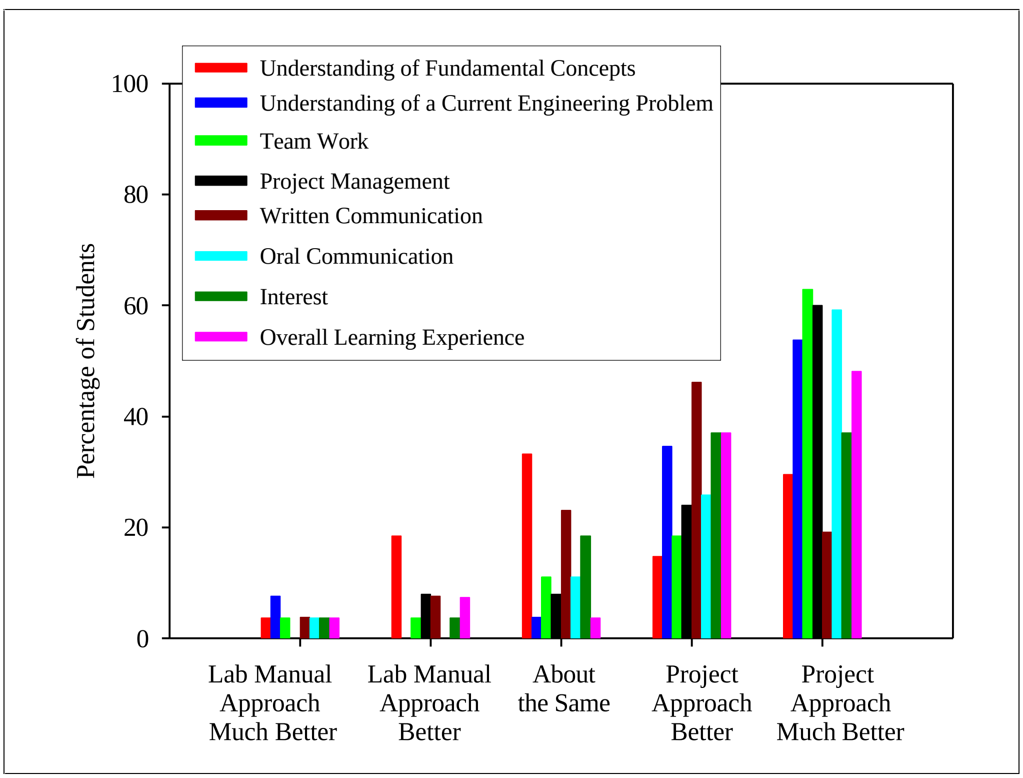

Figure 2. Comparison of Research Project Experience to Lab Manual Approach

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an oral presentation. Also, students indicated that the projects were more interesting and that they provided a better overall learning experience. The one disadvantage of the research project format was student understanding of fundamental concepts. Some students commented that they missed out on learning about a range of water quality topics covered in a more conventional laboratory setting. As a result, more demonstrations have been incorporated into the lecture portion of the course to replace the missed laboratory experience.

The water quality engineering laboratory was designed to incorporate project management and communication skills that are not generally part of other courses. The responses to this set of questions are presented in Figure 3. Approximately 65 % of the students felt that they had improved or significantly improved their skills in dividing up work and planning a multi-person project. About 85% of the students indicated that they had at least one unreliable member in their group. By having to directly deal with this issue in a semester long project, 30% of the students felt they had improved their skills in this area and 22% of the students felt they had significantly improved their skills. Overall, students felt that the project improved their communication skills. Having to present their results to the sponsors and other engineering professionals motivated the students to work hard at preparing and presenting their results.

