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Work in Progress: Project-Based Service Learning Shapes the Morals of First-Year Engineering Students

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Dr. Assanah is the team lead for ENGR 1166: Foundations of Engineering, a core course for all first-year engineering students at the University of Connecticut consisting of over 400 students. She has developed and implemented project-based lessons to build Corsi-Rosenthal boxes for all first-year engineering students through this initiative. Dr. Assanah's research focuses on the synthesis of hydrogels to mimic the mechanical behavior of the brain matter and investigate the cellular response to injury. My past research focused on biomaterials and tissue engineering with a particular emphasis in bone tissue regeneration. This involved combining hydrogel-based cell therapy and acoustic radiation forces via Low Intensity Pulsed Ultrasound (LIPUS), for healing large scale bone defects. Previous research also involved hydrogels as three-dimensional cultures to study the effects of mechanical forces on axons for repairing spinal cord injury.

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Kristina Wagstrom is an Associate Professor in Chemical and Biomolecular Engineering at the University of Connecticut. Her research focuses on providing tools to improve the estimates of human and ecosystem health impacts from poor air quality. Her research portfolio has recently expanded to include indoor air quality with the testing of the effectiveness of Corsi-Rosenthal boxes (a low-cost, DIY air filter) to lower aerosol concentrations in occupied classrooms. In addition, she has substantial experience mentoring project-based service-learning teams.

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. **Work in Progress: Project-Based Service Learning Shapes the Morals of First-Year Engineering Students**

Abstract

Project-Based Service Learning (PBSL) has recently become an essential pedagogical tool in engineering education. Through a PBSL experience, students enhance their learning and build a meaningful connection with the community by contributing their engineering skills and knowledge to impact a socio-cultural problem. These PBSL experiences are student-based, specifically designed to align with the course objectives and connect with the community's needs. Therefore, there are profound effects of PBSLs that benefit all students (inclusive of background and cultural groups), foster creative and critical thinking, promote engagement and teamwork, and implement engineering solutions to real-world problems.

The COVID-19 pandemic has impacted the world in all respects and continues to pose unprecedented challenges to public health and the economy. This virus primarily spreads through respiratory aerosols from infected individuals. Improved indoor air filtration processes and proper ventilation of public spaces are some of the mitigation strategies to prevent the transmission of this virus. Unfortunately, these strategies are challenging and expensive for many public schools across the United States due to older infrastructure, leading to a need for simple, effective indoor air filtration systems to improve air quality and prevent student sickness.

The University of Connecticut conducted a PBSL experience where approximately 400 first-year engineering students designed and built Corsi-Rosenthal (C-R) boxes (DIY Air Purifiers) that trap 56-91 % of respiratory aerosols and improve indoor air quality. The C-R boxes were built for a nominal cost of $60 per box, using a 20” box fan, four 20”x20”x2” MERV-13 filters, the box from the fan, and duct tape. The project was carried out by small groups (3-4 students) working in the First-Year Design Laboratory over four weeks. At the end of the project, the C-R boxes were distributed to the local elementary schools.

During the pandemic, these first-year engineering students had completed their final year in high school remotely, under lockdown. Thus, this C-R box project had a meaningful and personal impact since students could relate to their experiences during the pandemic and were motivated to build the DIY filtration system to positively impact the lives of school-going children. In addition to building the C-R boxes, students also plot graphs to show the effectiveness of the boxes in removing particle number concentration. They measured the noise levels and vibration for different fan speeds of these box filters to ensure the fans were not too loud during teaching sessions. Each week students submitted engineering logs of their building process. Students were also asked to reflect upon their design and testing methods and develop efficient design improvements. Students also highlighted their learning experiences through this project in their Engineering Portfolios at the end of the course.

This activity provides insight into how PBSLs shape first-year engineering students' identities, morals, attitudes, and learning experiences. These efforts prove how such a meaningful project may promote student motivation and understanding on multiple cognitive levels.

Role of Project-Based Service Learning in Educational Development

John Dewey (1938), the famous philosopher and leader of the progressive movement in education, mentioned, “a student must experience education in the context of life to participate effectively in education”[1]. Experiential learning helps students to learn meaningfully and in practical ways, and this is where service learning (SL) becomes an essential pedagogical tool in engineering education. Bringle et al. describe SL as a credit-bearing educational experience as part of the course in which students engage in a service activity to identify social issues and solve real-life problems in the community. Through this course-based SL project, students understand and apply the knowledge earned in the course in a meaningful way. They appreciate the broader implications of the field and develop a sense of civic responsibility [2] [3]. Bielefeldt et al. mention that a service learning project leads to a “greater maturation of the whole self” [2].

