# SDG-focused project-based learning in engineering design courses with diversity and inclusion interventions

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## Abstract

This paper describes the framework of Sustainability Development Goals (SDG) focused team projects and ongoing interventions on diversity and inclusion in an engineering classroom. Some literature on classroom diversity and its effect on educational outcomes is discussed. SDG-focused project-based learning and students design work products are presented. Level of diversity in students' teams and its possible effect on team psychology and learning is discussed. The presented framework is currently being implemented in a freshman design course to identify individual or personal characteristics that students bring to an educational setting and their influence on learning.

## Keywords

SDG-focused project-based learning, Diverse Teams, Engineering Design

## SDG focused project-based learning

University training in problem solving is primarily done using decontextualized text-book problems. In the context of teaching & learning, engineering design is viewed as a technical problem-solving discipline where the engineering student is identified as problem solver – not problem definer. This process also assumes that communities are homogeneous entities and can be treated as a "client" or "customer"[1]. For many students, design means "design-for-Industry". In teaching and learning, it is important to use human-centered design problems defined with context. Students, as future engineers, should be taught the importance of listening to community and stakeholders to understand who benefits and who suffers when designing new products and structures that promote sustainable use of natural resources and protect the environment. The United Nation has recognized the development of Sustainable Development Goals (SDG) by 2030 as a priority. Higher education universities are working towards addressing these SDG with learning activities, academic projects, definition of competencies, courses, extracurricular activities, etc. that complement education through teaching–learning models[2].

A socio-technical project-based learning model[3] is currently used in a freshman-engineering design course. Contextualized design problems are assigned to engage students throughout the course. A situated cognition teaching / learning model[4] framework is used, where concept, context, and authentic activity are involved in student learning for negotiable meaning and socially constructed understanding. The socio-technical project-based teaching model engages students throughout the course by utilizing Computer-Aided-Design (CAD) problems that incorporate SDG-focused design problems within both individual and team projects. Figure 1 shows a couple of examples of students' design work products and a description on design

models addressing SDG 6 (Clean water and Sanitation) and SDG 15 (Life on Land). In Spring 2022, SDG-focused project-based learning is extended to incorporate diverse teams with interventions on supportive and inclusive learning environments with equal status conditions. The level of diversity in student teams and its possible effect on team psychology and learning and details on various interventions is discussed here.

