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Education for Thriving in a Changing Climate: Private Property, the Commons, and America's Policy Barriers

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Education for Thriving in a Changing Climate: Private Property, the Commons, and America's Policy Barriers

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Abstract Engineering solutions to climate adaptation increasingly require fluency in governance, policy, and ethics. Traditional U.S. frameworks, rooted in private property and exclusionary conservation, often conflict with collaborative, shared-governance models that support sustainable resource management. Engineering education can prepare students to navigate multi-actor governance challenges, develop policy literacy, and integrate ethical reasoning into technical solutions. Using case studies on wildfires and prescribed burns, water governance in interdependent infrastructure, and parametric insurance for fisheries, we illustrate how multi-actor, policy-informed decision-making can be taught through experiential learning, role-playing, and system design exercises. By synthesizing theory, practice, and pedagogy, and integrating insights from Nobel laureate Elinor Ostrom, indigenous stewardship models, and adaptive governance literature, we provide recommendations for preparing engineers to operate as ethical, policy-savvy practitioners capable of addressing planetary health challenges. The pedagogical approaches are offered as concrete contributions that are intended to align with and extend the forthcoming NASEM consensus study "Education for Thriving in a Changing Climate."

Introduction

Climate change is increasing the frequency and intensity of natural hazards - including wildfires, floods, and water scarcity - that directly affect human and environmental health. Engineers play a central role in designing resilient systems to address these challenges. However, technical expertise alone is insufficient. Effective climate adaptation also requires policy literacy, ethical reasoning, and interprofessional collaboration [1] [2] [3]. The emerging concept of environmental engineering as a discipline dedicated to planetary health underscores this imperative [2]. Engineers must therefore develop competencies that enable students to learn to engage with governance systems, navigate complex social-technical interactions, and contribute to multi-stakeholder decision-making processes.

Traditional engineering curricula often emphasize deterministic, command-and-control solutions, which may leave many graduates underprepared for challenges requiring negotiation, ethical stewardship, or collective governance. Recent scholarship argues that while engineering ethics is increasingly taught, the "political" dimension - collective decision-making and power dynamics - remains largely absent in classroom pedagogy [4]. This gap is critical because technical interventions inherently function within political economies. From a global perspective, the Royal Academy of Engineering [5] notes that while sustainability is a key learning outcome, the policy literacy required to implement this imperative is often missing.

Previous efforts have demonstrated the feasibility and value of integrating policy and diplomacy into engineering education. For example, Oerther [6] developed a STEAM (science, technology, engineering, art, and math) diplomacy course that introduced engineering students to science diplomacy and governance frameworks through experiential learning, simulations, and case studies. Diplomacy Lab initiatives have enabled students to tackle real-world policy problems while cultivating interdisciplinary collaboration skills [7] [8]. In parallel, environmental health education research highlights the need for interprofessional curricula that connect technical engineering knowledge with public health and governance literacy [1] [9] [10]. Integrating the V-shaped professional and convergence education frameworks further frames engineers as governance actors capable of navigating complex social-technical and ethical challenges [3] [7].

This paper addresses three interrelated objectives:

- Identify policy and philosophical barriers in U.S. environmental governance - particularly tensions between private-property conservation ethos, shared governance models, and indigenous stewardship - and their implications for engineering practice in climate adaptation;
- Translate these insights into curricular recommendations, proposing pedagogical tools and course designs that develop policy literacy, interprofessional collaboration, and ethical stewardship [3] [7]; and
- Formulate research questions that guide further investigation into how engineering students develop competencies in governance-informed design, commons management, and multi-actor problem solving.

Consistent with the third objective above, and to help the reader engage with the substance of this paper, we introduce the following proposed research questions to structure future empirical work, namely:

- First, how do engineering students' mental models of environmental governance shift when they are exposed to the triad of exclusionary ("Wild"), shared-management (Ostrom), and kinship (indigenous stewardship) frameworks?
- Second, which pedagogical strategies – resource-valuation exercises, role-play and negotiation simulations, or scenario-based case comparisons – most effectively develop policy literacy and ethical reasoning in engineering students?
- Third, to what extent do governance-literacy competencies developed in coursework persist into capstone design, early professional practice, and technical decision-making over a career?
- Fourth, how do these pedagogical interventions scale across institutions with different demographics, disciplinary cultures, and regional governance contexts?

