A SERVICE LEARNING PROJECT
ON ALUMINUM RECYCLING

Developing Soft Skills in a
Material and Energy Balances Course

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In the core courses of a chemical engineering curriculum, the bulk of technical and scientific content that must be covered imposes time constraints that can inhibit addressing the professional skills employers want and ABET requires.[1,2] Accomplishing this in a meaningful way can be especially challenging in the introductory material and energy balances course, where class sizes are typically larger and students’ engineering knowledge is limited. Attempts to assess teamwork in the course are often restricted to standard group homework assignments, and students do not yet have sufficient engineering knowledge for in-depth technical communications assignments. Furthermore, without that foundational knowledge, how are they to develop an understanding of contemporary chemical engineering issues or the “impact of engineering solutions in a global and societal context”?[3]

Service learning offers a means of enriching student learning by application of academic knowledge to fulfill a community need.[4] Service learning provides an opportunity to engage students in activities outside the classroom to reinforce learning and to develop professional skills in communication and teamwork. The connection between learning and community service is fairly clear for courses in social science and health. Recognizing that engineers also work to serve the public good, service learning in engineering courses provides a platform to address those more abstract educational objectives of societal responsibility and global impact.[5,6] In the past 10-15 years, the engineering education literature presents numerous examples of service learning projects in civil, mechanical, and electrical engineering.[7-9] These examples are mostly employed in first-year experience classes or in capstone design courses.[10] Even in comprehensive, college-wide initiatives, it is more difficult to find examples that incorporate core chemical engineering principles with service learning.[11] A recent report addressing the use of a Chem-E-Car program for STEM outreach discusses the benefits of service learning for both the undergraduates involved and the public image of the chemical engineering department.[12]

In the project described here, students studied the processes associated with mining and refining aluminum and compared them to those involved in recycling aluminum. Each group used this information to prepare a presentation on the impact and importance of aluminum recycling, suitable for a lay
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on it.\[14\] problems with student teams, and wrote a short reflection teamwork. The students also read an article about potential phase, the memo was to summarize results obtained and/or one-page memorandum was submitted. Depending on the interval, with completion of the final phase required the third week of the semester, and the others at three- to four-week intervals, the instructor followed up with the teams to address any specific major teamwork problems that needed to be addressed. The calculations and PowerPoint slides were also evaluated, and corrective feedback was provided as needed.

Phase I

The first phase of the project involved planning the project and obtaining background information about aluminum manufacturing processes. A preliminary task-assignment grid shown in Table 2 was provided to the students with the initial project handout to assist the teams in dividing tasks. They were to fill in assignments based on individual strengths and interests, and to make sure tasks were shared evenly between the four group members. In the final assignment, they were to once again submit the grid, edited to reflect any changes based on the actual execution of tasks.

So that students were familiar with general recycling behavior and the local infrastructure for recycling, a representative from each team was required to attend the College of Engineering’s football tailgate event and to coordinate with attendees from other groups to deliver the cans to the local recycling facility. This reinforced the service learning aspect of the project, ensuring that the students had hands-on experience with recycling when they went to speak to their respective external groups. Having to coordinate with other groups for transportation to the game and to deliver the cans also added an extra element of project management to the task.

The final portion of the first assignment was to perform research on the internet regarding processes involved in aluminum refining and recycling. Each student was to perform research on the internet regarding processes involved in aluminum refining and recycling. They were required to consult a database such as the NIST Webbook or a database available via Knovel through their AICHE memberships. Using heat capacity formulas, heats of fusion, and heats of formation, they determined the minimum energy associated with each process. These were treated as state functions, where the net processes could be represented as follows:

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\begin{align*}
\text{Al}(s, 25^\circ\text{C}) & \rightarrow \text{Al}(l, 660^\circ\text{C}) \\
\text{Al}_2\text{O}_3(s, 2\text{5}^\circ\text{C}) & \rightarrow 2\text{Al}(l, 660^\circ\text{C}) + 3/2\text{O}_2(g, 25^\circ\text{C})
\end{align*}
\]

These calculations provided insight into the ultimate thermodynamic difference between the two processes—one only a physical change, and the other also involving a highly endothermic chemical reduction.