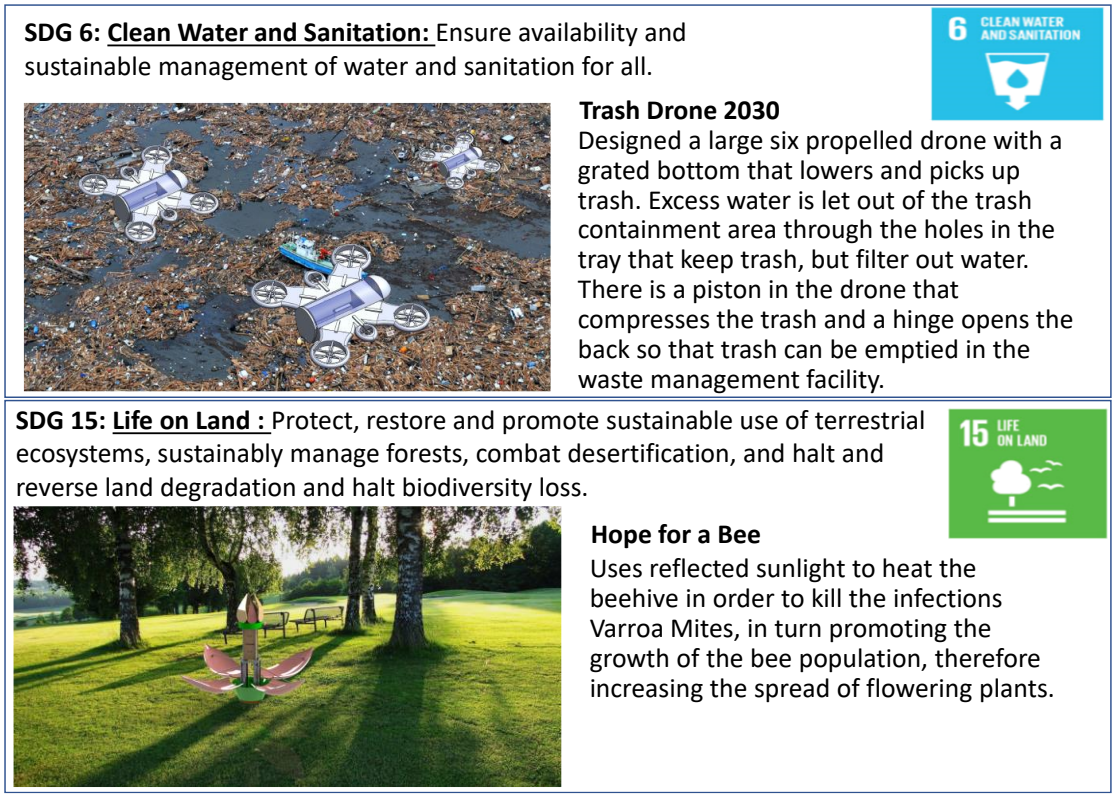


**Figure 1: Students design work products on SDG-focused team projects**

## Classroom diversity and educational outcomes

In recent years, changing demographics of the U.S. population drive growing attention by the National Academy of Engineering (NAE) and the American Society for Engineering Education (ASEE) on diversity and inclusion in STEM education and the workforce. This demographic shift suggests that the role of higher education will remain essential in training a work force that can both economically sustainable communities and forge relationships across the diverse populations that make up American society. The diversity that is increasingly part of American society needs to be reflected in the student body, faculty and staff, approaches to teaching, and in the curriculum[5]. Recent studies have also shown that racial diversity can improve educational outcomes such as complex thinking among students in college. In STEM fields such as engineering, encouraging inclusivity among undergraduate students from different economic, social, or racial and ethnic backgrounds can produce greater perceived learning gains.

The impact of diversity on students' self-perceived improvement through multicultural curricula and classroom activities is not well studied. Researchers have identified three aspects of diversity to facilitate understanding of the topic[6]: (a) structural, (b) interactional, and (c) classroom.

Structural diversity refers to the demographic representation of students from different backgrounds. Interactional diversity refers to the frequency and quality of interactions with diverse peers across numerous campus domains including, but not limited to, campus events and residence halls. Classroom diversity refers specifically to learning about diverse peers that occurs in formal instructional settings like classrooms, lecture halls, and laboratories. Research on interactions with diverse peers supports the notion that encountering others who have diverse backgrounds and perspectives can lead to interactions that promote learning and development.

## Diverse teams

Diverse teams change how team members coordinate, which can facilitate learning, but the success depends on various factors. One factor is the level of diversity. Surface-level diversity (e.g., demographics) facilitates learning by signaling to team members that they need to coordinate their informational resources more because there are identifiable differences between each team member.[7] However, deep-level diversity (e.g., expertise or training) can potentially inhibit learning because it produces representational gaps, or inconsistencies in how different team members understand the task, making the integration of diverse information more difficult.[8] Another factor that affects the benefits of diversity in teams is the power balance of the group. Diverse teams can lead to power imbalances due to privilege, which can affect the psychological safety of the team (i.e., feeling like it is safe to take an interpersonal risk[9]). Team members who do not feel psychologically safe may withdrawal from or assimilate with the team.[10]

In this work, diverse design teams composed with 'medium' diversity are considered, as this has been shown in prior research to lead to the largest learning gains in problem-solving and group skills.[11] Medium diversity is roughly defined as a 33% and 67% split, where the team can either consist of 33% majority group team members (e.g., white students) and 67% unrepresented group team members (e.g., students of color) or vice versa. The Comprehensive Assessment of Team Member Effectiveness (CATME) SMARTER Teamwork[12] system is used to facilitate the selection of diverse teams. During the early part of the semester, students complete a survey with questions asking about their race or ethnicity, gender identity, software skills, hands-on skills, schedule, and more. The instructor uses this information to select teams with a 'medium' level of diversity. CATME is also used to facilitate peer evaluation throughout the teamwork portion of the course.

To counteract possible power imbalances due to the team's composition, the instructor facilitates an identity safe or inclusive learning environment with equal status conditions where all individuals are welcome, supported, and valued. Students are encouraged to create an inclusive environment in their teams by signing a team contract where they establish guidelines for the team and agree upon a set of rules selected by the instructor.[13] The contract rules include behaviors such as interacting respectfully, maintaining confidentiality, meeting team responsibilities, showing up on time, holding everyone to high standards, disagreeing academically rather than interpersonally, and giving credit where it is due.[14] Teams agree to uphold the rules for the length of the team project. Each team member shares a joint responsibility for enforcing the rules within the team.

## Ongoing interventions and assessment plan

The following interventions are currently implemented in a freshman engineering course. (i) Identify individual or personal characteristics that a student brings to an educational setting (teaching / learning, design projects, etc.). (ii) Just-in-time lectures to introduce engineering design with historical context relating to social and cultural aspects. (iii) Through SDG-focused socio-technical project-based learning, provide opportunities in the curriculum activities / humanitarian design projects that explore connections between socio-cultural resources and the practices of engineering design. (iv) Facilitate diverse (race/ethnicity and gender) student design teams encouraging student collaboration and interactions with others who are of different economic, social, or racial/ethnic backgrounds and (v) create supportive and inclusive learning environments with equal status conditions. The objectives of these interventions include, identifying individual or personal characteristics that students bring to an educational setting and their influence on students learning. The ongoing assessment plan includes (i) pre and post surveys to assess the level of students' knowledge gain on sustainability aspects and perceptions on various interventions. (ii) Post activity reflection and quality of student work products in both individual and team projects (a) to understand the effect of socio-cultural aspects each student brings on design and (b) to understand the role of diverse teams on psychological aspects on team interactions and learning.

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