

The K-12 Engineering Outreach Corps: A Service-Learning Technical Elective

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Abstract

The service-learning educational method actively engages students in community service as an integral component of coursework, fostering both civic responsibility and leadership. Research has shown that the use of service-learning pedagogy has significant positive effects on students' academic performance (GPA, writing skills, critical thinking skills) and development of civic values (commitment to continued civic participation).¹ Service-learning courses are emerging in engineering colleges as a mechanism to provide engineering students with meaningful community-based learning experiences through which they develop the values and skills of citizenship and leadership, while maturing their own communications skills and strengthening their commitment to the engineering profession.



An Outreach Corps student team leads an in-classroom engineering discussion and demonstration with fifth-grade students.

The Integrated Teaching and Learning (ITL) Program at the University of Colorado at Boulder established a *K-12 Engineering Outreach Corps* service-learning technical elective comprised of junior- and senior-level engineering undergraduate students. In the three-credit hour course, students build upon the knowledge learned in their discipline-based engineering courses, gaining a deeper understanding of those concepts through using engineering to teach fundamental science and math concepts to students in grades 3-6. While making engineering come alive to youth through classroom teaching, engineering students develop their own communication skills *through practice*, and become ambassadors for the engineering profession as they help youngsters imagine a bright future for themselves.

University students in the *K-12 Engineering Outreach Corps* elective course also contribute to the broader educational community by creating a hands-on engineering lesson for inclusion in the peer-reviewed *TeachEngineering* digital library collection — an online, searchable, standards-based resource comprised of inquiry-based curricula that use engineering as the context for advancing science and math learning in K-12 classrooms.²

In this paper, we examine the benefits — to both the K-12 learning community and university engineering students — of an engineering elective that meets the traditional definition of a service-learning course. We also examine how this course creates connections between engineering colleges and K-12 learning communities, promoting the excitement of the engineering profession and challenging engineering students to translate the complex concepts they have learned into easily-understood hands-on engineering lessons appropriate for, and valuable to, science and math learning in grades 3-6.

Why Service Learning?

Service learning is an educational method through which students actively participate in community service as an integral component of their coursework, fostering both civic responsibility and leadership through the integration of academic instruction and community-based service. Through their participation in public and community service, students engaged in service-learning experiences develop the values and skills of citizenship and leadership. A longitudinal study of more than 22,000 college undergraduates conducted by UCLA's Higher Education Research Institute concluded that the use of service-learning pedagogy has significant positive effects on students' academic performance (GPA, writing skills, critical thinking skills) and development of civic values (commitment to continued civic participation).¹

Service learning involves cooperative, rather than competitive, experiences that promote and develop teamwork, community involvement and citizenship skills. Service learning also offers students the opportunity to gain contextual knowledge and solve real-world problems that could not be formulated in a textbook. For instance, students engaged in the National Engineering Projects in Community Service (EPICS) projects rate the impact of their ability to work in teams as the highest outcome of their service-learning experience, followed by enhancement of communication skills.³ Students also report honing other skills that are components of the ABET criteria⁴, which are customarily hard to teach in conventional engineering courses. Those skills include communication, project planning and leadership. Of the students who participated in the EPICS program, 68% said that participation in service learning positively impacted their determination to continue in engineering. The 32% of students who did not respond positively were already firmly committed to engineering before their EPICS service-learning experience and continued to be afterwards.³

Retaining the interest of women and students of color in engineering is known to be improved when subject matter is framed in its social context, and cooperative, interdisciplinary approaches to addressing problems that have holistic and global impacts are employed.^{5,6,7} With a focus on practicing engineering in perspective and context, coupled with a strong emphasis on teamwork, communication and commitment to the profession, service-learning programs may be effective

approaches to encourage women and minority students to remain in engineering. Many service-learning programs report a higher percentage of women in their programs than are enrolled in their engineering program at large. For example, 33% of the computer science students in the spring 2001 EPICS program were women, compared to 11.5% of the undergraduates in their computer science department.³ For these reasons, service learning could potentially contribute to improved retention of gender- and ethnically-diverse engineering students.

Lastly, another success of service-learning projects is the positive impact on the community, with community partners' understanding of engineering increasing through real-world interaction with the engineering students.

Course Overview and Components

The K-12 Engineering Outreach Corps course, piloted in spring 2004 and repeated in spring 2005, established a college-wide service-learning technical elective for upper-division undergraduate engineering students. Students engage in the course to teach engineering weekly in two grades 3-6 classes, integrating and gaining a deeper understanding of the concepts they previously learned in their engineering disciplines, while using *engineering as a vehicle to teach fundamental science and math concepts* to elementary and middle school youth. Through making engineering come alive to youngsters, engineering students develop their own communications skills *through practice* and become proficient at communicating about the broader world of engineering and its impact on society.



