Benefits of Service-Learning in Meeting Learning Objectives: Examples from Air Pollution/Environmental Engineering Courses

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Abstract

Service learning is "a teaching method which combines community service with academic instruction as it focuses on critical, reflective thinking and civic responsibility."[1] Dozens of studies have documented many benefits of service learning for students, including improved 1) ability to apply what they have learned in class to "real-world" problems (bridging the gap between theory and practice), 2) critical thinking skills and problem analysis, 3) communication skills, 4) teamwork skills, and 5) sense of civic responsibility and awareness of opportunities for community involvement. Many of these skills are important outcomes of engineering programs, and are evaluated as part of ABET. Service learning also promotes active involvement of students in their own learning, which has documented positive results.

This paper summarizes relevant research regarding the benefits of service learning in achieving the ABET outcomes mentioned above. It also describes examples of 4 service learning projects that the author's students have conducted:

- Operation SMART air quality presentations to elementary school girls for Girls, Inc.;
- Air Pollutant Sampling of Carbon Monoxide, Particulates, and Ozone for the American Lung Association;
- Analysis of Environmental and Economic Impacts of Energy and Water Efficiency Improvements for a Habitat for Humanity House;
- Analysis of Air Pollution Emissions for the Tema Oil Refinery, Ghana.

Effectiveness of the projects in improving student skills in application of knowledge, critical thinking, communication, and teamwork is evaluated, along with impact of the projects on students' sense of civic responsibility. Based on qualitative information from student project reflections, the projects were effective in helping students improve their skills in these areas.

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Introduction

In an age when entire digital libraries are available to students at the click of a mouse button, the role of the college professor as transmitter of information is diminishing. With students proverbially awash in information via the Internet, the role of the faculty member in teaching students to think critically about this information becomes paramount. Faculty members also need to teach students how to apply this information effectively to real-world problems.

One pedagogy that allows faculty members to develop critical thinking skills in their students, including application skills, is service learning. Service learning is "a teaching method which combines community service with academic instruction as it focuses on critical, reflective thinking and civic responsibility."[1] Another well-known definition of service learning states:

> Service learning is a credit-bearing educational experience in which students participate in an organized service activity that meets community needs and reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility.[2]

Unlike volunteer projects, which focus primarily on service, or internships, which focus primarily on learning, service learning project balance the goals of both service and learning. The relationship between service and learning becomes synergistic: "Service, combined with learning, adds value to each and transforms both. Those who serve and those who are served are thus able to develop the informed judgment, imagination, and skills that lead to a greater capacity to contribute to the greater good."[3]

This paper will first summarize relevant research regarding the benefits of service learning related to selected Accreditation Board for Engineering and Technology (ABET) outcomes. It will next describe examples of 4 service learning projects that the author's students have conducted in her own classes. Effectiveness of the projects in improving student skills in application of knowledge, critical thinking, communication, and teamwork will be evaluated, along with impact of the projects on students' sense of civic responsibility. The evaluation will be based on qualitative information from student reflections.

Research Regarding Service Learning Benefits

Dozens of studies have documented many benefits of service learning for students. Many of these skills are important outcomes of engineering programs, and are evaluated as part of the Accreditation Board for Engineering and Technology (ABET) reviews of undergraduate programs. Selected service learning benefits, their related ABET outcomes, and research studies documenting these benefits for engineering students are listed in Table 1. The studies listed used various methods of determining the effectiveness of service learning projects in meeting ABET learning objectives. Some studies relied on faculty observations/judgment [4-6]; other studies relied on student perception of effectiveness as reported in reflections [7,8] or surveys [9-13]. Only one study [14] employed a direct rather than indirect method of measuring gains in skills for service-learning vs. non-service learning students.