In engineering, SL is primarily conducted through project-based service learning (PBSL). Recently, PBSL has been incorporated into capstone design projects, core engineering classes, or extra-curricular activities as part of the engineering curriculum to improve the achievement of the course’s learning outcomes [2]. Therefore, such projects are intentionally designed for all students (inclusive of background and cultural groups) to meet the course learning objectives, foster creative and critical thinking, promote engagement and teamwork, and connect to the needs of the community by developing a socio-economic context, where students can implement engineering solutions to real-world problems.

There are profound outcomes associated with PBSL. Studies have shown that PBSL effectively helps students develop core concepts, technical skills, and critical thinking in engineering [2] [4] [5]. Critical thinking involves identifying, analyzing, and testing information at a high cognitive level [5]. Developing the art of critical thinking in students is a persistent effort in an engineering curriculum. Students are encouraged to exercise this by identifying the problem, making accurate and reliable judgments, and implementing logical and dependable solutions to real-world problems. Issa et al. studied a significant difference in student learning between conventional and project-based learning strategies [5].

Students understand the needs of their community through PBSL. Studies as early as 1994 by Batchelder et al. demonstrated that PBSL positively affects students’ psychological, social, and cognitive development. PBSL exposes students to many social, economic, and environmental issues that students may not have otherwise encountered. This experience enhances students’ awareness and broadens their perspective to help society, thus acquiring a more profound sense of responsibility. This sense of responsibility, in turn, increases the students’ involvement in future civic activities [6]. Bernacki et al. demonstrated that students who participated in SL projects acquired more compassion and understanding to solve a social problem and were likelier to contribute and help with socioeconomic problems [7]. Assessments conducted on these groups of students (such as the SL outcome scale and moral justification scale) reported that students who participated in SL activities were more compassionate and had a better ethical understanding compared to the students who did not participate in SL projects. This is consistent with the findings of Moely et al., which showed that students engaged in PBSL developed a positive attitude towards civic responsibilities and interpersonal skills [8]. Students in this study also achieved a sense of satisfaction and confidence regarding their coursework and reported higher cognitive skills compared to students who did not participate in PBSL.

PBSL allows students to reflect on their values, beliefs, and actions. This self-reflection can help students better understand their moral development and identify areas where they can grow and improve. By providing students with opportunities to engage in ethical decision-making, problem-solving, and community service, service-learning projects can help students build a solid moral foundation and become active and responsible members of their communities.

Description of the Relevant First-Year Engineering Course

The Foundations of Engineering (ENGR 1166) course at The University of Connecticut (UConn) is a required core course for all first-year engineering students from all engineering majors. This course provides an excellent platform for all incoming engineering students to understand and experience what engineers do in the real world through collaborative and meaningful engineering projects.

The learning outcomes for this one-semester course are to 1) demonstrate an understanding of concepts and solve fundamental problems in your primary area of study; 2) iteratively design, build and improve a device or a process to meet a specified need within given constraints; 3) work effectively in multidisciplinary teams; 4) communicate effectively by presenting work in a structured, clear, and engaging way to a range of audiences; 5) apply the ethical responsibilities of their profession to the design process. Students strive towards these course objectives through active learning methods and multiple hands-on projects throughout the semester.

ENGR 1166 is divided into three components, which occur concurrently. The first component includes large lecture meetings where students are introduced to crucial engineering concepts, software, and tools. Even in the large lecture halls, students are teamed into smaller groups to build hands-on, in-class projects. The [University] offers a state-of-the-art active learning classroom to facilitate such projects in smaller groups of students in the big lecture halls (Figure 1). These activities promote problem-solving skills, teamwork, technical communication, and ethics. Students are introduced to concepts such as creative thinking, prototype design, estimations, essential software such as Excel, CAD designs, Solidworks, Microelectronics, CircuitPython, Jupyter Notebooks, and ethics-related activities. Each topic is presented at the time in the semester when students begin applying the topics to their design projects. In the second component, students learn about engineering concepts and problems related to their major engineering fields. Students develop critical thinking and problem-solving solutions through feedback-orientated learning from multiple instructors specific to their major disciplines. The third component of the course is the design lab, where students apply their knowledge and technical skills from the lecture and major-specific components to design, iterate, and build a prototype of a real-life project with given constraints.