By aligning climate adaptation challenges, governance frameworks, and interprofessional pedagogies, this work situates engineering education at the intersection of technical expertise, planetary health, and global-local policy systems [1] [2] [11] [12] [13].

Philosophical Foundations and Pedagogical Recommendations

The United States (US) has a long-standing tradition of valuing private property and "set-aside" conservation, rooted in historical notions of the frontier and the mythos of "Wild America" [14]. This ethos emphasized the preservation of wilderness through exclusionary practices, often restricting active human management and framing land primarily as a resource to be owned or left untouched. However, Anderson [15] empirically refutes this myth, demonstrating that what European settlers perceived as "wild" was actually a carefully "tended" agro-ecological system managed by indigenous peoples for millennia.

This reveals a critical distinction between the "Wild" (exclusionary) versus "Garden" (management) dichotomy and indigenous frameworks. Indigenous conceptions often reject the "resource" framing entirely, viewing the environment through a lens of kinship ("Land-as-Mother") rather than ownership or management. As Kimmerer [16] explains, this involves "reciprocal stewardship," where the relationship between humans and land is based on gratitude and responsibility rather than extraction.

While Nobel laureate Elinor Ostrom [12] challenges the "Wild" model by proving that communities can sustainably manage resources through rules, indigenous critics might argue that even Ostrom's model remains anthropocentric - focused on the efficient extraction of goods rather than reciprocal stewardship [2] [17].

From an educational perspective, understanding this philosophical triad - exclusion (wild), management (Ostrom), and kinship (indigenous) - may be an essential touch point. Students who are trained with an emphasis on technical design may inadvertently replicate exclusionary approaches. Integrating the study of these conflicting ethos in the curriculum provides a foundation for discussions about shared governance and ethical stewardship [2] [11].

Hardin's Tragedy of the Commons [18] formalized the notion that commonly accessible resources are vulnerable to overuse unless controlled through privatization or centralized authority. Hardin's solutions inherently rely on exclusionary mechanisms, mirroring the "Wild America" model. In other words, control, regulation, or privatization are required to avoid system collapse. However, this framework is philosophically limited, especially when applied to modern climate adaptation and sustainability challenges on a global scale. Ostrom [12] [13] demonstrated that collective management through trust, rules, and local governance can achieve sustainable outcomes without privatization, and that the scale can be expanded from local governance through the global commons.

As an example for the engineering classroom, Hardin's Tragedy of the Commons illustrates challenges in managing common-pool resources without exclusion or centralized control. Oerther [19] [20] adapted this concept into effective pedagogy by engaging students in a valuation exercise of a public sunset and demonstrating the total cost curve of a shared resource. Based on the success of these pilot efforts, one pedagogical recommendation is to integrate a module of "environmental valuation" into courses on environmental policy, systems thinking, or ethics, which allows students to visualize the interaction between engineering decisions and social/economic incentives.

To refute Hardin, Ostrom [12] [13] demonstrated that common-pool resources can be sustainably managed through mutual trust, collective rule-making, and locally adapted institutions. Educators can utilize resources such as Anderies and Janssen's [21] *Sustaining the Commons*, which translates these complex social-ecological systems into frameworks accessible to undergraduate students. Engineers can apply this framework to infrastructure and environmental interventions requiring multi-stakeholder coordination. For example, Oerther et al. [9] [10] highlight cases in wildfire management and water quality demonstrating the effectiveness of collective decision-making. Based on the success of these pilot efforts, a second pedagogical recommendation is to integrate role-playing simulations and case studies to provide students with an opportunity to practice negotiating rules for resource management while balancing technical feasibility, ethics, and social considerations.

Beyond Hardin and Ostrom and a US-centric approach, governance frameworks differ internationally. The European "precautionary principle" emphasizes proactive harm prevention, ensuring public protection but potentially constraining innovation. The US litigious model assigns liability after harm occurs, fostering entrepreneurial activity but potentially increasing downstream social costs. A third pedagogical recommendation is to integrate scenario-based exercises comparing frameworks for wildfire or water management to enable students to analyze trade-offs between innovation, risk, and ethical responsibility [9] [10].