Table 1. Studies documenting service learning benefits for engineering students, and related ABET outcomes

Service Learning Benefit	**Studies Documenting Service Learning Benefit for Engineering Students**	**Related ABET Outcome**
1) Improved ability to apply classroom knowledge to "real-world" problems	Borg and Zitomer, 2008 [9]; Budny and Gradoville, 2011 [10]; Goggins, 2012 [5]; Ropers-Huilman et al., 2005 [11]; Sevier et al., 2012 [13]	**(a)** An ability to apply knowledge of mathematics, science, and engineering Also likely, depending on the project: **(c)** An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability **(h)** The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context **(j)** A knowledge of contemporary issues **(k)** An ability to use the techniques, skills and modern engineering tools necessary for engineering practice
2) Improved critical thinking skills	Borg and Zitomer, 2008 [9]; Chang et al., 2011 [4]; Lemons et al., 2011 [14]; Ropers-Huilman et al., 2005 [11]; Sevier et al., 2012 [13]; Talbert et al., 2003 [6]	**(e)** An ability to identify, formulate, and solve engineering problems
3) Improved communication skills	Borg and Zitomer, 2008 [9]; Chang et al., 2011 [4]; Goggins, 2012 [5]; Ropers-Huilman et al., 2005 [11]	**(g)** An ability to communicate effectively
4) Improved teamwork skills	Borg and Zitomer, 2008 [9]; Goggins, 2012 [5]; Ropers-Huilman et al., 2005 [11]; Schaffer et al., 2012 [12]	**(d)** An ability to function on multi-disciplinary teams
5) Increased sense of civic responsibility	Borg and Zitomer, 2008 [9]; Chang et al., 2011 [4]; Dukhan et al., 2008 [7]; Goggins, 2012 [5]; Ropers-Huilman et al., 2005 [11]; Wallen and Pandit, 2009 [8]	**(f)** An understanding of professional and ethical responsibility

Each of the service learning benefits is discussed in more detail below.

1) Improved ability to apply classroom knowledge to "real-world" problems

Since students apply knowledge learned in the classroom to a real-world situation, service learning projects obviously facilitate ABET Outcome (a), An ability to apply knowledge of mathematics, science, and engineering. Because the students address the real-world problems *in context*, they must address realistic constraints in their designs or analyses (Outcome (c)), and understand the impact of their solutions in societal context (Outcome (h)). The real-world projects expand student knowledge of contemporary issues (Outcome (j)), and in many cases will give students practice using the techniques, skills and modern engineering tools necessary for engineering practice (Outcome (k)).

2) Improved critical thinking skills

Service learning projects give students an opportunity to use higher order thinking skills, including application (discussed above), analysis, synthesis, and evaluation. The projects frequently require students to synthesize information learned in various sections of one course, or in multiple courses, in conducting an analysis or designing a solution. In choosing among multiple potential solutions, students may use an alternatives analysis to evaluate the potential solutions. These skills are necessary in solving engineering problems (Outcome (e)).

3) Improved communication skills

Students typically must communicate the results of their analysis or design to the client both orally and in writing, which provides an opportunity to improve communication skills (Outcome (g)). They often communicate with the client during the analysis/design process as well. The reflective component of service learning, which may be oral and/or written, also provides an opportunity to practice communication skills.

4) Improved teamwork skills

Service learning projects are often designed so that students work in teams; this at least partially facilitates Outcome (d), an ability to function on multi-disciplinary teams, although the teams may or may not be multi-disciplinary.

5) Increased sense of civic responsibility

Since students perform a service for a community client, they naturally learn about opportunities for community involvement as part of service learning; reflecting on their experience can lead to an increased sense of civic responsibility. These outcomes fall under ABET Outcome (f), understanding of professional and ethical responsibility.

Other Benefits

Many other benefits of service learning, such as improvement of student satisfaction with college, while worthy, do not relate directly to ABET outcomes and thus are not discussed at length here. A couple of benefits that merit a brief mention are the fact that service learning is a form of active learning pedagogy; it thus promotes active involvement of students in their own learning, which has documented positive results [15-18]. In addition using service learning projects (as opposed to "made-up" case studies, for example) can increase student motivation: the project has a community partner "client" interested in the result [4,5].

Service Learning Project Examples Related to Air Pollution and Environmental Impact Assessment

During the past 3 years, I have used service learning projects to help students learn how to apply the course content to solve real-world problems, as well as build critical thinking skills, communication skills, teamwork skills, and a willingness to contribute to the profession and community. So far, my students have conducted 4 service learning projects in 4 different environmental engineering courses, as summarized in Table 2.

