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Engineering and Climate Change: A Liberal Education Approach to Sustainability

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Abstract

Engineering plays a crucial role in addressing climate change, necessitating a shift towards interdisciplinary, values-driven education. This paper examines the development and implementation of a *Liberal Arts and Sciences Curriculum (LASC)* at a private university, addressing three core questions: WHY is such a curriculum necessary, WHAT are its key elements, and HOW has it been structured and implemented. Aligned with the United Nations' Sustainable Development Goals (SDGs), the LASC encourages students to transcend technical expertise and engage with broader societal and environmental issues. This paper highlights the Water-Energy-Food (WEF) Nexus as a key component of the proposed curriculum, aiming to equip students with the skills to develop sustainable resource management solutions—an essential global challenge. To evaluate the LASC's effectiveness in fostering climate change preparedness, a mixed-methods research protocol is being implemented. This protocol includes outcome-based learning assessment, pre- and post-course surveys assessing changes in knowledge and attitudes about climate change, along with focus groups and interviews exploring students' experiences and perceptions of the curriculum's relevance. Longitudinal tracking of graduates will further assess the curriculum's long-term impact on their professional engagement with climate-related issues.

1 Introduction

The climate crisis poses a profound threat to the planet, disrupting ecosystems, destabilizing societies, and crippling economies. From rising sea levels and extreme weather events to resource scarcity and mass displacement, the impacts are far-reaching and deeply concerning. Engineers, with their ability to design and build the technologies that shape our world, play a pivotal role in both exacerbating and mitigating this crisis. Many of the technologies we rely on today, from fossil fuel-powered transportation and energy generation to resource-intensive industries, contribute significantly to greenhouse gas emissions and environmental degradation. However, engineers also possess the unique skills and knowledge to develop innovative solutions, such as renewable energy technologies, sustainable transportation systems, and climate-resilient infrastructure.

Despite this critical role, studies have shown that senior engineering students often hold misconceptions about climate change [1]. These misconceptions can include underestimating the severity of the crisis, lacking a comprehensive understanding of its interconnected impacts, and over-relying on purely technological solutions. Faulkner [2] and Cech [3] highlight how engineering education often reinforces a technical/social dualism, where technical aspects are prioritized while social, ethical, and environmental dimensions are sidelined. This dualistic framing limits engineers' ability to engage in sociotechnical thinking [4], which is essential for addressing complex sustainability challenges.

To effectively address the climate crisis, it is crucial for engineering education to go beyond the traditional focus on technical skills. There is an urgent need to cultivate a deep understanding of the social, ethical, and environmental implications of engineering projects [5], integrating principles of environmental justice [6], [7] and sustainability into the curriculum. This shift necessitates a re-evaluation of teaching methods, incorporating interdisciplinary learning, emphasizing real-world case studies, and providing opportunities for students to engage in projects that address real-world sustainability challenges. By fostering a deeper understanding of the climate crisis and equipping engineers with the knowledge and skills to develop sustainable and equitable solutions, we can empower them to play a crucial role in mitigating climate change and creating a more sustainable future for all.

This paper examines the development and implementation of an interdisciplinary Liberal Arts and Sciences Curriculum (LASC) at a private university. Designed to integrate sustainability principles into engineering education, the program aligns with *the United Nations Sustainable Development Goals (SDGs)* and equips students to address the multifaceted challenges of climate change. A key component of this LASC is the Water-Energy-Food (WEF) Nexus, a framework that guides students in exploring sustainable resource management. This paper will address three core questions: WHY is such a curriculum necessary, WHAT are its key elements, and HOW has it been structured and implemented.

2 Rationale for Curriculum Development (WHY)

Engineering education has historically prioritized technical problem-solving, frequently neglecting the broader societal and environmental implications of projects. However, as the world confronts the climate crisis, engineers are increasingly called upon to tackle complex, interconnected challenges such as decarbonization, sustainable resource management, and climate justice [8], [9]. These unprecedented challenges, characterized by their scale and urgency, demand that future engineers possess a broadened skillset encompassing ethical reasoning, systems thinking, and an understanding of social justice. Consequently, a fundamental reimagining of engineering education is imperative to equip them for this expanded role.

