Project-based Learning as a Vehicle for Social Responsibility and Social Justice in Engineering Education

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This work-in-progress paper will provide a brief overview of PBL – the main principles, opportunities, hurdles, requirements, and a framework of best practices. Then, it will make an argument for using PBL as a vehicle for teaching SR and SJ, as compared to other methods of teaching. Next, concrete examples of how three faculty members have used PBL to deepen students' understanding of SJ and SR will be presented. As these courses are being completed throughout the 2017/2018 academic year, only limited analysis as to their efficacy in teaching SJ and SR has been completed, and experiences teaching these courses compared. Finally, the paper will provide suggestions and a set of preliminary best practices for faculty who would like to bring SJ- and SR-themed PBL into their own courses.

Engineering problems are complex and have many constraints that go beyond technical constraints, such as fulfilling corporate interests, meeting community priorities, and protecting the environment. Often, these problems are difficult to solve in ways that are satisfying to all involved parties, and are intertwined with complex societal elements such as activist debates, nationalism, and poverty. Thus, engineering problems are complex, and often lead to challenging ethical situations for engineers[1].

In 2005, the National Academy of Engineers' *Engineer of 2020* stated that there is "a disconnect between engineers in practice and engineers in academe"[2]. Practicing engineers work on complex, open-ended, sociotechnical problems, whereas typical engineering programs teach students to solve confined problems, limited in scope to the technical, that have only one answer[3]. In response to the misalignment of engineering education and practice, significant academic research has also been accomplished in the broad space of engineering with context and communities; these include NSF-funded research, the International Journal of Engineering, Social Justice and Peace, and the Synthesis Lectures on Engineers, Technology, and Society that has incorporated into more and more courses around the country within engineering programs that recognize the value of changing the status quo of higher education.

Project-Based Learning (PBL) offers promise for providing engineering students an avenue for bridging this "disconnect" by providing practice solving complex, open-ended problems with socio-technical contexts. PBL is a pedagogy that centers curriculum around projects that involve students in design, problem solving, decision making, and other investigative activities. Students engaged in PBL typically work autonomously over extended periods of time to create realistic products or presentations[4]. These assignments provide opportunities for students to solve complex, open-ended, *socio*-technical problems, and to practice serving specific groups of people in our society[3-6]. In addition, PBL enriches students' learning, retention and commitment by enhancing their interest, motivation and ability to see the relevance of classroom activities to solving real world problems[5–8]. PBL is an excellent vehicle to help students recognize the intertwined ethical, social and technical dimensions of engineering, as called for by ABET outcomes f, h, and j [9]. This also allows for deep, authentic learning of important themes such as social justice (SJ) and social responsibility (SR), which otherwise currently exist primarily on important fringes of mainstream engineering curriculum.

SR is a complex topic that most engineers would define quite differently. Some previous research shows the diversity, and sometimes misalignment, of definitions by engineering faculty[10] and students[11]. There is not one definition that is widely accepted, but rather a spectrum that spans from narrow to expansive. Some scholars have called this the difference between microethical (health and safety) and macroethical (sustainability, compounding effects, contextualized problem solving) responsibilities of engineers[12]. Research in recent years has qualitatively and quantitatively explored the ways that engineering students think about SR and how these ideas change over time[13]. One recent article even described how SR attitudes, in addition to many other influences, were a factor in students' decisions to leave engineering[14].

The timing and context of these efforts at the university are relevant. The following opportunities were created for students and faculty in a larger effort to create distinctive and impactful learning experiences for all students:

- A new center for teaching and learning that supports innovative and active learning was opened.
- Teaching faculty, which comprise 20% of the faculty on campus, are encouraged to participate in ASEE and engineering education scholarship and applications within the classroom
- A new division and major were recently created that provides the opportunity to re-design educational offerings and incorporate PBL.
- Through NSF-funded research projects outside of the work presented in this paper, faculty from multiple departments already enjoyed strong relationships that were combining new pedagogies with more traditional engineering programs such as mining and petroleum engineering; these programs had mutual goals towards improving the Corporate Social Responsibility (CSR) offerings on campus.
- An established campus program offers minors in Engineering for Community Development and Leadership in Social Responsibility
- The authors attended a PBL workshop at Worcester Polytechnic Institute where the following interventions could be intensively planned in a supportive and productive environment over 3 days. These efforts led to some of the classroom interventions explained below.