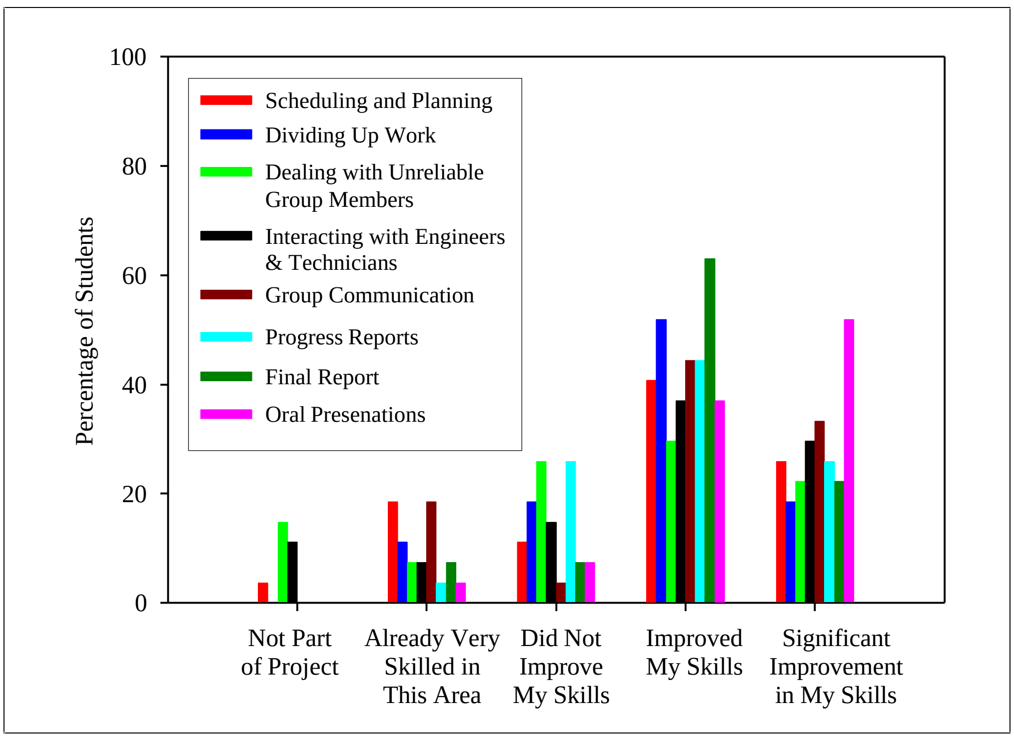

Figure 3. Project Management and Communication Skills Learned

One of the concerns of having students working on different projects is that they will feel that their project requires more work than the other projects. In response to this question, 59% of the students thought that the projects had about the same amount of work, 22% thought that they were slightly unequal and 19% thought that the work required was very unequal. While 60% of

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the students felt the workload was about equal, 80% of the students indicated that their project was more interesting than the other projects (see Figure 4). This suggests that some of the students liked their project more than the other projects even though it required them to work harder than the other students.

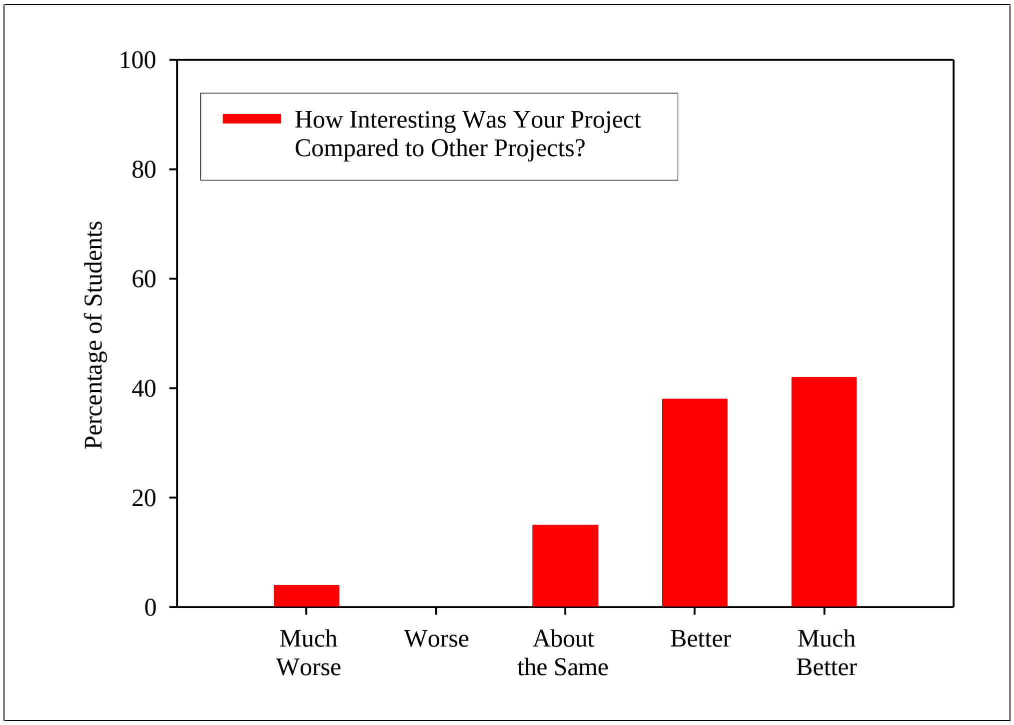

Figure 4. Students Impression of Their Project Compared to Other Projects

The final question asked the students to rank the overall water quality engineering laboratory experience. Given the four choices of excellent, good, fair, and poor, about one-third of the students thought it was an excellent experience and two-thirds of the students rated it as a good experience.