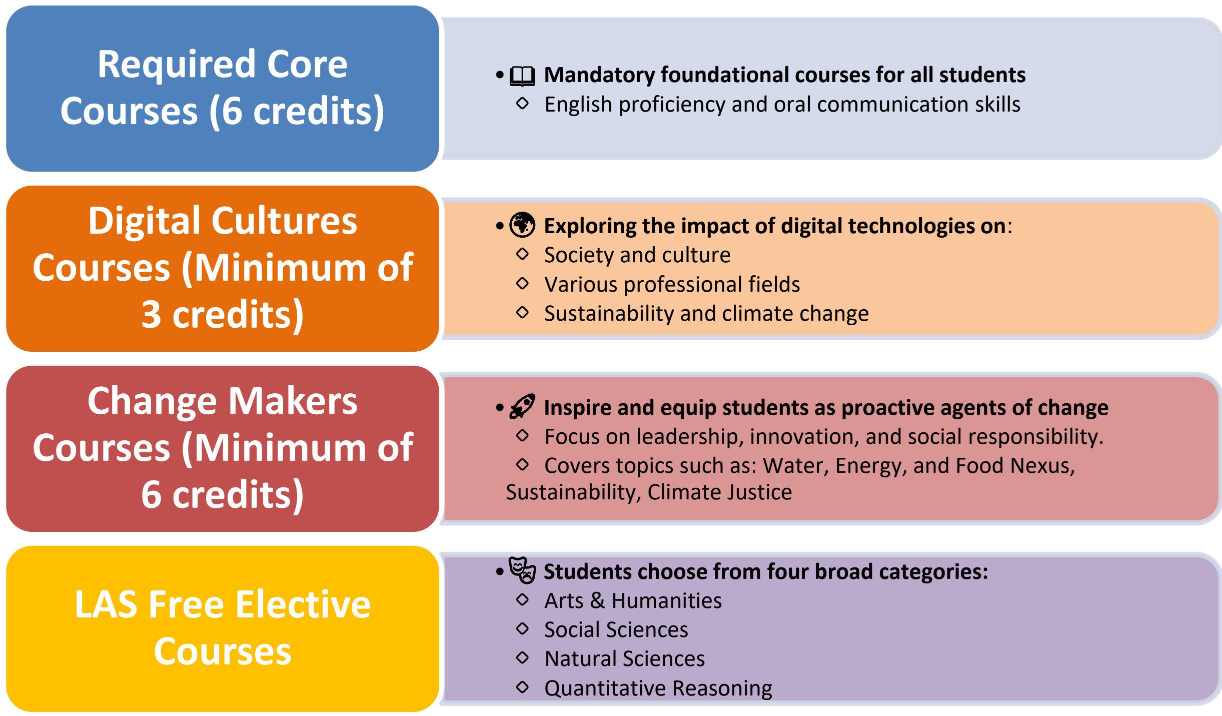
Engineering education's reliance on a technical/social dualism [2], [3] contributes to a fragmented understanding of climate change solutions. Traditionally, engineering curricula emphasize technological innovation while sidelining the social, ethical, and political contexts that shape environmental challenges. This mis-framing [3] limits engineers' ability to recognize how their work is embedded in broader societal structures, reinforcing depoliticized and technocratic approaches to problem-solving. As Leydens and Lucena [4] argue, adopting a sociotechnical perspective is essential to reframe engineering as a field that integrates both technical expertise and social responsibility.

Environmental justice provides another crucial lens for rethinking engineering education. The disproportionate impacts of climate change on marginalized communities highlight the need for engineers to engage with the principles of environmental justice [6], [7]. By incorporating environmental justice frameworks into engineering curricula, students can critically assess how technological solutions affect different communities and develop approaches that prioritize equity and inclusivity.

