Integration of service learning to teaching thermodynamics

Dr. Farshid Zabihian, California State University, Sacramento

Farshid Zabihian, Ph.D. Assistant Professor Department of Mechanical Engineering California State University, Sacramento

Education: Ph.D., Mechanical Engineering,Ryerson University, 2011 M.S. Mechanical Engineering, Iran University of Science and Technology, 1998 B.S. Mechanical Engineering, Amir Kabir University of Technology, 1996

Authored or coauthored more than 70 papers in Journals and peer-reviewed conferences.

©American Society for Engineering Education, 2020

INTEGRATION OF SERVICE LEARNING TO TEACHING THERMODYNAMICS

Farshid Zabihian

California State University, Sacramento

Sacramento, California, U.S.A.

Abstract

Unlike many other engineering subjects, thermodynamics deals with abstract ideas and this makes the course very challenging for many students. Modern and innovative educational technologies and methods have been employed to address this problem including using flipped classes, active learning, and integration of simulation software tools. The integration of service learning is another tool for this purpose. Service learning is an experiential learning approach to foster students' deeper understanding of intended academic contents of a course through activities involving community partners to address social needs and problems. It is typically in the form of either direct service or project-based activities. Service learning as a pedagogical tool is gradually gaining momentum in engineering programs across the country. In this paper the efforts of the author to introduce service learning to an undergraduate thermodynamics course will be presented. For this purpose, communications with the following museums were initiated: Powerhouse Science Center, Roseville Utility Exploration Center, and Aerospace Museum of California. These communications led to identification of the topics of interests for the community partners that were related to thermodynamics and energy. The objective of these projects was to demonstrate thermodynamic- and energy-related concepts to the public audience in general and elementary and middle school students in particular. The students could choose a project from a list of projects that museums were interested in or they could initiate their own project. The staffs from community partners visited the class and explained some of the projects and their general expectations to students. The students prepared a proposal for the project which then was shared with the museum contact persons for their comments and approvals. The students implemented their team projects and prepared a report. Then, they presented their projects to museum staffs and handed over the project to them with the instruction on how to use it for educational purposes. Due to the unexpected university closure, most teams lost two crucial weeks to finalize their projects. While this caused some stress and discomfort, the author's personal interview with the students after they presented their work to museums indicated general satisfaction and a sense of accomplishment. The feedback from museum staffs was very positive and they expressed willingness to continue the collaboration. The addition of service learning to the course was an overall success. However, there are several factors to take into account before full and permanent integration of the approach, including

- providing the financial support to teams at the beginning of the semester
- streamlining the involvement and communication with museums
- better communication of pedagogical objectives and project topics to students
- better integration of projects to course contents
- balancing the service learning component with the overall course load

- adding some flexibility to the schedule
- diversifying community partners and projects

Introduction

Understanding social complexities and awareness of social and cultural issues are essential skills for engineering program graduates [1]. These skills are outlined by the Accreditation Board for Engineering and Technology, Inc. (ABET) in at least two of the student learning outcomes in "General Criteria for Baccalaureate Level Programs", Criterion 3, as follows [2]:

- Outcome 2: "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors."
- Outcome 4: "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts."

Various experiential learning strategies in general and service learning in particular are some of tools in educators' disposal to teach these skills [3]. Service learning is an experiential learning approach to foster students' deeper understanding of academic contents and expected learning outcomes of courses through activities involving community partners to address social problems and community needs. An essential part of service learning is "structured opportunities for reflection" [4]. While some aspects of service learning are similar to other community-based activities, such as community service, and experiential learning approaches, such as internship, there are some important distinctions. The difference between service learning and community service can be described primarily by highlighting two words in the above definition of service learning: structured learning and reflection. While community service is to address needs of a community, it lacks these two essential components of service learning. On the other hand, service learning and internship are both related to practical experience and both can be on- or off-campus with collaboration with non-profit, government, or businesses entities. However, they are different since the latter is not concerned with community needs and is focused mostly on skills students need for their careers. Moreover, typically internships are standalone unit-bearing activities while service learning is just one of the pedagogical tools used by an instructor in a course.