An Outreach Corps engineering student helps a fourth-grader understand the workings of her hovercraft.

Two university engineering instructors with experience in K-12 education co-teach the three-credit hour course. The class meets three times weekly for the first three weeks of the semester — twice for hands-on, two-hour studios and once for a 50-minute discussion period — for a total of five hours weekly. Beginning in the fourth week, Outreach Corps students teach in two local classrooms weekly, at which time the second studio period is dropped.

Breaking the Ice — At the beginning of the semester, students engage in team dynamics and logic exercises to solve challenging problems. Participation in a social styles workshop increases students' awareness of the different ways we each interact with others, and how others perceive us in the communication process — knowledge that is especially important for effective teaching. These workshops also allow the instructors to observe the communication and social styles of the students, which is taken into consideration as they are paired for team-teaching.

Exploring Educational Pedagogy and Literature — During the semester, weekly lectures and discussions, supported by required readings from the educational literature, prepare engineering

students for teaching in K-12 classrooms and working with K-12 teachers to plan the curriculum that they will teach in those classrooms. Topics considered valuable by classroom teachers and K-12 principals were incorporated into the course's methodology instruction. The guided discussions also provide engineering students with a perspective on aspects of engineering education that pertain to the K-12 setting. Through this research and discussion, Outreach Corps students consciously develop the language necessary to communicate with teachers on a professional level, important to the success of their teaching experience.

Throughout the semester, engineering students read and summarize, in about 400 words, five articles from the educational literature pertinent to K-12 engineering. With this approach, the instructors find that the students are prepared for the classroom discussions and interested in the educational topics, and rousing discussions ensue. However, students do not find the written summaries valuable to their learning, and, in hindsight, the instructors agree.

To cultivate teaching awareness and effectiveness in the K-12 classrooms, guided discussions explore a range of topics, including:

- Useful techniques for managing youngsters in a classroom setting
- Age-appropriate communication
- Compliance with math and science educational content standards
- Techniques for teaching inquiry-based science and math through engineering lessons
- Incorporating literacy, math and assessment into their instruction and lesson plans
- Understanding the impacts of *No Child Left Behind* legislation on public school education
- Exploring the rationale for the *Small Schools Initiative* as it pertains to science and math education
- Working with diverse learners, such as English as a second language (ESL) children
- Strategies for alternative teacher licensing
- Exploring alternative educational models, such as the Montessori Method

K-12 Classroom Teaching — During 12 weeks of the 15-week semester, two student teams partner with two same-grade level teachers in a local elementary or middle school. Each week, the Outreach Corp teams teach engineering content that supports the teacher's topics, and exposes youngsters to the application of science and math that addresses relevant, real-world situations. The engineering students use existing curriculum from the online *TeachEngineering* digital library collection² (see TeachEngineering.com), and each also develops a new, standards-based engineering lesson with hands-on activities to publish in the *TeachEngineering* collection. Often, their weekly presentations are referred to as "Engineering Day" at the school. Throughout the experience, they informally serve as in-classroom engineering role models for the youngsters.

Practice Makes Perfect — Students peer teach K-12 engineering lessons in studios throughout the semester, practicing teaching to their peers in a safe environment. All students in the class provide constructive verbal feedback on what they like about the lesson taught, coupled with suggestions for improvement, commenting on both the curricular content and the pedagogical approach used. Positive reinforcement methods are modeled and enforced, and have the dual benefit of developing a strong sense of trust, openness and camaraderie among the students.

Weekly Journaling — Students keep a digital journal of their weekly in-class teaching experiences and their reflections about those experiences. The journaling helps the students review their own performance and provides a confidential mechanism for them to communicate with the instructors, typically about challenges they encounter in their team-teaching.

Creation of a K-12 Engineering Lesson Plan — Students create a new elementary or middle school engineering lesson for inclusion in the *TeachEngineering* collection. This is a major intellectual and creative undertaking and must meet specific *TeachEngineering* curricular guidelines. Before teaching their lesson in the K-12 classroom, students refine it with feedback from their peer teaching practice sessions.