In fact, these challenges present unique, complex problems posed by climate change that cannot be solved by traditional engineering methods alone. These issues demand innovative thinking and the ability to navigate uncertainties, ethical dilemmas, and long-term impacts, making an interdisciplinary educational approach essential. The LASC aims to bridge this gap by incorporating interdisciplinary and values-driven education. By exposing students to case studies that encompass a range of perspectives and integrating topics from environmental science, social justice, and ethics, the curriculum encourages a holistic understanding of climate-related challenges.

The proposed Liberal Arts and Sciences Curriculum (LASC) aligns with the *Engineering for One Planet* (EOP) framework, a growing initiative focused on embedding sustainability within engineering education [10]. However, the LASC adopts a broader approach, integrating insights from the social sciences, humanities, and environmental studies alongside technical coursework. Furthermore, LASC courses are electives open to undergraduate students from all majors. This cross-disciplinary emphasis fosters collaboration among students from diverse backgrounds, encouraging them to consider the cultural, social, and ethical dimensions of sustainability and develop a more nuanced understanding of the challenges they will face as professionals.

By incorporating insights from critical theory and sociotechnical thinking [11], the LASC seeks to move beyond the traditional engineering paradigm and cultivate professionals who are equipped to address the multifaceted challenges of the climate crisis. In doing so, it bridges the gap between technical expertise and ethical responsibility, fostering a new generation of engineers who can contribute to a more just and sustainable world.



The required credits in each category depend on the student's chosen degree program.

Figure 1. Structure of the LASC (Liberal Arts and Sciences Curriculum)

3 Core Elements of the Curriculum (WHAT)

3.1 General structure

The LASC curriculum (Figure 1) is designed for the entire university student body (engineering and non-engineering) and serves as part of the general education requirements to ensure that students receive a holistic education, preparing them to address complex real-world issues with a well-rounded perspective. The LASC completes more "traditional" major-related content, such as math and physics in the case of engineering.

The specific number of credits required from each LAS category varies depending on the student's chosen degree program. However, at least 3 credit hours must come from Digital Cultures Courses, and a minimum of 6 credit hours must be earned from Change Makers Courses. This structure ensures that students across all disciplines gain a foundational understanding of sustainability and climate-related challenges, integrating these principles into their respective fields.

3.2 *Key Focus Areas*

The LASC incorporates sustainability principles through the following three key focus areas:

1. *Water-Energy-Food (WEF) Nexus:* A core component of the curriculum is the WEF (Water-Energy-Food) Nexus, an interdisciplinary framework that examines the intricate interdependencies among water, energy, and food systems. This nexus highlights the inextricable connections between these resources: water is essential for energy production and food cultivation; energy is required for water treatment, distribution, and food production; and food production depends on inputs of both water and energy. The WEF nexus allows the curriculum to move beyond siloed approaches to resource management, encouraging students to consider the cascading effects of interventions in one sector on the other two. Students participate in real-world projects that address sustainable resource management challenges. These projects include optimizing water use in agriculture through efficient irrigation techniques and drought-resistant crops, developing renewable energy systems for food production and processing, or designing integrated strategies that maximize resource efficiency across all three sectors. This hands-on, project-based learning approach deepens students' understanding of the interconnectedness of these critical resources. It also fosters systems thinking, a vital skill for tackling complex sustainability challenges effectively. Examples of courses within this focus area include the three Water-Energy-Food Nexus courses (classified as Change Makers in figure 1):

- *LAS201 Water Security*: The course provides a comprehensive examination of water security issues confronting human society with particular focus on the attainment of United Nations Sustainable Goal 6 to ensure access to water and sanitation for all.
- *LAS202 Sustainable Food Systems*: Food is the strongest lever to optimize human health and environmental sustainability. Addressing the global imbalance of nutrition, and its causes, is a central aim of the United Nations' Sustainable Development Goals (SDGs). This course uses an interdisciplinary approach to address present and future challenges to a more sustainable food system that can provide healthy, nutritious, safe and affordable foods locally and globally.
- *LAS203 Sustainable Energy*: This course explores conventional and renewable energy with a particular focus on the progress towards achieving the United Nations Sustainable Development Goal 7: Ensure Access to Affordable, Reliable, Sustainable, and Clean Energy for All. Energy systems are covered from technical, environmental, economic, social, and policy perspectives. An overview of various energy resources and technologies is provided, including fossil fuels, nuclear, biomass, hydropower, geothermal, ocean, wind, and solar energy. The promise and limitation of each technology are examined in the framework of achieving energy sustainability on local, regional, and global scales.