A major challenge for any service learning practice is the fine alignment between learning outcomes for the course and community outcomes [5]. The community outcomes are defined by the added values for community partners to respond to community needs and social problems [4]. The mutual benefits for educational institutions and community partners stand in the center of any service learning activity. In the educational side, service learning can help in achieving the following learning outcomes: specific field-related outcomes, personal growth, interpersonal outcomes, and general positive college experience [4]. In the community partner side, service learning can help to bring a fresh energy to current practices and development of new ones as well as access to new resources [4].

Service learning approach not only can benefit students, community partners, the public, and faculty, but also can directly help many universities to achieve their mission statements and the goals of their strategic plans. For example, at California State University, Sacramento University, this approach is perfectly aligned with the University Mission to "prepare students for leadership, service, and success" and to "commit to engaging the community by building enduring partnerships that strengthen and enrich the region" [6]. Also, one of the strategic goals is to "incorporate and expand experiential learning opportunities (e.g., internships, service learning)". Two of the "indicators of achievement" of this goal are "increase student participation in credit bearing internships and service learning projects by 20% by 2020" and "increase the number of formalized partnerships by 20% by 2020" [6]. The engineering curriculums have an untapped potential to help in achieving these goals.

There are limited studies available in the literature on the effectiveness of service learning pedagogy particularly in engineering courses and programs [3]. Warren (2012) [8] analyzed 11 research studies on the effectiveness of service learning in improving learning in a variety of fields, including communication, English, sociology, psychology, political science, and pharmacy. These studies utilized a wide variety of tools to measure student learning. The results indicated that regardless of measurement tools, service learning improved student learning. This type of study is even more limited in engineering education [7]. However, it has been shown that students from different backgrounds, cultures, and learning styles can hugely benefit from service learning experience [9-12].

Service learning as a pedagogical tool is gradually gaining momentum in engineering programs across the country [7]. Service learning is typically in the form of either direct service or project-based activities. The latter approach is dominant in engineering service learning. A quick review of published articles in engineering service learning indicates that great majority of the utilization of service learning in engineering education is in the form of implementing engineering projects for underprivileged communities. A rare exception in this regard is Traum et al. (2013) [13]. While technically speaking these projects can be categorized as service learning, they are not effective in engaging students in understanding social problems and their complicated nature. Furthermore, they are typically implemented as independent projects or as senior design projects (capstone projects) and they are not integrated into learning outcomes of a course. In this paper, the efforts to integrate service learning to a junior level undergraduate thermodynamics course will be presented.

Thermodynamics and service learning

The author's first exposure to service learning as a pedagogical tool was when he participated in a faculty learning community (FLC) called "Service Learning, Novice" offered by California State University, Sacramento's Community Engagement Center (CEC). This led to the integration of service learning into Thermodynamics, a core course for mechanical engineering students and a very popular elective course for civil engineering students. With typically a high student enrolment, Thermodynamics is a high demand core course with a low rate of student success compared to other engineering courses.

Unlike many other engineering subjects, thermodynamics deals with abstract ideas and this makes the course very challenging for many students. The difficulty in conceptualization and visualization of thermodynamics concepts make traditional teaching methods ineffective for many students. Modern and innovative educational technologies and methods have been employed to address this problem. Some of these methods include using flipped classes, active learning, research-based teaching [14], and integration of simulation software tools [15-16] to help students with different learning styles to get engaged and actively involved in their learning process. The integration of service learning is another tool for this purpose. To the author's best knowledge, this course is the first course in the College of Engineering and Computer Science at California State University, Sacramento that is embracing this teaching-learning pedagogy and can pave the road for the introduction of the approach to other courses in the college.

The project-based service learning is used for this course. In these projects, students work with community partners (non-profit and/or governmental entities) to raise public awareness on energy-related issues and address the needs of community partners. In this project-based service learning experience, students have a limited interactions with community partners. In essence, community partners are "clients" who provide students with the scope of projects and constraints for their design.