Table 2. Service Learning Project Examples - Air Pollution and Environmental Engineering

Semester	Course	Project Title	Community Partner	Learning Objectives	Classroom Knowledge Applied
Fall 2010	CE 5324 Transportation & Air Quality	Operation SMART (presentations to elementary school girls)	Girls Inc. (Arlington)	1, 2, 3, 4, 5 (defined below table)	Various information about transportation & air quality
Spring 2011	CE 5322 Air Pollution Chemistry & Meteorology	Air Pollutant Sampling	American Lung Association (Ft. Worth)	1, 2, 3, 4, 5	Sampling of ozone, carbon monoxide, and particulates
Spring 2012	CE 5316 Current Topics in Environmental Engineering	Analysis of Environmental and Economic Impacts of Energy and Water Efficiency Improvements	Habitat for Humanity (Ft. Worth)	1, 2, 3, 5	Life cycle analysis software and methods
Fall 2012	CE 4350/5328	Analysis of Air Pollution Emissions	Tema Oil Refinery (Ghana)	1, 2, 3, 4, 5	Air pollutant emissions estimation, dispersion modeling, & control technology selection

1. Apply classroom knowledge to a real-world situation.
2. Apply critical thinking skills (application, synthesis, evaluation).
3. Improve oral and/or written communication skills.
4. Practice teamwork skills.
5. Increase sense of civic responsibility and awareness of opportunities for community involvement.

Students in the courses are primarily environmental engineering students, although a significant number are environmental science students. In the Transportation and Air Quality, typically about half of the students are specializing in Transportation Engineering. Although 3 of the courses were exclusively graduate courses, the service learning objectives and ABET-related outcomes are still relevant; just like undergraduates, graduate students need to be able to apply classroom knowledge to real-world problems, think critically, communicate effectively, and work well in teams. Each of the projects is discussed in more detail below.

1. Operation SMART Air Quality Presentations to Elementary School Girls for Girls, Inc.

In this project, teams consisting of 5 UTA students in my "Transportation and Air Quality" graduate course were responsible for developing and presenting 45-minute workshops to 20 girls grades 1-6 (ages 6-12) as part of Girls Inc. Operation SMART. The 3 teams each presented one workshop for Arlington, Texas, Girls Inc., for a total of 3 workshops on 3 successive weeks.

The workshops were supposed raise the girls' curiosity about careers in science, math, and engineering, as well as teach the girls about transportation and/or air quality, primarily through hands-on activities. I provided a selection of hands-on activities, obtained primarily from government and non-profit organization web sites, from which the teams could choose. Students started the workshops with a brief overview of what transportation and/or environmental engineers do. Next, the UTA students facilitated the following hands-on activities (one activity per week):

- Air quality activity: "'Hole'-y Ozone! It's the CFCs!"
- Transportation activity: "Balloon-Powered Car"
- Transportation and air quality activity: "When a Car Coughs: Taking a Close Look at Vehicle Exhaust"

Girls Incorporated of Tarrant County (www.girlsinctarrant.org/) is a nonprofit youth service organization dedicated to inspiring all girls to be "strong, smart, and bold" and increase the social competence of boys & girls. Girls Inc. sponsors Operation SMART (Science, Math, and Relevant Technology) to change girls' attitudes about science, math and relevant technology. The girls attend weekly Operation SMART meetings and participate in hands-on activities that are geared toward increasing their knowledge and confidence in each area.

2. Air Pollutant Sampling of Carbon Monoxide, Particulates, and Ozone for the American Lung Association (ALA)

Working together, the American Lung Association (ALA) and graduate students enrolled in my Air Pollution Chemistry and Meteorology course conducted a study of the air quality at four local area elementary schools during Spring 2011. The schools, identified by the ALA Dallas/Fort Worth office, fell in zip codes in the Dallas/Fort Worth area that had some of the most frequent pediatric emergency room visits for respiratory diseases.

4 teams of 3 graduate students each sampled ambient air at each designated elementary school in the morning when school began and afternoon when school ended on 3 different days. Concentrations of ozone, particulate matter, and carbon monoxide were measured using hand-held samplers, as well as wind speed, measured using a hand-held anemometer. Students were given instructions in class concerning proper use of the samplers and anemometer.

To help students improve their communication skills, they were given handouts with tips for effective presentations and writing. At the conclusion of the project, students gave oral presentations to the ALA representative summarizing their results. They also summarized their results in written reports, which were provided to the ALA. The ALA was interested in making the information available to appropriate representatives and senators in the state legislature, to underscore the importance of achieving good air quality for children in their district. The ALA also wanted to determine whether the sampling would support ordinances restricting school bus idling.

