Service-Learning in Aerodynamics at San José State University

Nikos J. Mourtos
San José State University, San José, USA
nikos.mourtos@sjsu.edu

ABSTRACT

Purpose:
A service-learning project was introduced in the Aerospace Engineering Program at San José State University in Fall 2011 to enrich students' learning experience through meaningful community service and increase their civic awareness. The project promotes science, technology, engineering, arts, and mathematics education in economically disadvantaged and ethnically diverse K-12 student populations.

Design Methodology:
Aerospace engineering student teams design and build devices that demonstrate aerodynamic concepts to K-12 students. They first submit a proposal for a project, follow up with a literature search on science, technology, engineering, arts, and mathematics education, carry out the detailed design of their apparatus, and finally, present an aerospace engineering expo to students of local schools. Aerospace engineering students are graded on the effectiveness of their demonstration and interaction with the K-12 students as well as on the quality of their technical report.

Findings:
The service-learning project has shown potential for engaging K-12 students, meeting the needs of local schools in the city of San José and increasing aerospace engineering student learning through teamwork, creativity, hands-on design and analysis. Aerospace engineering students enjoy tremendous satisfaction being of service to their community and acting as role models for the K-12 students with whom they interact.

Conclusions:
The service-learning project has added an entertaining yet challenging dimension to the aerodynamics course at San José State University. Feedback from local schools has been enthusiastic and the project has now been established as a permanent feature of the course.

Keywords: *Service-learning, STEAM education, course design and assessment, student recruiting.*

BACKGROUND

Jacoby et al (1996) define service-learning (SL) as "a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student-learning and development". SL integrates meaningful community service with formal instruction and reflection for the purpose of (a) enriching students' learning experience, (b) increasing students' civic awareness, and (c) meeting the needs of local communities.

SL has the potential to play a significant role in meeting Engineering Criteria 2000 (The Accreditation Board for Engineering and Technology, 2012-2013). These criteria for accrediting engineering programs include, in addition to traditional technical skills, several sets of non-technical skills, such as an ability to function on multidisciplinary teams, an understanding of professional and ethical responsibility, an ability to communicate effectively, a broad education necessary to understand the impact of engineering solutions in a global and societal context, a recognition of the need for, and an ability to engage in lifelong learning, and a knowledge of contemporary issues. SL provides a mechanism for integrating any or all of these skills along with technical skills in a typical engineering course.

Capstone, senior design courses constitute a great venue for integrating SL into engineering curricula, and many schools have successfully implemented such projects (Tsang, 2000). First-year courses, which introduce engineering design to freshmen, provide yet another opportunity (Lord, 1999; Tsang 2000; Budny, Lund & Khanna, 2013). On the other hand, SL programs like EPICS have grown into multi-university collaborations, with vertically integrated long-term, large-scale, multidisciplinary design projects, in which undergraduate student teams work closely with not-for-profit organizations across the US to deliver projects of significant benefits to local communities (Coyle, Jamieson & Oakes 2005). It is worth noting that students may participate in EPICS projects for up to seven semesters, allowing them for a more complete and meaningful experience. Finally, organizations like Engineers Without Borders, which have chapters in many engineering schools including SJSU, emphasize projects that serve the needs of communities in developing countries around the world, helping students become more culturally aware and better prepared to become responsible professionals in a globalized world. These examples show that SL can be integrated successfully into any engineering course or combination of courses at any level, allowing students for meaningful, real-world engineering experiences.

While SL projects vary in scope across universities, the benefits extend beyond providing a meaningful way to satisfy ABET requirements. For example, SL increases engineering students' motivation, retention, and graduation rates, especially among women and under-represented minorities (Astin, Vogelgesang, Ekeda & Yee, 2000; Ropers-Huilman, Carwile & Lima, 2005; Bringle, Hatcher & Muthiah, 2010). Astin, Vogelgesang, Ekeda & Yee (2000) performed a longitudinal study in which they tracked more than 22,000 undergraduate students from various undergraduate institutions across the US, in an effort to explore the effects of SL on the cognitive and affective development of students. They concluded that student participation in SL had a measurable positive effect on their degree of interest in their subject matter, GPA, writing skills, critical thinking, values (e.g. promoting racial understanding), self-efficacy, and leadership. Furthermore, they found that students who participated in SL projects were more likely to participate in service upon graduation and even seek a career in public service. This finding is significant, as it shows that the impact of participating in even small SL projects can have a lifelong impact on a student's life outlook regardless of his/her original career choice.