The objective of these projects is to provide the students with an opportunity to apply their overall engineering knowledge, especially what they learn in the course, combined with their innovation to describe a real world problem to public audience. In these projects, the students will come up with demonstration, presentation, experimentation, and/or poster projects to explain thermodynamic- or energy-related concepts to the public, particularly elementary and middle school students. They can present their work as an exhibition in a museum and/or in the college open house. Alternatively, they can visit a school science class to present their work.

Preparation

The author initiated communication with various community partners to evaluate if there is a common interest for partnership long before the intended course started. With help from the Partnership/Program Coordinator at Community Engagement Center (CEC), he was able to establish partnership with three public museums in Sacramento area: Powerhouse Science Center, Roseville Utility Exploration Center, and Aerospace Museum of California. These communications led to the identification of the topics of interests for the community partners that were related to thermodynamics and/or energy. Also, the project implementation approaches were coordinated. With collaboration with the CEC, the new "Academic Internship/Service Learning (IN/SL) for Community Partner Agreements" were signed with Aerospace Museum of California and Powerhouse Science Center by the two parties. For the case of Roseville Utility Exploration Center, the existing partnership was renewed.

Upon completion, the systems are placed at the community partners' facility where it will be accessible to their audience. The projects are funded by community partners. The projects are designed and manufactured in the College of Engineering and computer Science facilities. Access to the machine shop is available for any machining work that may need to be performed. The community partners also provide supports based on their available resources.

To demonstrate the diversity of projects, a few of the projects that some community partners have expressed interest on are as follows:

- Develop projects that would help illustrate
  - hydroelectricity principles and how hydro power is converted to electricity.
  - the power grid and how various energy sources go into the mix.
  - how electric vehicles operate compared to combustion engines and their environmental impacts.
  - energy use and carbon output for electric vehicles vs combustion engines.

  - how electric utilities deal with varying loads at different times of a day.
  - how a natural gas power plant works and how it is used to balance out the grid demand.
  - the challenge of voltage vampires in homes. How is it that a microwave clock draws more power over the course of a year than cooking time over the course of a year? How do TV's and DVR's use power in standby mode so that they can turn on quicker?
  - how utilities are using bio solids to reduce impact on landfills and also generate energy.
  - how insulated windows (and reflective film in windows), insulation, wall construction, etc. work to save energy.
  - the challenge of flushable wipes, fats/oils/grease (FOG), roots, etc. in a wastewater collection system.
- Design and build a portable table top model that illustrates principles around solar gain and why shade trees can reduce energy use for cooling.
- Design and build a portable table top model that would illustrate wind power.
- Develop projects that would illustrate solar power – especially for residential use.
- Develop a table top model that would illustrate the water and wastewater treatment processes.
- Develop a model that demonstrates the importance of gravity in water delivery and wastewater collection systems.
- Develop a model that illustrate how new bio-digesters that are being installed in the wastewater treatment plant work. How are they creating fuel from bio solids?
- Develop a table top model that illustrates how water is delivered from the distribution system to homes, and then how it is split at the home to interior and exterior uses.

The author also collaborated with the Services to Students with Disabilities (SSWD) and Accessible Technology Initiative (ATI) at California State University, Sacramento to make sure that all developed materials and activities are properly accessible. All three public museums, in which the initial partnerships have been established, have their own accessibility policies in place. These policies were obtained and compared to the university's accessibility policies to make sure that they are compatible. In case of any discrepancies, they were addressed before start of service learning activities.

Furthermore, as noted earlier, the service learning activities involve a variety of activities including demonstration, presentation, experimentation, and poster projects. So students with disabilities have various options to choose their project from that suits their unique circumstances. Moreover, there are alternative activities to replace the service learning component if students have legitimate reasons, including disabilities that prevent them from actively engaging in service learning. The instructor works with individuals in a case by case basis to make sure their particular needs are met while the intended learning outcomes are achieved.

Implementation

The objectives of service learning are reflected in the service learning outcomes that are added to the course syllabus as follows:

"After this course, the students should be able to:

- develop a stronger connection to the course content, the major, and the field of study by applying their knowledge in a real world setting.