To provide the students with ample opportunities to work in the lab, the University provides 20 design lab sections in a dedicated physical lab (First-Year Design Laboratory) and makerspace on the Storrs campus, equipped with various tools and individual tables to promote teamwork (Figure 2A). Each section consists of approximately 25 students divided into teams of 4-5 students in each team. There are dedicated instructors and undergraduate teaching assistants to guide and help the students with two different projects in the design labs.

Figure 1. (A) Students in large lectures in the Science One Active Learning Classroom. (B) Student teams are working on 'Spaghetti Challenge' as part of their lecture activity.

In the early portion of the semester, students complete a short-term service learning project, and towards the latter portion, students are given the option to choose between two long-term projects. Students are provided a brief introduction to the technical skills and plenty of resources to complete these tools-based projects. Students learn how to design and build prototypes, test the prototype, and iterate their designs. They also learn how results vary with different variables and the choice of materials. Students accomplish the project goals and implement several stretch and discussion goals as part of their design. Each week, student teams accomplish individual design steps culminating in their final design implementation. The engineering logs (submitted weekly by each team) document their work progress, results, and next steps, using Gantt charts and timelines. Students design and print 3D parts and use circuits/Arduino sensors and microcontrollers for their projects. They also have access to design lab tools, such as soldering, adhesives, drilling, and measurement tools.

For both projects, students are strategically placed in teams of 4-5 students based on their technical skills, engineering majors, and identities. In addition to including lessons on biases in engineering and creating equitable teams, instructors form teams strategically that minimize the "loneliness" of marginalized identities. Strategic team formation is shown to reduce microaggressions, increase confidence, and support healthy collaboration between teammates.

The long-term project culminates in a final poster presentation and project demonstration in the first-year expo and submission of an engineering portfolio where students have to demonstrate how they learned the course's learning objectives. These demonstrations are essential parts of communication and professional development skills.

Description of the Corsi-Rosenthal Box

The Corsi-Rosenthal box (C-R box) is a potentially infectious disease transmission mitigation approach that arose in August 2020. COVID-19, like respiratory syncytial virus (RSV) and influenza, is primarily spread through respiratory aerosols from infected individuals [9] [10] [11]. Transmission is particularly acute in poorly-ventilated indoor spaces. Many public schools in the United States, particularly those in the northeast, lack sufficient ventilation, and updates require substantial budget and time [12] [13] [14]. Conway-Morris et al. demonstrated that commercial HEPA air purifiers could effectively remove the size aerosols most associated with the transmission of COVID-19, but these units can be cost-prohibitive [15]. Lower cost, commercially available air purifiers do not effectively remove the aerosols most responsible for

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Implementation of Project-Based Service Learning building Corsi-Rosenthal Boxes

During the pandemic year, the UConn shifted to complete online learning in the middle of the spring semester of 2020. All project-based learning in ENGR 1166 was adapted to online experiments. After continuing the “at-home” learning through the fall semester of 2020, the University adopted a hybrid learning modality in the spring of 2021, where student cohorts of ENGR 1166 returned to the lab every other week to carry out a DIY air filtration project and design a manometer to test their design.

In spring 2022, when UConn commenced its in-person class schedule, we introduced, for the first time, the Corsi-Rosenthal (C-R) boxes (DIY Air Purifiers) Service Learning Project for all the 400 first-year engineering students for ENGR 1166 as their short-term project. At the beginning of this project, students were informed that all their units would be donated to the local public elementary school, which was the alma mater for some students. The primary goal of this service learning project was to inform the students about the persistent problem with indoor air quality in many public schools in the state, increase their moral reasoning and sense of responsibility, and to motivate them to build something as engineers to help school-going children.

The project was carried out by small groups (3-4 students) working in the First-Year Design Laboratory over four weeks (Figure 2 B). The importance of indoor air quality and how to mitigate the problems associated with poorly ventilated buildings were thoroughly discussed with the students through journal articles and real-life examples. Each week students were presented with an outlined lesson plan that described how to build and test the C-R boxes, and the ethical implications of this project were frequently discussed with them.