The discussion above focused entirely on the educational benefits of the engineering students, who participate in SL projects. Needless to say, there are tremendous benefits to the communities served through these projects. For example, K-12 students, who are served in projects such as the one described in this paper, are exposed to science and engineering through direct contact with engineering students. Furthermore, engineering students serve as role models for K-12 students, increasing the confidence of the latter in striving towards college. Clearly then, SL provides multiple and substantial benefits to all involved. Hence, in Fall 2011 it was decided to introduce a SL project in the AE Program at SJSU. The purpose of the project is to present AE expos as a way of promoting STEAM education and careers in economically disadvantaged and ethnically diverse K-12 student populations in the city of San José.

SERVICE-LEARNING AT SJSU

The California State University and SJSU in particular, place great value in community service. A strategic planning process initiated in 1997 to encourage faculty and students to participate in SL projects, led in 2005 to CommUniverCity San José, a collaborative effort between the Five Wounds/Brookwood Terrace communities, SJSU, and the City of San José. The collaboration is built around the priorities and goals of the residents, which include improving quality of life, building community, and engaging all participants in civic life. The steering committee of CommUniverCity presents a menu of projects to the Five Wounds/Brookwood Terrace Neighborhood Advisory Council (NAC), which then selects a subset of these projects based on the needs of local communities. External grants from local organizations help fund many of these projects.

Some of the CommUniverCity projects implemented so far are listed below:

- Education students read to elementary school children on a monthly basis.
- Hospitality and recreation students organize booths for a safe and green Halloween fiesta.
- Psychology students conduct intimate violence prevention workshops.
- Communicative sciences and disorders students test the hearing of kindergartners.
- Public health and health science students organize a community health fair and provide a healthful meal to the participants.

- Health science students work with local school health clinics to develop a marketing campaign that centers on finding innovative ways to inform the community about the various services available to the community.
- Urban planning students propose plans for improving neighborhood safety and livability.
- Science and engineering students present expos to K-12 students.

Organization of the Aerodynamics Service-Learning Project

Aerodynamics I (AE160) is a junior-level, lecture/lab course, with prerequisites Calculus III (Math32), Physics I – Mechanics (Phys50), and Engineering Reports (E100W). It is the first AE core course in the BSAE curriculum.

Students are assigned in teams by the course instructor to ensure that all teams are fairly balanced in terms of abilities, gender, and ethnic background. Student abilities are determined based on grades in course prerequisites.

The SL project involves the development of a hands-on demonstration for K-12 students to illustrate a concept studied in the course (e.g. viscosity, lift, drag, thrust, etc.). The idea is to have K-12 students experiment with an apparatus or a device, so they can explore the concepts introduced to them. The project consists of the following parts:

a. *Project proposal (2nd week of the semester):* Each team submits a proposal for the demonstration they would like to develop. The proposal includes a sketch that illustrates the conceptual design of their apparatus. It also includes one or two learning objectives for the K-12 students. The course instructor approves each proposal before the team moves forward with their project.
b. *Literature search on the topic of the demonstration (4th week of the semester):* Just like any project, a search is deemed necessary, so that students become familiar with the variety of devices that may be available for their particular demonstration. For example, if a team proposes to explore the concept of viscosity by developing a viscometer, they will benefit from studying the various types of viscometers available in the market before embarking on the design of their own device. Students are expected to summarize their findings and provide a list of references.
c. *Literature search on STEAM education (6th week of the semester):* The purpose of this search is to increase students' understanding of the importance of STEAM education for the US and the world, so they can better appreciate the importance of their project. Again, students are expected to summarize their findings and provide a list of references.
d. *Detailed design of apparatus (8th week of the semester):* Students design their apparatus in detail and provide 3-view dimensional drawings and list of materials needed.