Grading — Course grading reflects the work that students do:

- Teaching in two K-12 classrooms weekly throughout the semester, including curriculum preparation for such teaching (accounts for 30% of their grade)
- Preparing and delivering three individual in-class presentations (20%)
- Developing, testing and fully documenting a new, standards-based engineering lesson (augmented by one or two hands-on activities) for publication in the peer-reviewed *TeachEngineering* digital library (25%)
- Completing five written assignments, critiquing assigned educational pedagogy articles from the literature (10%)
- Participating in class discussions (5%)
- Peer testing of hands-on activities developed by other students in the course (5%)
- Class attendance, critical in a discussion-based course (5%)

School Partnerships — Schools selected for participation are public schools with high populations of students with backgrounds that are under-represented in engineering or that have high populations of low-income or first-generation college-bound youth. Our college's partnerships with these schools are well-established through our NSF-funded GK-12 Program.

Teacher Partnerships — Close teacher partnerships are critical to the success of the Outreach Corps students in the classroom, as teachers provide classroom management leadership and underscore the excitement of the engineering curricula to their students. Of utmost importance to teachers is university student reliability — always showing up on scheduled days, and being in class and set up ahead of time. Teachers also appreciate Outreach Corps students doing advance curricular planning with them, using the engineering curricula to augment other science lessons the teacher is concurrently teaching. The teacher partnership is strengthened by inviting teachers to lead university Outreach Corps classroom discussions on topics such as “What math does a fourth grade student already know?”

Assessment and Evaluation

The Outreach Corps elective is assessed and evaluated through multiple avenues:

- Pre- and post-semester surveys are conducted to assess the students' expectations and biases in 18 areas, and how those expectations are met or not met by the course.
- Evaluations of the classroom practicum component are conducted mid-semester by each partnering K-12 classroom teacher.

- Peer evaluations are routinely conducted in studios to provide feedback to students on their success at presenting lessons to the entire class.
- An hour-long observation of the students in action teaching in the K-12 setting is made by one instructor, with constructive feedback immediately provided to the student.
- Students are asked to respond to a series of written open-ended questions about their experiences in the course.
- An independent student focus group interview is conducted at semester end, with emphasis on how to improve the course for future offerings.

All students in the pilot offering were final semester aerospace and mechanical engineering seniors. The number of students was too few to test for statistical significance, so only descriptive information is reported below; thus, it should be interpreted with caution.

Overall, students were confident in their skills at the beginning of the course (average = 3.9/5.0) and reported being highly confident at the end of the course (average = 4.5/5.0), for a 15% gain. The strongest gains in confidence were for the following topics:

- Integration of engineering curricula into the K-12 classroom (73% gain)
- Development of K-12 engineering curriculum (67% gain)
- Working with ESL children (60% gain)

By contrast, students reported deterioration in their confidence in the following topics:

- Working with K-12 principals (-22%)
- Working with special needs children (-12%)
- Teamwork skills for team teaching (-6%)

Open-ended questions elicit student opinions on their expectations of the service-learning experience, the perceived value of the course and suggestions for course improvements. Most students reported that the course exceeded their expectations, with one commenting, “I learned a lot about the different aspects of teaching (in and out of the classroom).” Another wrote, “OCorps exceeded my expectations in academic rigor work load (that’s a good thing though) and learning experience.”

All students thought integration of engineering into the K-12 experience is a valuable practice. One reported, “The value is priceless. Influencing kids at such a young age is the right step towards education.” Another said, “I think [including engineering in elementary level classes] is imperative to increasing the number of engineering graduates. This class has strengthened that view.”

Of great delight to the instructors, all engineering students in the pilot reported envisioning themselves engaged in K-12 teaching in the future in some capacity, with half considering full-



An Outreach Corps engineering student helps a fourth-grade student with his design/build project.

time teaching. Others commented that they would like to engage in after-school programs or become licensed as a substitute teacher.

Unfortunately, Outreach Corps students had almost no interaction with school principals because their point of contact was directly with the teachers. We intend to change this in the future by arranging for the principal to meet with the Outreach Corps student teams before they enter the classrooms, to share her/his school philosophy.

Teacher Feedback — Teachers are confidentially surveyed during the middle and end of the semester to learn their insights on the strengths and areas for improvement for their Outreach Corps students. All the teachers reported that the “Engineering Day” each week was a hit with their young students and that they want to participate in future course offerings. Teachers also provided confidential grades for their Outreach Corps students; the lowest grade given was 95%.