During this project phase, the students also chose an external group for whom their presentation would be tailored, and scheduled a date for it toward the end of the semester. Their instructions stated that points would be allotted based on the potential impact of the presentation to that group. For example, a presentation to a single person who could exert influence on community-wide decisions would receive credit equal to a large group of university students.

Phase III

Now that the students had an understanding of the refining and recycling processes and the energy differences, the focus shifted toward communicating that information to their respective lay audiences. To make the energy difference more tangible, students were instructed to come up with “energy equivalents,” comparing the amount of energy saved by recycling a single can, six-pack, or case to another familiar energy usage, such as charging a cell phone. This required that students research energy requirements for these other applications and perform unit conversions to calculate the equivalents.

At this point, the students prepared a first draft of their PowerPoint presentations, including graphics and information to be included on each slide. They were instructed that the presentations should be between 5 and 10 minutes in length.

Phase IV

Upon receiving the instructor’s comments on the first draft of their slides, the students edited the slides and prepared the presentation. They were required to present it to the class at least two weeks before their scheduled meetings with the lay audiences. The class offered critiques and improvements that were incorporated in each case. Finally, the presentation was delivered to the external audience.

Grading

Students were given the point distribution shown in Table 3.
with the original assignment. The final grade accounted for 10% of their course grades.

Student survey
At the conclusion of the course, students were asked to answer reflection questions regarding their experience and learning during the project. The prompting questions are listed below:

- Did this project affect your perspective on the societal responsibilities of an engineer? If so, how?
- How was the experience of preparing and presenting technical information to a non-technical audience?
- Did this project affect your thoughts about energy on a daily basis? Do you have a more tangible understanding of energy use? Explain.
- How was the experience of learning about an engineering process without it being taught in the classroom?
- What did you learn about working in groups? Do you now have an answer for potential interview questions about solving team problems?

A selection of student responses is included in Table 4.
Instead, they gave consideration to which members were best suited to the required tasks, generally dividing the workload fairly.

In their reflections, students made insightful comments about what they learned about working in groups. A common theme in their discussions is that successful teamwork requires compromise and flexibility. Another recurring comment was that the frequent communication with other team members was beneficial. They also noted the importance of timely intervention if a team member was not performing as expected. A few students discussed the leadership skills they had discovered as they stepped up to make sure the project was performed to their standards, while making sure that the tasks were delegated to match individual strengths.

In both their memos and in the survey response, the students discussed some of the challenges facing working out schedules and managing poor performers. These included team members missing meetings, not responding to communication, or not meeting agreed-upon deadlines. The reflections were mostly focused on what solutions they employed and what they learned from the experience. The class was frequently challenged through the semester that these problems would arise, and that if they were able to resolve them without the instructor’s intervention, they would be developing insightful answers to common job interview questions. All in all, the project was an excellent opportunity to develop teamwork skills early in the curriculum and should enhance their approach for the projects they will encounter in the junior- and senior-level courses.

In addition to the group performance, the students submitted a brief evaluation of their peers to their audience. This lessened the intimidation factor that is often inherent when students present to an instructor, which is likely founded in their fear of saying something incorrect to a more knowledgeable audience. In essence, the speaker’s approach became “I have a message to communicate” rather than the more common “I have to communicate” often associated with oral presentations. The students reported that this made the presentation fun and gratifying, rather than something to be dreaded.

The first drafts of the slides that were turned in contained process information that was far too complex, technical, and detailed for the audiences. Following the instructor’s suggestions, the students distilled the information, mostly into graphics, and highlighted the energy-intensive parts of the processes. Students learned that in most professional presentation situations, the speaker should know far more depth than is actually presented, but condenses the information, reserving detail for later discussion if needed. They also found that knowing so much more than they were actually presenting gave them confidence in their expertise to present the material. They reported that trimming down the material to present required a deeper understanding of the process they had to analyze what was important to communicate

Before presenting to their audiences, the students delivered their presentations to their classmates, who then offered constructive criticism. This practice was especially effective in enhancing their critical thinking with regard to oral presentations, and the critiques were strikingly insightful. Comments included suggestions on the material included with respect to the various audiences, recommendations for improvements to visual aids, and observations about delivery. The comments were sometimes just complimentary remarks, but more often constructive feedback. The peer evaluation of the presentations was so effectively that the instructor felt only needed to reinforce it rather than to add more commentary.

