Engineering for People and Planet: A Multidisciplinary Course Proposal for Engineers on the UN Sustainable Development Goals

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WIP - Engineering for People and Planet: a Multidisciplinary Course Proposal for Engineers on the UN Sustainable Development Goals

This paper proposes a multidisciplinary course introducing students to critical engagement with the intersections between Engineering, Ethics, Society, and the Environment, emphasizing the United Nations Sustainable Development Goals (SDGs). Founded in pedagogical theory based on current practices from across multiple disciplines, the structure and coursework of the class allow students to explore varied perspectives and approaches to addressing global problems. This paper argues that engineering students need to engage with the SDGs in the context of engineering problems to equip them as innovative problem solvers. Further, evaluating engineering projects and processes simultaneously through social, political, and environmental lenses expands the context and considerations taken in the problem-solving process.

The proposed course will be piloted through the Civil and Environmental Engineering Department at California Polytechnic State University, San Luis Obispo (Cal Poly). To encourage collaboration between students from diverse disciplines, the course will be offered to students in the College of Engineering and students enrolled in the Science, Technology, and Society (STS) minors program in the College of Liberal Arts. Through interactive class exercises, multidisciplinary topic readings, case study examinations, and personal reflections, students will conduct detailed exploration into ethics, sustainability, and problem-solving processes. The overarching objectives for this class are to equip students to identify, analyze, and address problems at the intersection of engineering, technology, and personal and societal value systems. Students will be challenged to develop and utilize problem-solving approaches from across disciplines in the context of both technological and social challenges, using the SDGs as a framework.

Understanding and applying sustainability principles is essential to problem-solving for both the short term and long term. Some argue that the planet is our greatest limiting factor in society and development. Students will discuss and apply key concepts in pollution prevention and waste minimization, and work toward understanding the difference between prevention-based solutions and reactionary solutions. Students will explore challenges in sustainability from across multiple disciplines and utilize multidisciplinary problem-solving approaches to address these challenges.

Engineering solutions to complex problems

It is becoming increasingly obvious that the major challenges facing the world today – climate change, lack of worldwide access to adequate resources, health and human rights crises, and more – require complex, multi-faceted solutions [1], [2]. As such, developing these multi-faceted solutions requires a multidisciplinary approach. Policy-makers and leaders, communications and community developers, scientists and health-care professionals, economists, engineers, and many other disciplines must all come together if there is to be hope to develop workable and sustainable solutions [3]. Leaving the problem definition and solution development in the hands of anyone of these groups alone will not suffice [3].

The UN Sustainable Development Goals (SDGs) define the 2030 global agenda for strengthening universal peace for people, planet, and prosperity. Established in 2015, the 17 SDGs and 169 targets were expanded upon from the UN Millennium Development Goals that were not achieved [4]. The SDGs, presented in Table 1, have become a benchmark description of 17 key challenges that must be addressed to achieve equitable and sustainable opportunities for all [3], [4].

Table 1. UN Sustainable Development Goals [4]

Goal	Description
1. No Poverty	End poverty in all its forms everywhere
2. Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3. Good Health and Well-Being	Ensure healthy lives and promote well-being for all at all ages
4. Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5. Gender Quality	Achieve gender equality and empower all women and girls
6. Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all
7. Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable, and modern energy for all
8. Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all
9. Industry, Innovation, and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10. Reduced Inequalities	Reduce inequality within and among countries
11. Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient, and sustainable
12. Responsible Consumption and Production	Ensure sustainable consumption and production patterns
13. Climate Action	Take urgent action to combat climate change and its impacts
14. Life Below Water	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development
15. Life on Land	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

16. Peace, Justice, and Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17. Partnerships for the Goals	Strengthen the means of implementation and revitalize the global partnership for sustainable development

The breadth of the SDGs demonstrates the need for multilateral and multi-stakeholder collaboration. While the specific role for engineers in achieving the SDGs is not clearly defined, it is clear that science and technology must play a role in making progress toward any of the SDGs [3]. This is emphasized through the establishment of the collaborative UN Multi-Stakeholder Forum Science, Technology, and Innovation for the SDGs [4]. The call for collaboration from members of civil society, private sector, scientific community, and UN entities establishes the critical role of engineers and scientists in informing strategies and in actualizing the SDGs.

The role of engineers in achieving the SDGs takes many forms. The mobilization of young people and capacity building for multidisciplinary problem solving through engineering education is critical in supporting the implementation of the SDGs [5]. The SDGs provide a framework for understanding sustainable development priorities, which in turn supports engineering research agendas [6]. To ensure climate action and achievement of all SDGs, engineers are called upon to be a part of the transformational shift needed in the global economy and approaches to development [6]. To ensure good health and wellbeing for all people, there are calls for engineers to develop innovative, multidisciplinary approaches to public health solutions [7]. Despite the recognition for the variety of roles engineering has in actualizing the SDGs, there has been limited curriculum development that heavily integrates the SDGs into engineering problem-solving.