3. Analysis of Environmental and Economic Impacts of Energy and Water Efficiency Improvements for a Habitat for Humanity House

Graduate students in "Current Topics in Environmental Engineering" conducted a life cycle analysis of the environmental and economic impacts of efficiency improvements for a family home in the U.S., built by Habitat for Humanity. Habitat for Humanity is a non-profit that builds affordable houses with people in need.

The students first estimated environmental impacts for a typical Habitat home as a baseline, using EIO-LCA life cycle analysis software developed by Carnegie Mellon, and available free of charge via the Internet. We had discussed general principles of life cycle analysis in class, along with specifics of the EIO-LCA software, so students were able to apply this knowledge. Next, the students conducted a web search to find technologies for saving energy and water in houses. They chose $4000 of these improvements for the Habitat house, and used the software to estimate environmental impacts for the improved house. Finally, students conducted a cost analysis to determine the payback period for the efficiency improvements, and the cost savings over the lifetime of the home. We had discussed life cycle cost analysis in class, so students were able to apply this knowledge.

The results of the analyses were compiled and given to the local Habitat for Humanity chapter, Fort Worth's Trinity Habitat for Humanity. This provided Habitat information about the environmental and economic impact of installing efficiency improvements in their houses.

4. Analysis of Air Pollution Emissions for the Tema Oil Refinery, Ghana

Given the global nature of much engineering work now, I wanted to give my students experience working with an international project. I contacted one of my former Ph.D. students, Dr. Benjamin Afotey of Kwame University, Ghana, about potential projects in his country. He suggested Ghana's government-owned Tema Oil Refinery (TOR) as an interesting air pollution source.

Undergraduate and graduate students in "Fundamentals of Air Pollution" were thus charged with determining whether the Tema Oil Refinery in Ghana poses a threat to human health. In conducting the project, students applied information covered in various course units concerning emissions estimation, dispersion modeling, and particulate and gas control technology design. Students were first to estimate air pollutant emissions from various refinery processes using emission factors. Next, students were to estimate ambient concentrations of pollutants downwind from the plant under various meteorological conditions using dispersion modeling. Students then compared estimated ambient concentrations with health effect standards, to determine whether emission control technologies were needed. Finally, students were taught how to use a decision-making matrix, and told to construct a matrix to choose among pollution control alternatives. Students then estimated sizes of pollution control technologies. The results of the analyses were presented to Dr. Afotey to provide to oil refinery personnel.

Student Reflections on Project Effectiveness in Meeting Selected ABET-Related Objectives

As mentioned above, 3 methods are most often used for assessing the effectiveness of service learning projects in achieving student learning objectives: faculty observations/judgment, student perception of effectiveness as reported in reflections, and student perception of effectiveness as reported in surveys. This paper uses information from student reflections.

For all 4 projects, students answered written reflection questions about what they learned from the project. Reflection questions used for each project are listed in Table 3. Each project is identified by its client, as the most succinct way of identifying the project.

The Girls, Inc. project was the first one I conducted. In subsequent semesters, I shortened the list of reflection questions. The earlier question lists asked students to comment specifically on the project's impact on certain skills, such as communication and teamwork. The later question lists simply asked more generally what students learned from the assignment.

Table 3. Project Reflection Questions

Project Client	Reflection Questions
Girls, Inc.	1) WHAT? **Describe**: In 2-3 sentences, briefly, the service performed. 2) SO WHAT? **Examine** some of the following questions: • What was the significance of the service? • What did it mean to you personally? • What did you learn that could enhance your professional career? • Did the project help you develop communication skills? Why or why not? • Did the project enhance your understanding of course content? Why or why not? • What skills and knowledge learned in the classroom did you use/apply? • What skills or knowledge did you lack? 3) NOW WHAT? **Contemplate** some of the following questions: a. What insights did you gain that might assist you in your career? b. What is the connection of this experience to your future? c. What did this experience teach you about community involvement and professional responsibility? d. What is the relationship of your service experience to the big picture (societal changes)? e. How can you best use what you've learned?
American Lung Association	• How did this project enhance the course content? • What did you learn about oral and written communication skills? Teamwork? Professional development? Yourself? How will you use this knowledge in the future? • What will the project mean for the ALA? For the community? • What were the most difficult and satisfying parts of the project? • What changes should be made in the project to improve it for students in future semesters?
Habitat for Humanity and Government of Ghana	1. How will this assignment help address community needs? 2. What did you learn from this assignment? 3. How can you use what you learned in this assignment in the future (in your career or in community service)?