e. *Building of apparatus (10th week of the semester):* Students complete the construction of their apparatus and demonstrate that it works properly and safely before taking it to one of the K-12 schools. Students are allowed to purchase an existing device for their project, if they so choose. For example, one of the teams in Fall 2011 purchased a remotely controlled helicopter for demonstrating the concept of lift. Technically speaking, students benefit the most by analyzing their device using the principles studied in class, hence building a device from scratch is not considered a necessary part of the project, although many students enjoy taking on this challenge.
f. *Aerodynamic analysis of the apparatus (12th week of the semester):* This is one of the most important parts of the project, as students are called to demonstrate their understanding of the principles studied in class. For example, the team that purchased the helicopter for their demonstration performed a momentum analysis of a helicopter in hover, in vertical climb, in descent and in forward flight. This analysis went beyond the scope of the basics studied in class and gave the students a thorough understanding of the importance of the momentum equation in analysing fluid flow problems. Furthermore, it gave the particular students an opportunity to explore applications of the momentum equation in aerospace propulsion, a course taken in their senior year.
g. *Demonstration of the apparatus to K-12 students (15th week of the semester):* This is, of course, the highlight of the project. At the end of the semester, AE160 students set up an AE Expo to one or more local schools. Team grades are based not only on the success of their demonstration but also their interaction with the K-12 students, i.e., how well they explain the concepts to them and answer their questions.
h. *Reflection (16th week of the semester):* The last part of the project involves an individual student reflection on their learning experience. In particular, students are asked to (i) state the two most valuable things, not related to aerodynamics, that they learned through this project, (ii) discuss one thing (concept, idea, application, etc.) about aerodynamics that this project helped them understand and apply, (iii) state how valuable was this project as a learning experience for them personally, and (iv) make suggestions, if any, for improving AE students' learning experience through similar projects in the future.

Each team submits a final report on the last day of class, which includes all the assignments discussed above along with individual student reflections. The SL project contributes 20% towards the course grade.

Examples of Projects Designed by Aerodynamics Students

Examples of projects designed by AE160 students are listed below:

- A viscometer to illustrate the difference in viscosity among fluids such as water, honey, chocolate, etc.
- Model cars of different shapes sliding from a ramp onto the floor to illustrate the effect of shape on aerodynamic drag.
- A radio-controlled, model helicopter to demonstrate rotor thrust and how it is used to hover, climb, descend, and cruise (Figure 1).
- An autogyro to illustrate harvesting wind energy and converting it to lift.
- Aerodynamic drag of parachutes and how it is used to train sprinters.
- A small, portable wind tunnel to illustrate wing lift and drag.
- A portable water tunnel to illustrate flow patterns around different objects (Figure 2).
- Paper gliders of different designs to illustrate the effect of wing shape on lift-to-drag ratio and gliding performance (Figure 3).
- Assembly of an instructional, low-speed wind tunnel and design of a series of experiments for students. The wind tunnel had been purchased through a grant at the SJHS, however, due to lack of expertise it had not been used until AE160 students put it together and demonstrated its use for measuring lift and drag on a variety of models (Figure 4).

Figure 1: An AE student gives flight instruction to two 4th-graders, who are about to fly a radio-controlled helicopter.

Figure 2: A 4th-grader observing the flow streamlines around a model airplane in a portable water tunnel.

Figure 3: A 4th-grader flying a circular wing glider.

Figure 4: SJHS students observing a wind-tunnel test.

Service-Learning Project Venues

One of the venues, in which AE160 students present their expo, is a 4th-grade class of an after school program at the Third Street Community Center in San José. Seventy 4th-graders are served by this expo on two different days in the last week of the semester. AE students are one of two groups of SJSU students, who regularly visit this 4th-grade class. Materials engineering students from an introductory course (MatE25) also set up hands-on demonstrations for the after school program every semester (Gleixner, Klaw & Backer, 2011). The 4th-grade students are very excited to have an opportunity to interact with college students and they are eager to try each and every demonstration prepared for them. AE students are instructed to teach the 4th-graders simple concepts involved in their demonstrations, according to learning objectives they set for them, when they design their apparatus. The combination of the two engineering expos set up by SJSU engineering students provides significant enrichment to the science program at the Third Street Community Center.

The second venue, in which AE160 students present their expo, is a 12th-grade class at San José High School (SJHS). SJHS has a very rich science and technology program, which includes engineering courses. The science and technology teachers at the school are eager to have our AE Expo, so that their students get a taste of how some of the things they learn in class are used in engineering. Furthermore, the Expo provides a great opportunity for recruiting graduating high school students into our AE Program. On Friday, December 7, 2012 six science teachers brought 18 classes – a total of 521 high school students – to our first AE Expo on their campus, presented by 48 AE students.

ASSESSMENT

SJSU AE Faculty Evaluation of Student Projects

There were eleven teams in AE160 in Fall 2011 (41 students enrolled) and twelve teams in Fall 2012 (48 students enrolled). As Table 1 shows, students in general do a fairly good job preparing their project proposal, reviewing the literature on the importance of STEAM education, and reviewing the literature on the technical topic of their project. Students also do well in the conceptual design of their apparatus. One area, in which students did very poorly in Fall 2011, was performing an aerodynamic analysis of their apparatus; they had great difficulty applying concepts we discuss in class in the particular context of their project, such as airfoil lift and drag, drag estimation using boundary layer theory, thrust calculation using the momentum equation, etc. Naturally, students who asked for help were coached and eventually performed a satisfactory aerodynamic analysis of their apparatus. Unfortunately, not every team who needed help asked for help, so many received low scores in this area. On the other hand, some teams produced a level of analysis, which exceeded by far the scope of the project and the course. Students overall performed significantly better in Fall 2012, although analysis remains an area of focus for improvement. As the last line in Table 1 indicates, overall, student reports were of high quality.