It should be noted that the in-class presentations and peer review required a total of about two class periods to accomplish for all 12 groups. They were not all presented in two days, though, but rather spread out over a couple of weeks. The lost time was recovered by the removal of one in-class assignment and one review day from the normal curriculum.

**Understanding societal impact**

Open responses in the student survey show that the project impressed upon the students their responsibility as engineers to educate the public on relevant technical issues, and opened their eyes to the impact that engineering decisions can have on energy consumption. Several students also reported that the project had also challenged them that thought about their future careers as chemical engineers. Interestingly, this change in perspective was approached from two different directions. In general, the students had chosen to study chemical engineering due to their interest in math and chemistry and for its potential as a lucrative profession. A surprising number of them stated that before this course they had thought of chemical engineering and manufacturing as a means to provide consumer products, without even realizing the potential energy and environmental impacts. Coming from the opposite direction, other students expressed interest in working in the chemical industry because of environmental impacts, perhaps as a result of common public perception and media coverage. Both groups stated that working on the project had given them a new perspective on the opportunities that industrial chemical engineers have to reduce the environmental impact of manufacturing the products that society demands. In effect, the first group was enlightened on an important aspect of their future careers, and the latter group was armed with a response to anyone who would challenge their career choice on the grounds of environmental responsibility. The most frequent responses to the reflection questions on societal impact and on energy indicated a new awareness of the importance of energy and environmental issues to the global chemical industry.

**Awareness of contemporary issues**

While deliberating the energy implications of a single material and the energy associated with its processing, in a broader sense it raised students’ awareness of at least two contemporary issues in green engineering. They had to consider the sources of raw materials that are used in manufacturing consumer products, While aluminum is not as limited a natural resource as many other metals that are employed in technological applications, the study exposed them to the ecological effects of mining and made them more cognizant of how we obtain and use mineral resources. Perhaps more importantly, they learned to investigate the energy differences between alternatives. The project focused on recycling, a familiar lifestyle choice, which made understanding the energy implications more accessible for the sophomore-level students. They were then able to extend that understanding to realize that the decisions they would make as chemical engineers would affect the energy requirements for whatever processes they designed, and that as a result those decisions could have profound economic and environmental consequences.

**Lifelong learning**

Through their own self-study, students became proficient in discussing the Bayer process for extracting alumina from bauxite. The Hall-Heroult process, one of the older processes entailed in recycling aluminum. Some reported that the experience had already inspired them to independently investigate other recycling processes. More generally, they stated that they had gained the ability to understand chemical processes and to take initiative to learn new concepts without a professor’s assistance. One said that the idea of being hired as an engineer to perform a particular role in a company seemed less daunting now that the ability to self-teach about a specific chemical process had been demonstrated.

**Service learning and student attitudes**

The service learning aspects of the project included both the presentations to public audiences and participation in aluminum recycling at football game tailgate events. The recycling activity was an essential part of the project because it ensured that the students had first-hand experience with the local recycling infrastructure, providing authenticity in their presentations to other audiences. It also infused the students’ attitudes during preparation for their presentations with meaning, as they were able to observe the low level of public awareness regarding the value of aluminum recycling — when the class’s recycling bin was placed immediately beside a trash can, most of the cans were still tossed in the trash can.

After learning about the processes and their energy differences, the students’ motivation to complete the project by delivering an informative presentation was increased. A recurring theme in the responses to the survey question regarding social responsibilities was that through performing the project they had realized there was a need to educate others and understand from a technical perspective that other people would not. In that, students saw a responsibility to inform people in ways they could understand about how everyday choices can affect energy usage and the environment.

**CONCLUSIONS**

The original objectives of this project were primarily to develop communication and teamwork skills in the sophomore-level course, with an emphasis on material and energy balances, course, while creating an awareness of the societal impacts of engineers. In the end, it accomplished that and more. Through struggles and successes, the students learned team and project-management skills, and each group produced a presentation that effectively communicated its message to its chosen audience. Beyond that, the fundamental material taught in the course was reinforced as the class sought to understand a real chemical process in significantly more detail than is addressed in typical problems. They also gained a more concrete awareness of the importance of energy usage in chemical processes that should bolster their
understanding as it is addressed in future coursework. Finally, the students have a new perception of the role that chemical engineers can play in addressing modern energy and environmental issues, both by increasing the public knowledge and by incorporating sustainable practices in manufacturing.

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REFERENCES

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