Tables 4-8 highlights student responses to the reflection questions that relate to the 5 service learning benefits/objectives discussed earlier. Student responses that the author judged to be representative are included in the tables, as well as those that the author found to be particularly meaningful/insightful or interesting. In Table 5, the thinking skill to which the comment relates has been added in parentheses.

The comments in Tables 4-8 are all positive, because in no cases did students state that the project negatively or neutrally impacted their skills. Students' failure to mention an impact, however, probably implicitly indicated that it was not significant. For example, in responding to the question "What did you learn from this assignment?", if a student did not mention "how to function in a team setting", then improved teamwork skills were likely not a significant project outcome for that student. In fact, the only project for which student reflections mentioned teamwork was the ALA project. The ALA project was the one that involved the most teamwork, and the only project in which the reflection questions specifically asked about teamwork.

No attempt was made to quantify how many students mentioned various benefits, given the different formats of the reflection questions for different projects. Tables 4-8 thus provide qualitative information only. Student surveys can provide quantitative data concerning perceived project impacts; although surveys were not used in the classes discussed in this paper, they will be used in future courses.

For some of the projects, students were provided information in class to help them develop oral and written communication skills (tips on effective public speaking and writing) and evaluation skills (construction of a decision-making matrix). Student comments in Tables 4-8 indicated that this information was helpful. Providing students guidance to facilitate their skill development likely does make service learning projects more successful. In the future, I hope to provide students with information about working effectively in teams as well.

The comments demonstrate that a portion, at least, of students in the courses believed that they learned skills from the service learning projects that would be valuable in their professional careers. In the area of critical thinking skills, student comments described development of analysis, synthesis, and evaluation skills that would be useful to them professionally. One student commented that the communication skills learned in the service learning project would help him/her in the public meetings aspect of his/her current job. The comments concerning civic responsibility were particularly encouraging. Although engineers (civil engineers in particular) deal with a variety of topics that impact the public, engineers often shy away from civic involvement, believing that they should focus their attention only on technical concerns. One student commented that he/she had learned that engineers <u>should</u> be engaged in the community, in this particularly articulate comment that bears repeating:

> This project taught me that our community is open to learning and that we as engineers have a duty to educate the general public about the adverse affects that their daily actions/choices can have on our current and future society. Often civil engineering projects/endeavors impact a vast portion of our society yet the many that we affect do not understand or know

> what or why we do what we do. It is up to us engineers to educate the public about our careers and related topics so that they, along with decision makers, can make educated decisions.

Along similar lines, another student wrote that he/she would now have the knowledge to intelligently contribute to city/town meetings. Another student even commented that the project led him/her to think more seriously about a job that would involve community service, such as a position with a non-profit. Finally, and likely most importantly, the comments concerning civic involvement indicate that the students learned personal efficacy - that their contributions can make a difference. As one student wrote: "I have contemplated joining Child Rights and You for long but I have not made the step till now. I was feeling too young to work in these programs but now I found out any contribution will help."

Table 4. Student Reflections on Project Benefits Concerning ***Application of Knowledge to Real-World Problems***

Project Client	Student Comments
Girls, Inc.	This experience also made me to realize a better picture of the course because to simplify the concept of ozone I needed to summarize what I learned in the class in a way that delivers the concept without sounding complicated.
American Lung Association	The Service Learning Project provided an opportunity to apply classroom knowledge to a real world situation…. The project also gave me an understanding of how difficult it is to assess pollutant levels in ambient air, and revealed first hand the significant amount of variability in meteorological conditions and how they can affect pollutant transport. The project gave us the opportunity to apply the knowledge that we have learned in the class. Using the devices to measure the meteorological parameters in the field was very helpful to understand the material practically. Considering the meteorological parameters in the study also helps to understand the relationship between the pollutants' concentration and the parameters. Service learning is particularly important for engineering students because often fresh graduates are blamed that they do not have enough practical knowledge. Service learning could decrease the gap between the academic and practical knowledge. This is a new experience that I might work on when I go back to my country (Kuwait) and I will apply what I learned to evaluate air quality especially with oil sector around exploration and production areas.
Habitat for Humanity	I learned how to apply previously obtained knowledge (from economics to engineering classes) to real-world projects, especially with regard to applying that knowledge to the long-term environmental impacts of efficiency improvements made to systems.
Government of Ghana	This assignment was very helpful in fully understanding all of the concepts learned in the classroom and a good learning experience in the application of these concepts. One of the major things I learned was how to utilize the dispersion modeling calculations and apply it to a project. In this assignment I learned how to analyze a "real-world" case of air pollution emissions and suggest controls to reduce emissions to an acceptable level… Overall, the assignment helped me to understand how the various topics that we have studied this semester come together and can be used to solve a real-world problem.