Addressing ABET Criterion — The nature of a service-learning course reinforces many of the criteria embedded in a progressive, authentic engineering education — and by ABET accreditation criteria. Several ABET criterion are addressed through the Outreach Corps elective, including:

- *The ability to apply knowledge of mathematics, science and engineering* is evaluated through the K-12 teacher evaluations, instructor evaluation of the student teaching and through the student’s effectiveness at developing a new lesson plan. (Criterion a)
- Because both oral and written communications are key to success in this course, *the ability to communicate effectively* is evaluated numerous times: through the teacher evaluation, the instructor evaluation of the student teaching, peer evaluations during in-class peer teaching and through student effectiveness at developing a lesson plan. (Criterion g)
- *An ability to function in multi-disciplinary teams* is evaluated by the effectiveness of the students to function in a four-person team for all K-12 teaching, with the team comprised of another engineering student and the two teachers whose classes they teach in for 12 weeks. (Criterion d)
- *Recognition of the need for and an ability to engage in lifelong learning* is a major goal of the course. The instructors hope to spark the interest of engineering students to give back to the K-12 community once they graduate — whether that is by becoming teachers themselves or encouraging their employers to promote K-12 engineering education. Their interest in doing so is specifically evaluated during the end-of-semester questionnaire. (Criterion i)
- *Knowledge of contemporary issues* is explored through student participation in classroom discussions based on readings from the contemporary literature, and on the written papers they produce based on the articles. (Criterion j)
- *An understanding of professional and ethical responsibility* is tested every time our engineering students enter a K-12 classroom. Do they represent the university and the engineering profession well? Are they reliable and trustworthy? Do they serve as effective role models in a K-12 educational setting? The teachers evaluate this every day, and the instructor evaluates this component during formal classroom observations. (Criterion f)

Course Benefits

For the College — The roles of an upper division service-learning course, such as Outreach Corps, in the overall college-wide curriculum lies in its interdisciplinary nature, in its requirement that students integrate subject matter from a wide range of prior courses, and that the course itself has embedded assessment to ensure that it is challenging. The Outreach Corps class further fits into the college curriculum because it advances science and math through engineering in the K-12 setting, and it aligns with the national priority of boosting the nation's science, mathematics engineering and technology workforce.

For Undergraduate Students — This course provides an upper-division service-learning experience that puts junior and senior engineering students in a position to promote engineering as a profession, and integrate engineering concepts and activities to advance science and math knowledge in the K-12 setting. At the same time, it opens their eyes to the challenges educators face in preparing youth for the engineering pipeline.

Oral and written communication skills are advanced through both teaching and creation of a peer-reviewed, standards-based engineering lesson that is published online. Feedback from students indicates that the creation of a lesson is intellectually challenging, requiring integration of multiple engineering disciplines and honing their ability to communicate complex engineering concepts in ways easy to understand by elementary and middle school students and their teachers.

For the K-12 Learning Community — Teachers value young, energetic, high-achieving Outreach Corps students teaching in their classrooms in a way to connect student learning with real-world experiences relevant to the lives of youth. The break in the daily classroom routine — for Engineering Day — brings energy into the classroom, and compels students to engage with the hands-on learning that is part of every lesson. Teachers also report that it benefits their students to develop relationships with science, math and engineering role models.

Lessons Learned

Teaching the Outreach Corps elective was incredibly satisfying. We especially enjoyed the spirited, in-class discussions in which students often disagreed on and debated controversial topics such as educational content standards.

Most students thought the course could be improved with better scheduling of the in-class teaching times; this is the most difficult challenge faced by the instructors. Due to the timing of student “pull outs” for music, physical education, etc., it is nearly impossible to schedule both same-grade K-12 classes at exactly the times that university studios are scheduled. Obviously, this would be ideal, as the university students already have that two-hour block in their schedule.

In future semesters, educational specialists from our local school district will lead seminars on classroom differentiation, sheltered learning, and development of lesson plans for their weekly classroom instruction.

Student Recruitment — Finding a five-hour scheduling block that fits into the schedule of upper-class students from various college disciplines is challenging. At our college, we found that all times when K-12 schools are in session conflict with required junior-level courses in several of our disciplines. Students are frustrated by this, as are the instructors.

College Buy-In — The course was approved by the college-wide curriculum review committee as a 4000-level, general engineering technical elective after its pilot offering. And, the course received enthusiastic support from our campus-wide service-learning leaders.

The range of responses from curriculum leaders throughout the engineering college to a service-learning technical elective engaging engineering students in teaching in K-12 classrooms ranged from highly enthusiastic and supportive (including our dean and associate dean of education) to derogatory comments from one faculty member regarding “the supposed technical elective.” All students who took the course were intellectually challenged, and claimed that its difficulty level warranted a three-credit hour engineering technical elective.

Conclusion

Service-learning courses are evolving in engineering colleges as a mechanism to elevate student communication skills, and provide engineering students with meaningful, community-based learning experiences. This course meets the traditional requirements of a true service-learning course, and creates connections between the university and K-12 learning communities, promoting the excitement of the engineering profession and challenging university students to translate the complex concepts they have learned at university into easily-understood, hands-on engineering lessons appropriate for elementary and middle school youth.

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