Beyond the SDGs themselves, there is heightened interest in the role of technology and engineering in addressing what has traditionally been considered “social” problems [8], [9], above and beyond simply addressing basic human needs [1]. Engineers may even be more effective if they embrace a role as a “bridge” between the stakeholders and the policymakers in implementing solutions to such challenges [3], or even serve as policymakers themselves in designing and effecting social change [10]. To effectively take on these nontraditional engineering roles, engineers themselves must stretch beyond a traditional engineering background. Issues such as social or environmental justice, global cultural considerations, and even engineers’ potential as policymakers are rarely discussed within the context of engineering-focused conversations or classes [8], [11], [12]. However, it is only engineers with a multi-faceted awareness of sociotechnical issues who will be able to play a key role in addressing those global challenges [2], [10], [11].

We propose that rethinking a traditional approach to engineering education will be an effective way to develop multidisciplinary skills that engineering students need to contribute – as they must – to solving major global problems. An engineering program that contextualizes the social challenges inherent in technical problems, and also investigates technical solutions to apparent social issues, will help engineers develop these sociotechnical skills in context along with their developing engineer mindset [1], [8]. That is, opening engineers’ minds while they are students, still developing their ideas about their roles and responsibilities as future engineers, will help them more readily embrace their opportunities to effect global change [1]–[3]. The SDGs provide an ideal framework for developing this multi-faceted perspective on what it means to be an engineer in today's society, and how to prepare to tackle today's global challenges [2], [3].

Course pedagogy

Traditional engineering education has not emphasized the development of multidisciplinary skills or consideration of challenges from multiple perspectives. Traditional programs isolate topics such as social issues, ethics, and communication skills to General Education classes, instead of focusing on strictly technical content in engineering classes [1], [8], [12], [13]. In a traditional program, the interaction between engineering and society is limited to a focus on business and project-related economics [1], [12]. Silos between the humanities and engineering are perpetuated through traditional education, as humanities courses rarely include technical content either [12]. The capacity to approach a problem holistically is left to the individual, rather than explicitly supported during the educational process [10]. This dichotomy between the role of engineers as technical matter experts and their responsibility to understand the social elements of a given project may then perpetuate into professional practice [12].

A study into the philosophy of science and engineering offers some explanation for this educational split. The Scientific Method, which forms the foundation for much of engineering work and other STEM endeavors, deliberately tries to remove any social or subjective influences from its problem-solving approach [2], [8]. As such, engineering is considered "pure" compared to social endeavors that inherently cannot be effectively separated from such influences [8]. Held in this high regard, engineering is sometimes seen as the optimal solution for solving even those "messy" social problems. Like a *deus ex machina*, the engineer descends, creates a technical solution to save the day, and rises again to his or her lofty position above the fray [8]. This ingrained mindset among engineers can lead to people's identity as an engineer superseding even national or cultural identities [1]. The values or principles taught alongside the Scientific Method in early engineering education seem to define a cross-cultural engineering ethic or identity [1]. The role of being an engineer becomes separate and above an individual's own culture [1].

However, such a mindset is dangerous. Engineering is not done in a social vacuum; engineering endeavors necessarily interact with the society they are employed. Engineering solutions become part of the society they are enacted in and are in turn hold social, political, cultural, environmental, and economic dimensions. Effective engineers and effective solutions must consider the contextual needs of the society in which they are implemented and potential implications for all members of society. Without an education that acknowledges this fact, practicing engineers find themselves ill-prepared for the multidisciplinary considerations necessary for the implementation of their solutions [1], [11], [14].

The American Society of Civil Engineers and other professional engineering societies have started to emphasize the need for both engineering students and practicing engineers to understand their roles in developing sustainable solutions, "with a special focus on the social aspects of sustainable development" [3], [9]. To support this goal, ASCE's Body of Knowledge has been adapted, which defines the essential concepts and skills necessary for entry into the position of a “professional” civil engineer . Knowledge of social science and the humanities has now been placed at the same fundamental level as math and natural science [10]. Further, this goal is expanded upon by ABET, the body which defines the learning objectives (LOs) and educational goals necessary for US-accredited engineering programs [8]. Of the seven ABET Student Objectives, two explicitly acknowledge the social and global implications of engineering design and decisions. Others focus on effective communication, teamwork, collaboration, and inclusivity [15]. The majority of the ABET Student Objectives now emphasize that engineering students must develop skills beyond those emphasized in traditional engineering programs [11].