Table 5. Student Reflections on Project Benefits Concerning ***Critical Thinking Skills***

Project Client	**Student Comments**
American Lung Association	The project required me to pull together a variety of concepts presented throughout the course, and to synthesize the information in order to analyze our data. (synthesis, analysis) Many factors effect air pollution such as wind speed, wind direction, atmospheric stability, and other local air factors like urban heat island. With this project, we were able to consider all of those factors while studying the air quality at our assigned schools. (synthesis)
Habitat for Humanity	This study helped us to figure out how to consider different parameters in making a decision through facing different options and evaluating their advantages and disadvantages. (evaluation) It will also aid in my decision making process as a professional.
Government of Ghana	…it was an excellent exercise in producing solutions to a problem that could very well be solved through various methods…. In order to … come up with a solution, a decision-making matrix had to be created to adequately explain why we chose the option that we did. (evaluation) I also learned how to use engineering judgment to create a decision-making matrix to compare different solutions, or in this case pollution control devices, in order to choose the best solution/design for a project. (evaluation) This case study was a practical application of what was learned in this course and it further familiarized the process of determining the needed air pollution control technologies. This process can also be implemented in all aspects of civil engineering: alternatives will always need to be analyzed and critical thinking used. (analysis, evaluation) …the detailed analysis and problem solving skills are and will continue to be used on a daily basis. (analysis)

Table 6. Student Reflections on Project Benefits Concerning ***Communication Skills***

Project Client	Student Comments
Girls, Inc.	I think that this experience helped develop my communication skills in new ways … having the ability to convert technical, scientific information into something that your audience can relate to and understand will be very helpful in the future. I think professionally it reminded me of the importance of connecting to audiences…. Being a professional engineer requires a lot of presentation skills, in company or out and having done this presentation was a great practice in my point of view. Most of my work consists of designing new roadways. These types of projects always involve the public which means lots of public meetings. Many of the issues that arise throughout the design process for roadways are technical in nature but the public often does not have the back ground education to fully understand the details of the problem/solution. This project has forced me to pay particular attention to my audience and their ability to understand the information I am presenting. This experience has helped me to be able to consider my audience's level of education and find effective ways to convey information that is technical in nature but yet interesting and understandable by someone without the background knowledge.
American Lung Association	…the writing assignments and writing tips helped me to evaluate my current skills and point to areas that need improvement…. The public speaking tips on how to clearly and effectively present information were also helpful and are something I can use to prepare for future presentations and meetings. By working with peers, professionals, and the community, this was an opportunity to improve my public speaking skills, management and organization, and writing techniques. Oral and written skills can be improved by practicing; it was a great chance to focus on these skills through our project and practice regularly…. For oral and written communication skills, I learned from my writing to be simple and clear in my ideas, know my audience and write on basis of how much they know, and write sentences that are related to the main point that I want to present. I learned about the importance of rehearsing before the actual presentation…. I learned that the audience wants me to succeed as much as I do. Thinking about this while preparing for the presentation will help me overcome the nervousness associated with it. As for report writing, I realized that figures and tables play an important part in preparing a good report. Having them in the report makes it easy to understand.
Habitat for Humanity	This assignment enabled me "to communicate effectively with clients, investors, and others within the construction industry, and be capable of articulating how decisions made from design conception through construction and occupation to building renovation and demolition affect the energy consumption and carbon footprint of the built environment."
Government of Ghana	If I go to work at a consulting firm, … I will have the experience of writing up a multi-page report describing results of a case study.