Methods

Project-Based Learning was employed in three different classes to help engineering students link technical issues with social responsibility and social justice issues. Each class is unique in their offerings, and each project was unique in its implementation. The duration of the projects, course content, and course structures all varied, but had common core goals related to the motivations described above. A description of each intervention follows.

Petroleum Seminar

Petroleum seminar is a required skills-development course for all petroleum engineering students. The main learning outcomes for the course focus on communication, team, and professional skills, along with evaluating how engineering projects and problems are affected by many issues, both technical and non-technical. These outcomes were integrated into a semester-

long project that was the focus of all of the assessments/assignments in the course. SR was one focus that was intentionally integrated into the project; the oil and gas industry frames social and environmental challenges in relation to SR, which is referred to as health–safety–security–environment and social responsibility (HSSE-SR as it is called by the Society for Petroleum Engineers). This allowed students to mimic the processes and procedures that their future employers use to reconcile their business practices with social and economic needs in the areas that they operate.

For their project, students worked in groups and selected contemporary, and/or controversial topics to analyze. The goal was to determine how the technologies/situations/events could have been handled differently to result in a better reputation for the oil and gas industry. These analyses were expected to include both technical and non-technical aspects. As part of the activities designed to help students frame their topics, they read papers that helped to frame how the public's perception of the oil and gas industry may differ from those who are involved in it. They completed a stakeholder analysis to learn about the different perspectives that different groups have, and determine how to best address their concerns. Speakers from a local oil and gas company came in and discussed how they engage the community, listen empathetically, communicate extensively, and deal with difficult social and environmental situations. Their conclusions, based on independent research, engagement with industry and community members, and the above activities were communicated in written and oral formats or both technical and non-technical audiences.

A pre- and post-survey was administered to the class at the beginning and end of the semester to measure how their stances regarding HSSE-SR changed over the course of the project. It was done in class, electronically, for a small amount of credit. The data are still being evaluated, however there are some preliminary observations and conclusions that can be gleaned from assignment performance. Before the project, it is anticipated that student attitudes were mixed between a) wondering how it was applicable, b) being excited to learn more about it, and c) being tired of the topic appearing in their courses, which takes away from time spent on "real" engineering. During the semester, the students interested in the topic were appreciative and engaged. Others felt that social responsibility was too much of a focus in the course and participated only because a grade was involved. Some were even bitter about the entire course because they didn't feel that they should be studying "non-technical things" that would not help their careers so close to graduation. These views need to be considered within the context that petroleum engineers tend to be tightly focused on the business and technical sides of the industry. Despite these views, the authors hope that all students will discover the reality that social responsibility, community and stakeholder engagement, and ensuring personal and environmental health are key business practices that lead to a social license to operate and business success.

Properties of Reservoir Fluids

Social responsibility was incorporated into the technical petroleum engineering course, Properties of Reservoir Fluids, through a team PBL assignment. In conjunction with the course learning objective, "Describe properties of oilfield waters and their solution chemistry," student teams researched four topics of community concern: drinking water, water consumption, crop

irrigation, and oilfield waste. Students provided answers to Stakeholders' technical questions and societal concerns during a simulated community meeting. Alumni, faculty, and students served as concerned community stakeholders and evaluated the team projects.

In development of their interactive demonstration, students researched community impacts and local oil and gas companies' HSSE-SR activities. Project deliverables included a written summary of the presentation justifying their responses to community concerns about the topic each group investigated; a visual aide with tangible components that were demonstrated during the community meeting; and an oral presentation wherein students responded to questions and concerns by community stakeholders about the water issue that each team investigated.

Student feedback on this assignment was very positive. Students expressed their enjoyment of self-directed work on a technical topic that impacts communities and working in teams. Additional comments supported that the PBL was worthwhile, interesting and fun. The project has been enhanced and continued in the subsequent course offering, Mechanics of Petroleum Production. An additional component of "leadership in resource management" has been added to the PBL assignment. This continuation of PBL provides an opportunity for students to explore how engineering decisions affect communities, provide their team's definition of leadership, demonstrate how CSR is effectuated and sustained through leadership in their project. The same group of students who were enrolled in the Properties of Reservoir Fluids class are enrolled in the Mechanics of Petroleum Production course. Therefore, pre- and post-course data may be assessed.