The project sponsors and other practicing engineers who attended the project presentations were asked to evaluate the water quality engineering laboratory experience. Specifically, they were asked to comment on the following topics:

- Effectiveness of the laboratory in preparing students for a career in engineering
- Technical quality of projects
- Quality of oral presentations and written reports

Overall, the comments have been very positive in their support of the projects. For example, one sponsor wrote "I was quite impressed with the presentations made by the students and it was very evident that they had learned much more then textbook theory about water and wastewater

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treatment issues. I think the hands-on, real world experience, that the students gain from undertaking cooperative programs is essential to the learning process." Also, the Manchester Water Department showed their appreciation of the student's effort by presenting the students who worked on the clearwell baffle design project a service accreditation award.

Students were also given a questionnaire to determine if the integrated labs improved their understanding of water treatment and / or analytical method. The results are presented in Figure 5. Because only nine students were concurrently taking both classes in fall 2001, these results provide only a qualitative assessment of the shared activities. In general, most students felt that the integrated labs improved both their understanding of the particular analytical technique and how the data can be used to analyze a water treatment process.

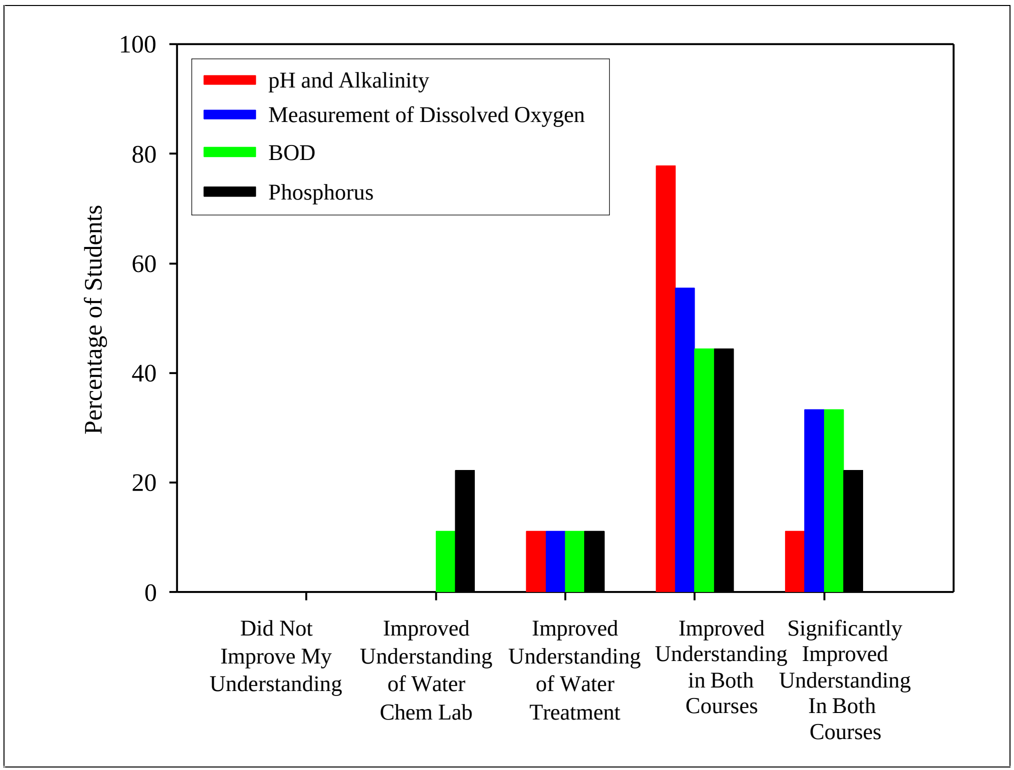

Figure 5. Effectiveness of Integrating Water Chemistry Laboratory and Water Quality Engineering Course

V. Conclusions

The water research projects and the integration of the Water Chemistry Laboratory and Water Quality Engineering courses have been very successful in providing our civil engineering students a thorough understanding of water treatment. Hands-on experience from working on a "real world" environmental research project has provided the students a learning experience not found in most other courses. Continual assessment of the environmental program is being used to constantly improve the quality of the courses. For example, the Water Chemistry Laboratory

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has been more directly integrated into the Water Quality Engineering course so students can analyze the performance of a water treatment unit process using measurements made in the lab. Also, more demonstrations have been incorporated into the Water Quality Engineering course to make up for the laboratory experience missed by working on a semester long project.

VI. Acknowledgements

The authors wish to thank Dr. Peter Weiss for his initial efforts on obtaining funding from NSF for starting the problem solving environmental laboratory at the University of Hartford.

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Biography

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David Pines is an Assistant Professor of Civil and Environmental Engineering at the University of Hartford. He completed his Ph.D. studies in the Department of Civil and Environmental Engineering at the University of Massachusetts, Amherst in 2000. He is actively involved with student projects sponsored by environmental engineering firms, municipalities, and water utilities.

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