Table 7. Student Reflections on Project Benefits Concerning ***Teamwork Skills***

Project Client	Student Comments
American Lung Association	I mentioned before that I have the tendency to take over projects. It was always the thought that "if you want it done right, do it yourself." With my group, I knew I could rely on them and trust their decisions. We worked great as a team and used each other's knowledge and experience…. I think that this project has set me up to be better prepared for a career in my field. For teamwork, … I learned to respect my friends' opinions…. In the future … when I work with different people, I will follow the same procedures that we did such as working plan, sharing data, respect each other …. …it helped me to know the importance of communication among the team members for better performance…. I learned that my greatest strength was to work in a team. While this was not the first team project I've worked on, it was the first team project I've been involved with that occurred outside of school. In this case, effective teamwork was more important because we had to coordinate our schedules with the sampling and decide how the written portions would be divided, often all through e-mail. I think this will benefit me professionally because projects that occur in the workplace will be in this manner. There will be no teacher to coordinate for us….; we'll have to arrange everything ourselves and work together to get it all done.

Table 8. Student Reflections on Project Benefits Concerning ***Civic Responsibility***

Project Client	Student Comments
Girls, Inc.	I have contemplated joining Child Rights and You for long but I have not made the step till now. I was feeling too young to work in these programs but now I found out any contribution will help. I think that it is important to "step out of the comfort zone" and become involved in community service projects such as this. This workshop taught me that internal satisfaction lies when you actually work for the betterment of others…. Donating one's time to … community service (learning) projects is a win-win situation for all participants. This project taught me that our community is open to learning and that we as engineers have a duty to educate the general public about the adverse affects that their daily actions/choices can have on our current and future society. Often civil engineering projects/endeavors impact a vast portion of our society yet the many that we affect do not understand or know what or why we do what we do. It is up to us engineers to educate the public about our careers and related topics so that they, along with decision makers can make educated decision.

American Lung Association	As I continue to pursue my professional career goals, this project has given me new perspective on careers that could assist the community and the environment. In the past I have considered pursuing a job with more of a service component. Working on this project has re-enforced the idea of working for a non-governmental organization or in a governmental position. I believe the skills and knowledge that I have developed would be put to good use in a service-oriented job that would give me a greater sense of job satisfaction. As I am planning to be a professor in one of the universities in the future, I will make the service learning technique the main part of the curriculum that I will teach, so many services can be done for the communities from the students and it will be beneficial for both sides. The satisfying part about the project is the knowledge that the information collected by us is going to be used for the benefit of the community. Also the fact that we got the opportunity to take part and make a difference is very gratifying.
Habitat for Humanity	It is the duty of engineers to the customers to utilize energy efficiency scenarios in construction by choosing appropriate building materials…. Doing this assignment provided an opportunity to demonstrate different ways of reducing community needs such as energy and water and designing houses more sustainable….
Government of Ghana	I learned that no matter what place or country you live in the world, an environmental engineer will use the same processes or general methods to design pollution control devices with the health and safety of the human population at the top of their concerns. I would also have the knowledge to intelligently contribute to city/town meetings discussing ideas such as construction of new facilities that would serve as a point source for pollutant emissions and air quality in general. In the future I will be able to inform others on the harmful effects of air pollution, and strive to do my part in helping to reduce the emissions. This newfound knowledge of air pollution will improve my awareness of the problem in my daily life, and give me the opportunity to inform my colleagues about the issue. ….I will be more conscious about the global impact of some of my design work. By learning the basis of how some pollutants affect the atmosphere and the health of others, I will try to design ways to provide the necessary transportation while reducing emissions. This will be done by looking at intelligent transportation systems and cleaner transportation systems. Bangladesh is a developing country and it is clear that we have not only natural gas but also oil reserves and the population of the country suffers most from asthma, heart diseases, and cancers and so on. In future I can help my country to reduce these types of problems.

Conclusions and Recommendations

Based on qualitative information from student project reflections, service learning projects in air quality and environmental engineering at UT Arlington were effective in helping students improve their skills in application of knowledge, critical thinking, communication, and teamwork, as well as increase their sense of civic responsibility. In future courses, student surveys will be used, along with reflections, to provide a more quantitative assessment of the impact of service learning projects on student skills.

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