Pilot Course: Engineering for Social and Environmental Responsibility (ESER)

In support of the Engineering for Community Development (ECD) and Leadership in Social Responsibility (LSR) minors, the ESER course was created to serve as a foundational prerequisite for second year students. The broad intention was to expose students to the complex context of any issue that engineers would address. Each week of the course, the students would learn a different part of the engineering profession and the history that created the conditions for this particular case to occur.

This course was an introductory survey to how engineers think about and practice environmental and social responsibility, an idea which has served as the foundation of the engineering profession. Broad themes were integrated throughout the semester. These included environmental sustainability, social and environmental justice, social entrepreneurship, corporate social responsibility, and communication and engagement with the public. The themes were explored through a variety of historical and contemporary case studies, and through a range of technologies, from those for basic needs (water, agriculture, housing, and health), to emerging technologies (nanotechnology, energy systems, information, and neurological), to those included in the National Academy of Engineering's Grand Challenges.

The PBL element of this course was for each student to choose a specific issue about which they were passionate. From there, the course scaffolded assignments that allowed the students to more fully understand all of the human and non-human actors surrounding their issue, how to

prioritize these actors in decision making, and to situate themselves and technology as important to addressing the issue, but not necessarily central.

While only seventeen students completed the course, each of them developed a deep understanding of the complexities surrounding their chosen issues. The seventeen included the Yemeni water crisis, factory farms in North Carolina, support for the arts in Albuquerque, and healthcare for the homeless. Through the various activities such as actor-networks, memos to decision-makers, and a final trade fair to the university community, it became clear that the passion these students found in their project, even though it was not hands-on, led them to a much deeper and expanded understanding of their potential responsibilities as engineers in the future. Most students shied away from describe their work as contributing to social justice as it was too politically charged and ambiguous. Some had taken an Engineering and Social Justice course, so the term came up, but was not actively used with a broad audience in their final presentations.

Progress to date

Each PBL intervention has preliminary indications, anecdotal and through reflections, that students were able to consider social responsibility and social justice issues in context with engineering problems in both technical and non-technical offerings.

In the Petroleum Seminar course, end-of-semester reflections show that evaluating an oil and gas issue in the context of an open-ended project allowed for students to grapple with social responsibility and social justice issues. Many students wrote comments similar to the following: “I realized that a problem… cannot simply be looked at from an engineering standpoint. Most of the issues stakeholders faced were non-technical. This meant a non-technical approach had to be taken to address their concerns.” Some students also went further to begin considering the needs of people in the context of engineering projects: “… facts don't always come across to everyone. People want to be specifically be heard and understood. This is an important aspect to know when working on projects in the future.” And some considered their own ethics and views in relationship to SR and SJ regarding how people affected by projects are treated: “The one thing I struggle with is finding a balance between the business side of myself, and the empathetic side of myself. The business side can easily come up with the key stakeholders that need to be addressed, but often overlooks the fact that the people with no voice and no one to protect them, desperately need advocates within the oil and gas industry to make sure they are not overrun. On the other hand, the empathetic side of me could happily take forever, and come up with a solution which perfectly fits everyone's needs--even though a perfect solution that makes everyone happen usually doesn't exist."

Limitations and Future Work

This work is a study of whether PBL is an effective classroom intervention for helping students learn Social Responsibility and Social Justice. Every course is different, as are the instructors and key outcomes. Students in different courses have different backgrounds and different contexts. As such, the surveys and assignments used in this study are not coordinated for a discipline-wide

analysis. Instead, they serve as illustrations of the general effectiveness of PBL as a way to learn Social Responsibility and Social Justice.

In the future, more analysis will be conducted through surveys to determine aspects of PBL that were effective, where improvements can be made, and to determine if there are some general trends and practices that would lead to students learning social justice and social responsibility through PBL. In addition, all three courses will continue development of the interventions used since they preliminarily seem to be successful. The future analysis will help guide what the next iteration of these projects will entail.

In addition, more project-based courses and projects will be developed on campus. The authors are providing a PBL workshop, mentoring interested faculty, and participating in faculty interest groups to continue to set the tone for the campus that PBL is an effective, essential tool for providing a high-quality education for our students that mirrors the needs of industry.

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