In addition to building the C-R boxes and discussing their impact, students also plotted graphs to quantify the aerosol concentrations in the air with and without the C-R boxes over a period of time. They validated the effectiveness of the boxes in reducing particle concentration. Students used the “Physics Toolbox Sensor Suite" app to collect and record data on the g-Force to understand how vibration levels varied with different fan speeds. Students were also asked to measure the noise level using the sound meter for each fan speed and how the noise level changed with distance from the fans. Sound Intensity (dB) over Distance (cm) graphs plotted by the students showed the noise levels. Depending on their findings, students had to suggest an ideal fan placement in the classrooms to ensure that the fans were not too loud during teaching sessions. Finally, many teams wrote inspiring personalized messages to the elementary students and decorated the C-R boxes, as they knew this was built to help the school-going students (Figure 2C).

Figure 2. (A) Corsi-Rosen box (B) ENGR 1166 students in First Year Design Lab building C-R boxes. (C) Personalized messages to elementary school students.

Students submitted engineering logs of their building process as part of their weekly group assignment. The engineering logs outlined their design process, project progress through Gantt charts, and future steps to improve the design of the C-R boxes concerning classrooms and student activities. They were also asked to reflect upon their testing methods and ethical implications. Instructors and teaching assistants also gave them constant feedback about their logs. At the end of the project, all the C-R boxes were donated to the local elementary schools.

Students highlighted their learning experiences through this PBSL experience in their Engineering Portfolios at the end of the course. Students reflected on how the C-R box PBSL helped them learn about iterative design, working in multidisciplinary teams, and communicating data and scientific ideas in their engineering portfolios. During the pandemic, these first-year engineering students had completed their final year in high school remotely, under lockdown. Thus, this C-R box project had a meaningful and personal impact since students could relate to their experiences during the pandemic and were motivated to build the DIY filtration system to positively impact the lives of school-going children. This activity provides insight into how PBSL shapes first-year engineering students' identities, morals, attitudes, and learning experiences. These efforts provide evidence of how such a meaningful project may promote student motivation and understanding on multiple cognitive levels.

Analysis of Student Perspectives on the Impact of the C-R Box Project

At the end of the semester, each student submitted a final engineering portfolio video where they needed to provide two examples of how they met learning outcomes #2-5 in the course. The students needed to list the activities and explain how their participation in each activity demonstrated how they met the objectives. For the Spring 2022 semester, we qualitatively analyzed the final videos of 24 of the 411 students in the course. As a result of the relatively low number of students who consented, we could not complete the full analysis we intended during the Spring 2022 semester. Instead, we identified how many students listed the C-R box project as an example for each learning objective and briefly discussed how students linked the project to the objectives, as shown in Table 1.

Table 1. The number and percent of students listing the C-R box project as an example for each learning objective.

Learning Outcomes	Number of Students	Percent of Sample
2) iteratively design, build and improve a device or a process to meet a specified need within given constraints	5	21%
3) work effectively in multidisciplinary teams	23	96%
4) communicate effectively by presenting work in a structured, clear, and engaging way to a range of audiences	16	67%
5) apply the ethical responsibilities of their profession to the design process	12	50%

Students strongly associated the project with helping them learn to work effectively in multidisciplinary teams (learning outcome #3). Specifically, they mentioned working with other students they had never met. They stressed working with each other's strengths and weaknesses and the importance of having the team, and multiple hands, to efficiently complete the project in the time frame provided. Finally, they highlighted the importance of having everyone on the team inspect the final design to catch any potential defects.

Two-thirds of the students also identified ways that the C-R box project helped develop their communication skills (learning outcome #4) through the development of graphs to communicate the data, Gantt charts to communicate the timeline and keep the team coordinated, engineering logs to communicate the process, and instructions and QR codes on the box to communicate with the end users. Half of the students identified the C-R box project as helping them apply ethics in engineering (learning outcome #5). Specifically, they raised the need to ensure that the design worked (i.e., the importance of testing) as intended so that it would protect people, the need to consider the noise level, so it did not distract the K-12 students in the classroom, and the need to properly document their work and credit sources. While the C-R box project was not specifically intended to help the student achieve learning objective #2 (iterative design), several students did mention the need for checking work, specifically the integrity of the duct tape, and suggested future improvements. Overall, the student acknowledged how this project contributed to completing the semester's learning outcomes while having different perspectives on how the project contributed.

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