2. *Sustainability and Climate Justice:* The curriculum introduces students to the complex interplay between climate change, environmental policies, and social justice issues. It explores how climate change disproportionately impacts marginalized communities who often bear the brunt of environmental degradation and lack the resources for effective adaptation. Students learn how environmental policies can either perpetuate or alleviate these inequalities through decisions related to resource allocation, infrastructure development, and pollution regulation. The curriculum also highlights the concept of just transitions" ensuring that efforts to combat climate change do not further disadvantage vulnerable populations but rather create equitable opportunities for all. Examples of courses within this focus area include (classified as Change Makers in figure 1):

   - *LAS301 Debating Sustainability:* This course introduces students to formal, structured debate as a tool in decision-making, leadership and civic engagement. It focuses mainly on case construction, cross-examinations, use of evidence, team debate, and ethics in argumentation. The debate topics emphasize a sustainable development agenda.

   - *LAS304 Energy & Environmental Policy*: This course provides an interdisciplinary exploration of energy and environmental policy, with a focus on how scientific, economic, and political factors shape policy decisions and outcomes. It aims to equip students with a comprehensive understanding of the policies governing energy production and consumption and environmental protection, their historical development, and their impact on society. The course emphasizes critical thinking and policy analysis skills, preparing students to engage with complex energy and environmental challenges.

3. *Ethical and Social Aspects of Sustainability:* Students also engage with the ethical dimensions of engineering, learning about the potential social impacts of their work. Students are encouraged to critically examine the potential social and environmental impacts of their work beyond purely technical considerations. This includes exploring the ethical implications of climate mitigation technologies, such as their potential for environmental justice issues, unintended consequences, and the equitable distribution of their benefits. Furthermore, the curriculum emphasizes the responsibility of engineers to advocate for sustainable practices within their profession and beyond. This involves understanding the societal and ethical obligations of engineers to use their expertise to promote environmental stewardship and address climate change. Students will also investigate the potential effects of new technologies on vulnerable communities, considering factors like access, equity, and the potential for exacerbating existing social inequalities. An example course in this area that provides a framework for students to critically analyze the societal and ethical implications of technological advancements while fostering a strong ethical foundation for their engineering careers is (classified as Digital Culture in Figure 1):

   - *LAS204 Technology, Ethics and The Global Society:* Topics include the impact of social media on individualism, collectivism and culture, and personal identity. Digital divide across class, gender, countries, and ethnic groups as well as privacy and civil liberties. Ethical and decision-making theories, professionalism, fiduciary responsibility, and mentoring. Course includes case studies from various disciplines.

3.3 *Cross-Disciplinary Integration*

The LASC adopts a cross-disciplinary approach that allows students to connect technical knowledge with broader societal issues, fostering a more comprehensive understanding of the challenges posed by climate change. In fact, one of the main strengths of the LASC lies in its integration of sustainability topics across various disciplines, rather than limiting them to isolated courses. For example, a course on sustainable energy draws on insights from sociology and political science and includes technical, environmental, economic, social, and policy perspectives in addition to conventional and renewable energy. Similarly, a course on sustainable food systems addresses challenges to a sustainable food system including the environmental footprint of food production and the social justice implications of food insecurity.

The curriculum was developed through a collaborative process involving faculty from multiple departments, including engineering, computer science, gender studies, sociology, environmental science, nutrition, and ethics. The planning process involved reviewing existing educational frameworks like Engineering for One Planet (EOP) and gathering input from external stakeholders such as industry professionals, and policymakers who highlighted the importance of interdisciplinary skills for addressing sustainability challenges. Input was also gathered from students through surveys and focus groups, providing valuable insights into their learning needs and perspectives. This iterative process, incorporating feedback from both internal and external stakeholders, helped shape a curriculum that is both responsive to current needs and adaptable for future changes.