To develop the multidisciplinary awareness students will need as professionals, engineering education must move beyond the traditional siloed approach to teaching both technical skills and social considerations [3], [8]. Developing effective sociotechnical skills requires student development of technical skills *in context* with social awareness and critical thinking skills [8], [10]. Teaching engineering in a social context must engage beyond the technical solution to the social ramifications – including potential unintended ramifications – of that solution [16]. This includes an understanding of not just the technical or infrastructure system, but the implications for sociocultural systems in society [3], [12].

Current common alternative approaches to traditional engineering education focus on social justice, ethics, and explicit preparation of “professional” skills necessary for a multidisciplinary career. These approaches provide a scaffold for critical aspects of sociotechnical education. A social justice focus leverages technological solutions to equalize disadvantages among marginalized members or groups of a larger social structure [8], [12]. Critical aspects of sociotechnical education are supported by the course design through the facilitation of students’ personal moral development and explicit directing of technical education [8], [9]. A focus on social justice issues encourages students to question the traditional social structure and the responsibilities of engineers within that structure [8], [14], [16].

Despite the standardization of engineering ethics in engineering curriculum [15], the scope is typically limited to a single class within a course (i.e. “Professional Practices”). To meaningfully engage students beyond the Code of Ethics, engineering ethics need to become a comprehensive element of engineering curriculum. This supports students in understanding the actual implication of those codes on practice within the larger social framework [17]. Further, a larger consideration of ethics must examine global contexts and how cultural values that vary across the globe may accept or conflict with the standard Canons of Ethics taught in most engineering programs [1], [17].

Sociotechnical skills can also be developed through a comprehensive curriculum concerning professional skills such as critical thinking and multidisciplinary coordination [3]. Writing practice in context, for example, encourages both consideration of how to communicate engineering concepts effectively with other groups and at the same time allows for the reflective process necessary to reinforce learning [13]. Future professional work will involve effective communication or teamwork practice across diverse stakeholders frequently [12].

Bringing elements of social justice, ethics, and professional attitudes together in engineering education provides a strong foundation for sociotechnical skills. Further, enacting these skills in the context of the SDGs provides students with a framework to explore their role in addressing multidisciplinary, complex challenges. This work in progress paper lays out a curriculum intended for upperclassmen engineering students to develop sociotechnical skills and critically engage with the SDGs.

Course pilot design and curriculum

The course learning objectives include:

1. Identifying the role of engineers in achieving the Sustainable Development Goals and the 5 Ps.
2. Identifying personal values and perspectives on the role of engineers and technology in society.
3. Understanding of complex problems in the US and globally.
4. Understanding that engineering as a social process, engineering both shapes and is shaped by society.
5. Recognizing the intersectionality of engineering and real-world problem-solving.
6. Understand the importance and identifying how engineers can work with other disciplines to improve the sustainability of engineering design and problem-solving approaches.
7. Applying sociotechnical skills to address potential implications from the development of technical solutions.
8. Effectively communicating across disciplines.

To meet the course learning objectives, students will be challenged to identify, develop, and utilize problem-solving approaches from across disciplines in the context of both technological and social challenges. This course engages students through interactive class exercises, multidisciplinary topic readings, case study examinations, guest lectures, and personal reflections. With the SDGs serving as a framework to engage students in complex, multi-faceted problems, students will be able to explore the various ways engineering intersects with sociocultural systems. Further, this course is founded in pedagogical theory based on social justice, ethics, and professional practices in engineering, supporting both the development and application of sociotechnical skills. An overview of course topics and assignments is provided in Table 2.

Table 2. Course topics and assignments

Week	Class Topics	Assignments

1	Role in society and as an Engineer Engineering as a social process Sustainable Development Goals 5 P’s	Survey: survey based on course objectives to assess the impact of curriculum Writing: self-reflection on personal values, role of engineers in society, and sustainable design Reading: Regulating Risk: Implications of the Challenger Accident [19] Reading: Chapter 1: The Age of Sustainable Development [20]
2	Complex Problems Sustainability – social, cultural, economic, environmental Sustainable design	Writing: choose an SDG for study for project and write one-page reflection on why Project: form groups for case study Reading: Chapter 1: Anthropology and Development: Challenges for the Twenty-First Century [21] Reading: Chapter 1: Freedom as Development [22]
3 - 4	Goal 6 - Clean Water and Sanitation	Project: group work on case study Writing: individual reflection on intersectionality of chosen SDG, Goal 6 and the project Guest lecture and discussion: lecture on inequality and health from professor in Social Sciences Department Reading: supplementary reading(s) determined by guest lecturer
5-6	Goal 13 - Climate Action	Project: group work on case study. Writing: individual reflection on intersectionality of chosen SDG, Goal 13 and the project Guest lecture and discussion: lecture on principals of resilience from professor in Social Sciences Department Reading: supplementary reading(s) determined by guest lecturer
7-8	Goal 16 - Peace, Justice and Strong Institutions Intersectionality of SDGs	Project: group work on case study Writing: individual reflection on intersectionality of chosen SDG, Goal 16 and the project Guest lecture and discussion: lecture on technology and