- solve a real world problem with real "clients" and needs.
- develop a sense of social responsibility.
- develop a broader understanding of the applications of the course content.
- develop teamwork skill.
- effectively communicate complex engineering/scientific topics to the public.
- explain knowledge of contemporary energy-related issues."

The class is divided into separate teams. Each team is composed of 4-5 students. First, they identify the topic of their project. The students can choose a project from a list of projects museums are interested in or they can initiate their own project. Based on their interest, students can visit the community partner museum/exhibition and possibly meet their staffs. Typically the staffs from community partners also visited the class and explained some of their projects and their general expectations to the students.

The next step is to prepare the proposal. The students prepared a proposal for their project which is then shared with the museum contact persons for their comments and approvals. Some teams met with the staffs to properly communicate the expectations and limitations. The students should incorporate the recommendations provided by the partners and the instructor into their proposal before it can be approved. They may be also required to arrange a meeting with the community partner staffs to accommodate their concerns. After approval of the proposals, they implement the proposed project. The next step is to prepare the interim report. In the interim report, they present the current status of the project, the challenges, the ways to address those challenges, the actual progress in the project compared to the expected progress, and a complete literature review. After the completion of the project, students present their demonstration to the class and to the staffs of the community partners to receive the final approval to present their project in an exhibition/event. After their presentation, in the final report they will present everything they did, learned, and achieved during the implementation of the project including reflection on the service learning aspects. Finally, they handed over the project to the partners with the instruction on how to use it for educational purposes.

The following general timeline is used for student projects:

- Team selection: Week 2
- Topic selection: Week 4
- Proposal: Week 6
- Interim report: Week 9
- Presentations: Week 15 (determined in a case by case basis in coordination with the community partners)
- Final report: Week 15

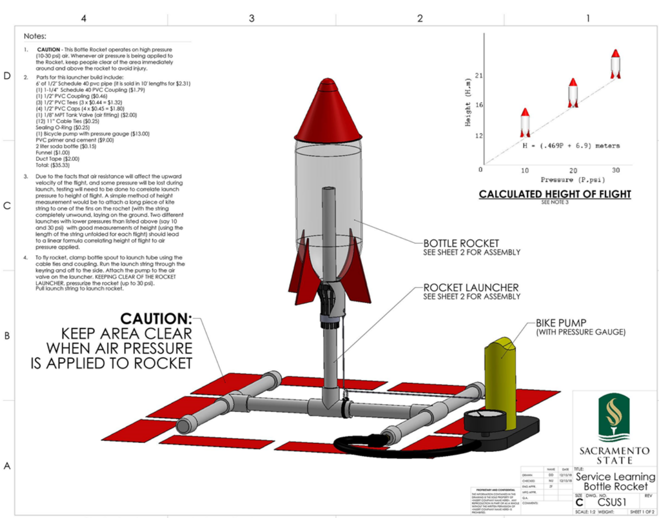
The student grades are determined by considering the following items: proposal 20%, interim report 15%, exhibition presentation 40%, and final report 25%. The service learning component was 20% of the final grade. As described in the previous section, the diverse nature of possible projects and the variety of available activities provide the instructor with various tools in his disposal to accommodate students with different learning styles. Similarly, students with different backgrounds, cultures, and learning styles should be able to find and take advantage of various projects that match their needs and preferences.

Results

After the introduction of the service learning component of the course to the class and going through the project selection process, the following projects were finalized between the student teams and the community partners:
Science Center, Roseville Utility Exploration Center, and Aerospace Museum of