4 Implementation and Teaching Methods (HOW)

To cultivate skills in cross-disciplinarity, complexity, and contextual understanding within students, the LASC curriculum strategically integrates several key approaches [3]. Student-centered learning methodologies, such as group projects, discussion forums, and independent research, encourage students to connect knowledge from diverse disciplines. This collaborative approach fosters interdisciplinary connections, as students from various fields work together to address complex challenges. Furthermore, the curriculum integrates theory and practice, enabling students to apply classroom learning to real-world situations through internships, case studies, and community-based projects. This hands-on experience allows students to face the complexities of real-world problems and develop practical solutions. Finally, the LASC leverages the power of online learning. This facilitates a deeper contextual understanding of global issues and encourages students to develop a broader worldview.

4.1 *Active Learning and Contextualized Education*

The LASC employs active learning strategies, proven to enhance student engagement and understanding, notably in engineering [12]. A key component is project-based learning, where students engage in real-world projects that address issues related to climate change and sustainability. For example, students studying the WEF Nexus might collaborate on designing a sustainable irrigation system for a local farm or develop a proposal for a community-based renewable energy project.

Contextualized education is another crucial element, fostering student understanding of how regional and cultural differences significantly impact climate adaptation strategies [13]. Through the use of case studies from diverse geographical contexts, students learn to consider how local factors, such as cultural norms, resource availability, and environmental conditions, influence the success of sustainability initiatives. For example, in a course on sustainable food systems, students compare case studies about the implementation of sustainable agricultural practices such as vertical farming in five different countries that have different political, cultural and geographical characteristics. This approach encourages critical thinking and emphasizes the need for tailored solutions that account for the unique cultural and regional specificities of each context.

4.2 Addressing Complex, Competing Issues

The curriculum also prepares students to navigate the competing priorities and contradictory systems often encountered in climate-related work. For example, while renewable energy projects are widely supported for reducing carbon emissions, they can also lead to conflicts over land use and impact local communities [6]. Through discussions and seminars, students explore these complexities, learning to balance different perspectives and make informed decisions that consider both technical and ethical implications.

4.3 Evaluation Plan

4.3.1 Evaluation Plan description

To evaluate the effectiveness of the LASC in preparing students to address climate change, a detailed mixed-methods research plan has been developed:

1. *Outcome-based learning assessment:* The LASC program is assessed over a 3-year cycle. To measure the program's effectiveness, the LAS student outcomes have been mapped into specific, fine-grained performance criteria, which are mapped to individual courses within the program. Data is being actively collected from these courses throughout the cycle, enabling ongoing tracking of student progress and performance. At the end of the cycle in Spring 2026, the program will undergo a comprehensive assessment.

2. *Pre- and Post- Surveys:* These are used to assess changes in students' understanding and attitudes towards climate change before and after completing the relevant courses. This helps gauge whether the curriculum effectively enhances students' knowledge and awareness.

3. *Focus Groups and Interviews:* Qualitative feedback will be gathered from students and faculty through focus groups and interviews. These sessions will explore participants'

experiences, the perceived relevance of the curriculum, and its impact on their perspectives and professional goals.

4. *Longitudinal Tracking:* Graduates will be monitored over several years to assess the long-term impact of the curriculum on their engagement with sustainability in their careers. This will provide insights into how well the program prepares students for real-world challenges.

The mixed-methods research protocol is employed to rigorously evaluate the LASC's effectiveness in equipping engineering students with the knowledge and skills necessary to address the complexities of climate change.

To ensure trustworthiness and reliability, multiple measures have been implemented. Quantitative data will be analyzed using statistical methods to assess validity and reliability, while qualitative data will be triangulated through multiple sources, including interviews, surveys, and longitudinal tracking. Member checking and peer debriefing will also be utilized to enhance credibility.