		policy from professor in Political Science Department Reading: supplementary reading(s) determined by guest lecturer
9-10	Final Presentations	Group presentations on case study with a focus on the SDGs and 5P's
Finals	Group discussion on intersectionality of SDGs, the role of engineers in reaching SDGs, and engineering as a social process	Survey: survey based on course objectives to assess the impact of curriculum and compare with initial survey Writing: self-reflection on personal values, role of engineers in society, and sustainable design and comparison with initial reflection

The first two weeks of the course focus on providing an overview of the SDGs and complex problems. While this course introduces engineering students to all 17 SDGs, students will primarily unpack three SDGs (Goal 6, Goal 13, Goal 16) and the 5 P's: People, Planet, Prosperity, Peace, and Partnership [4]. This is to ensure ample time to unpack each concept and discuss the intersectionality of the SDGs and 5P's in lecture and for students to engage with the other SDGs through coursework. Students will select one additional SDG as inspiration for a term-long group service-learning project. Three guest lectures that align with the respective SDG will be given by professors from the Social Sciences or Political Science departments. The goal of including guest lectures is to provide alternative perspectives, incite discussions, and demonstrate the importance of communicating and collaborating with experts across disciplines.

Service-learning projects are intentionally structured to engage students in activities that address human needs and provide a purposeful learning experience [18]. Incorporating a term-long service-learning project encourages collaboration and critical engagement with the material and peers. Students will form small groups (3-4 students) based on disciplinary background week two of the course. Each group will be provided the same case study based on a real-world problem, which will serve as the basis for their project. Further, students will individually select an SDG (excluding Goal 6, 13, 16) to unpack outside of lecture and in their group project. Each student in their respective groups will contribute different perspectives on the case study, based on their selected SDG. Students will be asked to analyze their assumptions and the potential implications of their case study through the lens of their selected SDG and as a group considering the SDGs collectively. This process will encourage students to critically engage with the context of the problem through social, political, and environmental lenses. Further, as students become their own "experts" on an SDG, they will need to communicate across areas of expertise to align their project priorities with each SDG. Students will also be asked to consult with professors outside of the College of Engineering throughout the case study.

As the course final, students will present their analysis of the given case study as a group, encouraging each team member to understand how the intersectionality of the SDGs and in turn technical and social systems. Students will reflect on the importance of collaborating with each other, consulting with professors from outside of the College of Engineering, and how these interactions apply to their future roles as professionals. While all of the students will be given the same case study, each team will provide unique solutions and perspectives based on their chosen SDGs and the intersectionality of their SDGs.

To encourage self-reflection outside of a group setting, students will individually reflect on the intersectionality of chosen SDG, the project, and the SDGs covered in lecture. Further, students will reflect on their personal values, the role of engineers in society, and sustainable design at the beginning and end of the course. This will encourage students to reflect on the course material, project, and personal value systems throughout the course.

Implications and future work

To understand the impact of this pilot course, student reflections will be collected and analyzed based on a survey and reflection papers. On the first and last days of class, the students will be asked to fill out a survey based on course objectives. Questions will ask students to rank the importance of different factors in engineering and their awareness of sociotechnical considerations on a scale of 1-5. Results will be quantitatively analyzed to understand the impact of the curriculum on reaching course objectives. The analysis will be supplemented with qualitative evaluations based on personal reflections writings assigned on the first and last days of class.

Questioning assumptions and evaluating the context of a technical problem from multiple perspectives will better equip future engineers to make informed decisions and adapt to a rapidly developing world. In turn, understanding the engineering process will better equip future social and political leaders to balance scientific and technological impacts on societal institutions and make well-reasoned decisions. Further, this course acknowledges that no single discipline can solve society’s most complex problems. Through coursework pedagogy and topics covered, this course encourages society’s problem solvers to value the importance of multidisciplinary teams and equips them with the tools to collaborate and communicate effectively across disciplines. The development of this course addresses the critical gap in engineering education concerning the role and potential of engineering in creating a sustainable world. After the course is piloted, an analysis of the course design and the curriculum will be completed based on student reflection essays and the course reflection survey and will be disseminated as a conference paper.

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