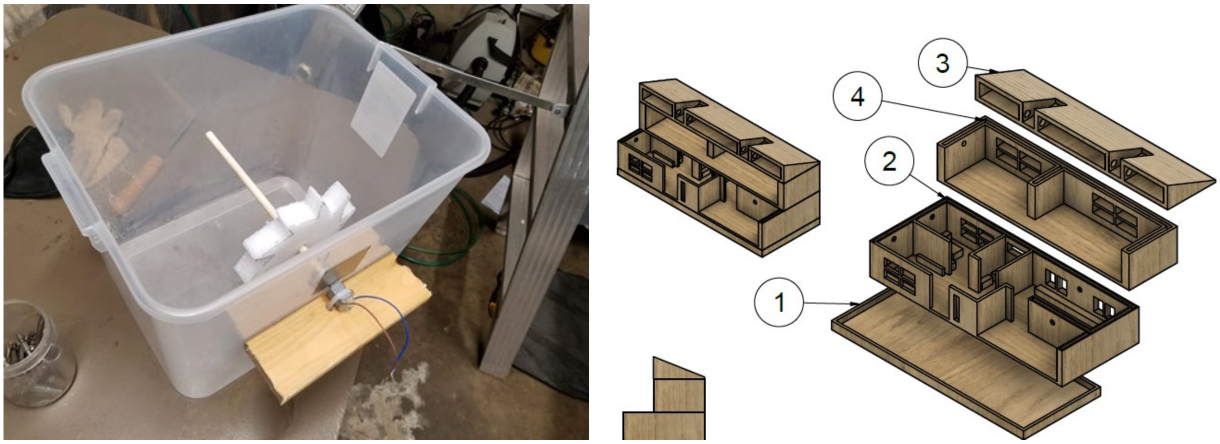
- Five projects with Powerhouse Science Center (with financial supports for the projects from the community partner)
- Two projects with Roseville Utility Exploration Center (with financial supports for the projects from the community partner)
- One project with Aerospace Museum of California (the project did not need financial support)

Due to the unexpected university closure, most teams lost two crucial weeks to finalize their projects. While this caused some stress and discomfort, the author's personal interview with the students after they presented their work to the museums indicated general satisfaction and a sense of accomplishment. Also, the review of the student reflections presented in their final report indicated that by working on these projects, the students started to think about why service learning matters and how their project can make a difference addressing social problems. Some of the projects are presented in Figures 1 and 2. The feedback from museum staffs was very positive and they expressed willingness to continue the collaboration.



a

b



c b

Figure 1: Some samples of projects: a) air rocket made of a soda bottle, b) vertical axis wind turbine concept, c) hydro-turbine concept, d) solar home model

a b

Figure 2: Students presenting their projects to community partners: a) solar home model, b) sun-tracking solar cell

The addition of service learning to the course was an overall success; however, there are several factors to take into account before fully and permanently integrating this approach. These factors are as follows:

1. While community partners were committed to financially support the projects, they provided the fund after students finished their projects and submitted products. However, some students expressed discomfort with the arrangement though the costs of projects were relatively small, between \$5 and \$35. For the future, the author would like to have the fund available and allocate it to each project (say \$40 per project) at the beginning of the semester.

2. The method of communication and involvement of museums should be more streamlined.
3. The project topics and the objectives should be better communicated to students and better integrated to the course contents.
4. The course contents and expectations should be revised in a way that adding the service learning component does not significantly add to the student load. Some students rightfully felt that the course load was heavy.
5. The project timing should be revised to add some flexibility to the schedule.
6. The available projects and the collaborating museums should be more diversified.

The collaboration with community partners has some unintended positive consequences. During discussions on projects for service learning, some other projects were identified that were suitable for senior design projects or as master theses. For example, a masters' mechanical engineering student is currently working on the energy modeling and optimization of Aerospace Museum of California building. Another master student completed an independent study on the economic analysis of an existing solar photovoltaic farm in Aerospace Museum of California. Furthermore, currently a team of five mechanical engineering students are designing and building a heavy duty hydro power plant demonstration unit for Roseville Utility Center that will be used to teach elementary and middle school students the principle of these power plants. Another similar project is the feasibility and economic study and design of a system to cover part of an exhibition area in Aerospace Museum of California with a covered roof with solar panels on top and then building a small scale model of the design.

Conclusion

The introduction of service learning pedagogy to an engineering curriculum can be beneficial for both engineering students and community partners. While community partners benefit from the implementation of projects, students receive educational benefits. The service learning experience not only sharpens students' technical skills but heightens their awareness of their responsibilities about complex social problems and even opportunities to develop empathy. This is critical because they are not typically exposed to the social and community aspects of engineering practices in other courses. Beside course-related outcomes, these projects can strengthen students' resume and graduate school applications. They can help students to explore career options that are typically under their radar as well as providing them with vast opportunities for professional networking. Also, these projects are very powerful tools to achieve some of engineering curriculum objectives, including developing critical thinking, problem-solving, leadership, conflict resolution, and written and oral communication skills. All these desirable skills can improve students' employability and help them to have a more fulfilling life. The service learning projects can also help the faculty to improve in all areas of teaching, research, and service.