Reliance on self-reported data in surveys and interviews may introduce response biases, posing a limitation. To mitigate this, data triangulation through multiple sources will help cross-verify responses, reducing potential biases. Additionally, longitudinal tracking presents challenges such as participant attrition over time, which may affect the consistency of findings. To address this, strategies such as periodic follow-ups and incentives for continued participation will be employed to improve retention. Furthermore, while the study aims for broad applicability, its findings may be influenced by institutional and contextual factors unique to the LASC, potentially limiting generalizability to other engineering programs. To enhance external validity, comparative analysis with similar programs and contextual adjustments in interpretation will be considered.

This ongoing research aims to assess the program's impact on student learning, critical thinking, and the development of a sustainability mindset. By combining quantitative and qualitative data collection methods, such as *surveys*, *interviews*, and *project assessments*, the research will provide a comprehensive understanding of the LASC's strengths and weaknesses. The findings will not only inform the continuous improvement of the curriculum but also provide valuable insights for other institutions seeking to integrate climate change and sustainability principles into their engineering programs. This iterative approach ensures that the LASC evolves to effectively prepare graduates to become not only proficient engineers but also responsible professionals who are equipped to address the critical environmental and societal challenges of the 21st century.

4.3.2 Preliminary results

Course No.	Assessed SLOs	Corresponding CLOs	Performance Criteria	% Students meeting criteria
LAS 201: Water Security	SLO1. Demonstrate knowledge, abilities and dispositions necessary for the continuing study of the worlds, peoples, arts, environments, literatures, cultures, sciences and institutions	CLO1 Identify how to achieve universal and equitable access to safe and affordable drinking water for all, and be able to formulate scientific-humanitarian opinion towards water-related issues.	Examine the student's familiarity with newly introduced terminology and definitions (In general on sustainability and focusing on water security)	85%
	SLO10. Apply ethical standards required to enter into the professional world.	CLO4 Define ways to substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity	Prepare a Term paper titled "Your Major and Water Security"	88%
LAS 202: Sustainable Food Systems	SLO6. Analyze evidence related to complex local and global problems	CLO4. Connect the concepts of food systems, healthy diets and sustainability	Respond to knowledge-based assessment questions that connect the concepts of food systems, healthy diets and sustainability	80%
	SLO9. Suggest creative solutions on open-ended local and global problems	CLO6. Suggest creative food system innovations for healthier equitable and sustainable diets	Produce a situational analysis paper aiming at suggesting reforms and solutions to make the food systems more sustainable in an assigned	81%
LAS203 Sustainable Energy	SLO9. Suggest creative solutions on open-ended local and global problems	CLO4 Assess the environmental impact of energy production and the relationship between energy production, consumption, and climate change	Answer knowledge-based assessment questions on energy production, consumption, and climate change	79%
	SLO11 Demonstrate commitment to the sustainability of the world.	CLO6 Identify best practices and solutions to improve residential energy usage in terms of efficiency and sustainability	Respond to knowledge-based assessment questions related to efficiency and sustainability in residential energy usage	82%

SLO: student learning outcome
CLO: course learning outcome

Table 1 Preliminary assessment results

Table 1 shows some partial assessment results from the first year. Accordingly, preliminary results for the assessment of the courses LAS201 Water security, LAS202 Sustainable food systems and LAS203 Sustainable energy show that the preset performance standards (70% of students should meet performance criteria) were all met.

Qualitative feedback from students and instructors was gathered to suggest improvements in the course delivery. For example, for LAS203, additional tools were provided for renewable energy experimentation to improve hands-on learning. Active learning methods including case studies and real-life examples were listed as a strength in all courses and are therefore increasingly being developed and used.

5 Conclusion

This paper presented an approach for tackling climate change within a Liberal Arts and Sciences Curriculum (LASC) which offers a comprehensive approach to reimagining engineering education by emphasizing the integration of technical, social, and ethical considerations. Focusing on sustainability, climate justice, and interdisciplinary learning, the program aims to equip future engineers with the skills necessary to address the unprecedented challenges posed by climate change. Although in its early stages, initial feedback suggests the approach is effective in fostering a well-rounded understanding of these complex issues. As the climate crisis evolves, the curriculum will undergo continuous refinement to ensure its continued relevance and robustness as a framework for educating the next generation of responsible engineers.

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