Table 1: Teams who scored 70% or better in the various parts of the SL project

	Fall 2011 (N = 11)	Fall 2012 (N = 12)
Proposal	100% (11)	100% (12)
STEAM Literature Review	73% (8)	83% (10)
Technical Literature Review	91% (10)	100% (12)
Conceptual Design	82% (9)	100% (12)
Analysis	36% (4)	67% (8)
3rd Street Expo	91% (10)	100% (12)
SJHS Expo	N / A	100% (12)
Overall SL Project Score	82% (9)	92% (11)

As was discussed earlier, the SL project requires integration of technical as well as many of the soft skills required in ABET EC 2000. For example, in addition to traditional aerodynamics skills, the SL project in AE160 helps AE students develop:

- Team skills. In fact, as some of the student comments in the next section indicate, teamwork has turned out to be one of the major challenges for them.
- An ability to communicate effectively engineering concepts to diverse audiences, such as 4th-grade students, high-school seniors, fellow AE students, and AE faculty.
- Lifelong learning skills through literature searches and the need to learn new material on their own, as needed for the completion of their project.
- Knowledge of contemporary issues, such as the importance of STEAM education in the 21st century for the world in general, the US in particular, and more specifically for the socioeconomic advancement of the diverse populations they serve and which are also reflected in the SJSU student body.
- Professionalism through exemplary service to the community.

Any or all of these skills may be assessed for ABET purposes, using appropriate rubrics.

SJSU AE Student Reflection

The four questions used to guide AE students in their individual reflection on their SL experience are repeated below along with a summary of their responses:

(i) State the two most valuable things, not related to aerodynamics, that you learned through this project.

The most valuable thing AE students learned was "an appreciation of how difficult teaching is, and in particular the challenge of explaining something in simple terms, so that 4th-graders can understand". AE students quickly realized that kids have the drive to learn, engage very quickly, and learn in unexpected ways. On the other hand, keeping young learners engaged for long is challenging because their attention span tends to be short. To overcome this challenge AE students had to keep the process exciting but also efficient and they often had to improvise on the spot.

The second most valuable thing AE students learned was the importance of teamwork in completing the project. Surprisingly, many students reported that this was their first time working in teams to complete a project in an engineering course. Nevertheless, they made very insightful comments about how to be effective in a team. For example, one student underlined "the importance of understanding the strengths, weaknesses, and intentions of their teammates, as well as how they function under pressure". Some teams proved quite savvy and used Google docs to prepare their report during the course of the semester. One team made the astute observation that even kids were learning more quickly when they were playing with each other during their experiments, pointing at the importance of teamwork in the learning process.

The third most valuable thing AE students learned was that "to design and build things that work well is challenging". As they pointed out "the simpler the design is, the better". Furthermore, students realized that the manufacturing phase of a project takes significantly more time than the design and planning phases combined because of the need to test many times. One student commented that this project made them "appreciate the difference between book problems and real engineering".

(ii) Discuss one thing (concept, idea, application, etc.) about aerodynamics that this project helped you understand and apply.

The majority of the students mentioned aerodynamic forces as the one thing their project helped them understand. They were almost equally divided between lift (how a kite generates lift, how airfoils generate lift, the effect of camber, thickness and angle-of-attack on the lift, etc.) and drag (car drag, rocket drag, parachute drag, etc.). Some students mentioned concepts that relate to lift (e.g. Bernoulli's principle, vortices, Magnus effect) and concepts that relate to drag (viscosity, boundary layers, effects of Reynolds number and body shape, etc.), while others mentioned the momentum equation, which they used to explore helicopter rotor and propeller thrust. AE students claimed that their projects helped them gain a much better understanding of these concepts and as a result, they performed better in their course exams.

(iii) State how valuable was this project as a learning experience for you personally.