Future work

The author will reach out to several other community partners, including California Automobile Museum, California Museum, and California State Railroad Museum, Sacramento Municipal Utility District (SMUD), and Folsom Powerhouse State Historic Park, for other potential projects. The author is also teaching a new general education course entitled Energy and Modern Life. The ultimate objective of the course is to improve the energy literacy and help non-engineering students to make informed decisions on energy-related issues in their personal life and as responsible citizens of the society. The author will try to integrate service learning to this new course in the near future.

Acknowledgement

The author would like to express his deep gratitude to Thomas E. Jones, the Executive Director of Aerospace Museum of California, Rachel Tooker, the Interpretive Services Supervisor of Roseville Utility Exploration Center, Rita Mukherjee Hoffstadt, the Deputy Director of Powerhouse Science Center, and Sheila Montgomery and Emily Anderson at Powerhouse Science Center. Without them none of these projects could have become a reality.

References

1. Stearns, Peter N. Educating global citizens in colleges and universities: Challenges and opportunities. Routledge, 2009.
2. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/#GC3
3. Slattery, Darina M., and Michael P. O'Brien. "Using Service Learning and Virtual Team Projects to Broaden the Curriculum and Enhance the Student Experience." Currents in Teaching & Learning 6.2 (2014).
4. Jacoby, Barbara. Service-learning essentials: Questions, answers, and lessons learned. John Wiley & Sons, 2015.
5. Hondagneu-Sotelo, Pierrette, and Sally Raskoff. "Community service-learning: Promises and problems." Teaching Sociology (1994): 248-254.
6. https://www.csus.edu/president/mission-imperatives/_internal/_documents/sac_state_sp.pdf
7. Tucker, Bowa George, et al. "The Reflective Learner: Perspectives of Engineering Faculty Engaged In Learning through Service." International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship 9.2 (2014): 29-46.
8. Warren, Jami L. "Does service-learning increase student learning?: A meta-analysis." Michigan Journal of Community Service Learning 18.2 (2012): 56-61.
9. Gross, Patricia A., and Virginia Anne Maloney. "Embracing diversity through service learning." The Clearing House: A Journal of Educational Strategies, Issues and Ideas 85.5 (2012): 192-196.
10. Jones, Susan R. and Kathleen Hill. "Crossing High Street: Understanding diversity through community service-learning." Journal of College Student Development 42.3 (2001): 204-16.
11. Marullo, Sam. "Bringing home diversity: A service-learning approach to teaching race and ethnic relations." Teaching Sociology (1998): 259-275.
12. Seidman, Alan. "Minority student retention: Resources for practitioners." New directions for institutional research 2005.125 (2005): 7-24.

13. Traum, M. J., et al.,“Engineering Design, Project Management, and Community Service Connected Through Servant Leadership,” Proceedings of the 120th American Society for Engineering Education (ASEE) Conference and Exposition, Atlanta, GA, June 23-26, 2013.
14. Zabihian, Farshid, “Research-Based Teaching in Undergraduate Thermo-Fluid Mechanical Engineering Courses in a Primary Undergraduate University”, American Society for Engineering Education’s (ASEE) 125th Annual Conference, Salt Lake City, Utah, June 2018.
15. Zabihian, Farshid, “Alternative Approach to Teach Gas Turbine-Based Power Cycles”, American Society for Engineering Education’s (ASEE) 122nd Annual Conference, Seattle, Washington, U.S.A., June 2015.
16. Zabihian, Farshid, “Educating Undergraduate Mechanical Engineering Students about Exergy Analysis”, American Society for Engineering Education’s (ASEE) 122nd Annual Conference, Seattle, Washington, U.S.A., June 2015.