Approximately 2/3 of the students stated that their project was very valuable and 1/3 stated that their project was valuable as a learning experience. Their reasons varied. Some of the comments students made are reproduced below:

- "Our project was one of the most enjoyable and fulfilling school projects that I have been involved in ☺"
- "Our project was very valuable for both the kids as well as for us."
- "Concepts are better understood by reading, hands-on work, and being able to teach others what you have learned, which was the essence of this project."
- "This project was one of the most enjoyable and useful learning experiences for me. I am particularly interested in the idea of having science and engineering expos, such as the one at SJHS. The expos can serve as an exciting and enjoyable extracurricular activity for students. I believe hands-on learning models can help students understand difficult scientific concepts more easily."
- "It made me feel like I have accomplished something with my time at SJSU. It made me feel like all of my time in college has been worth it, and now other people can benefit from it as well. The whole experience inspired me to throw myself further into my major and continue on with confidence."

As some of these comments reflect, the SL component of the project is very exciting for most of our students.

(iv) Do you have any suggestions for improving AE students' learning experience through similar projects in the future?

Surprisingly, most students had no suggestions for improvements. They found that everything works well and the project accomplishes what it intends to accomplish. The few students who made suggestions included things such as:

- Provide more guidance on what kind of analysis needs to be done in each project.
- Require all projects to be designed and built from scratch.
- Implement SL projects in lower division engineering courses as well.
- Have students reflect on their own reasons why they chose a career in AE, find their own source of inspiration, which convinced them to make this decision, and share it with K-12 students who are considering a career in STEAM.

In Fall 2012 students were also asked to:
(v) Comment specifically on your experience with the SJHS Expo and your interaction with the SJHS students.

The majority of the AE students stated that they had more enjoyable experience teaching high school students rather than 4th-graders. For one thing, high school students seemed to understand the concepts involved in the projects much faster and it was therefore easier to engage them in conversation. AE students felt a greater level of satisfaction, as they were able to teach at a much higher level, when they presented at the SJHS expo. As one AE student commented, "using simple equations for drag and terminal velocity seemed to motivate high school students to ask questions about engineering".

AE students observed that the majority of the high school students "were genuinely interested in the science and theory behind their projects". They found them to be "exceptionally polite, intelligent, and eager to learn", as they "listened carefully, took notes, and asked questions". High school students thought that "the projects were cool", another point of gratification for AE students. This was not always the case, of course, and one AE student lamented that "some high school students showed no interest at all. They would listen for a few minutes, but eventually slide past our table and venture off midway through our discussion… We had no success with the majority of the students, although the advanced students were very interested in our topic and made interesting remarks about drag". Nevertheless, based on the stories in the AE students' reflections this kind of experience was the exception, rather, than the rule.

As a closing comment, AE students observed that SJHS faculty were extremely grateful for their presence and enthusiasm, and they supported them in every way possible during their setup and during the expo.

SJHS Faculty Assessment of the AE Expo

The following is the SJHS faculty assessment of the AE Expo.

"The expo organized by the AE students was part of SJHS Project Lead The Way. SJHS students walked from booth to booth observing the various demos set up by AE students and asking questions. In addition to the Tech Expo, two AE students spent time assembling a brand new wind tunnel, which had been sitting in storage at the high school, still in its original box, for over three years because the school did not have anyone who knew how to assemble it. This wind tunnel is now in operation and was used at the Tech Expo for one of the project demonstrations. High school students will now be able to design and build projects that can be tested in this wind tunnel.

AE students also talked with high school students about the importance of STEAM education and the skills necessary to successfully engage in such education. They also explained the various engineering fields and how to prepare for a college degree in engineering. The SJHS is looking forward to hosting the AE Expo again next year in the fall semester."

CONCLUSION

A simple SL project that was introduced for the first time in an AE course at SJSU has shown tremendous potential for engaging K-12 students with engineering concepts, increasing AE student learning, satisfying several ABET outcomes and equally important, meeting the needs of local schools by enhancing STEAM education and promoting STEAM careers.

The effectiveness of the SL project described in this paper was assessed through input from all participating parties, namely the AE students, who provide the service as a course requirement, the course instructor (author), who evaluates their performance (learning and service), and finally the science teachers and school administrators, whose students are the primary beneficiaries of these projects. So far, the feedback from all three parties has been overwhelmingly positive. According to the AE students, the SL project has added an entertaining yet challenging dimension to their learning experience in AE160. Their challenge comes not only from attempting to present AE concepts in non-technical terms and engaging K-12 students but also from the expectation for rigorous analysis of their apparatus in their reports. The feedback from the local schools has been enthusiastic. AE160 students are expected back on a yearly basis and the SL project has been established as a permanent feature of the course.

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