By layering governance perspectives - Hardin, Ostrom, US/European risk philosophies, etc. - educators may equip students with multiple analytical lenses. A fourth pedagogical recommendation includes encouraging educators to integrate multiple pedagogical strategies that include resource valuation exercises (e.g., sunset example); role-playing and negotiation simulations; as well as scenario-based case studies evaluating risk, ethics, and policy trade-offs. The layered application of these four approaches – valuation, negotiation, scenario comparison, and explicit attention to indigenous stewardship frameworks – represents what may become a "best practice" for educating engineers to support society to thrive on a planet experiencing a changing climate. Table 1 summarizes the resulting mapping from governance concepts to case studies, pedagogical recommendations, and learning outcomes.

Examples of Engineering Practice Challenges Providing Context for Classroom Exercises

Increasing wildfire frequency and intensity presents challenges at the intersection of engineering, policy, and public health. Wildfire smoke contains PM2.5 and toxic gases linked to respiratory and cardiovascular illness, mental health stress, and school absenteeism [9]. These outcomes highlight the governance consequences of environmental engineering decisions and the importance of policy-informed adaptation [11] [13].

Prescribed burns reduce fuel loads, mitigating catastrophic wildfire risk. They exemplify the precautionary principle: proactive harm prevention [9]. Historically, this practice aligns with indigenous science and community building, where fire was a tool for land renewal rather than a threat [15] [17]. Prescribed burns operationalize multi-actor decision-making because they require coordination among landowners, fire managers, public health officials, and community stakeholders [22]. In the future, a pedagogical recommendation is to offer students an opportunity to analyze trade-offs between technical feasibility, ecological integrity, and community risk of prescribed burns through case studies, simulations, and design exercises.

Water infrastructure exemplifies interdependent socio-technical systems, affected by regulatory frameworks, community needs, and ecological constraints. Oerther's extensive work with the GRoWES (Global Research on WaSH to Eliminate Stunting) project in Guatemala illustrates this interdependence. In this context, technical solutions - such as water filters or latrines - are insufficient without governance structures to maintain them [23].

US water governance often operates reactively, while European frameworks prioritize precaution and prevention. Multi-actor collaboration - including engineers, public health professionals, and policymakers - improves outcomes. In the GRoWES project, successful intervention required identifying and mapping stakeholders to prevent childhood stunting, moving beyond simple infrastructure provision to complex community health management [24]. In the future, a pedagogical recommendation is to offer students an opportunity to model the tradeoffs between domestic water-infrastructure investment and investments in development aid abroad, examining how engineering decisions intersect with immigration and border policy.

Pedagogical strategies include scenario-based learning and systems design projects, which would benefit from the use of the "Modified Mastery Learning" developed by Oerther [25]. For example, in an existing sophomore-level course entitled, "*Fundamentals of Environmental Engineering*," students utilize Oerther's modified mastery learning pedagogy to analyze water quality governance. In a dual-level course (upperclass undergraduates and graduate students), Oerther uses GRoWES as a case study to help students learn to evaluate trade-offs between technical feasibility, policy constraints, and ethical responsibility [25]. These exercises develop policy literacy, ethical reasoning, and collaborative problem-solving skills.

As a final example, the Caribbean Ocean and Aquaculture Sustainability faciliTy (COAST) represents a pioneering application of engineering diplomacy and parametric insurance [26] [27]. Unlike traditional indemnity insurance which requires lengthy damage assessments, COAST uses parametric triggers (e.g., wind speed, wave height) to release funds immediately to fisherfolk after extreme weather events. This "rainy day" funding aligns financial incentives with ecological resilience and food security.

COAST as a case study is integrated into Oerther's *Environmental Systems Modeling* course [25]. Students are tasked with designing the "trigger" parameters for a hypothetical insurance policy. They must use oceanographic data to determine wave height thresholds that correlate with economic loss for fisherfolk. This exercise teaches students that "risk" is not just a statistical probability but a negotiated policy definition that determines survival for vulnerable populations. It forces them to grapple with the ethical weight of defining parameters in a life-critical system.

Discussion

Modern climate adaptation requires engineers to integrate technical expertise, governance frameworks, and ethical responsibility. Wildfire, water, and fisheries case studies illustrate these intersections and show how multi-actor governance can be operationalized in engineering education. Table 1 consolidates the mapping used throughout this paper: each row pairs a governance concept with an illustrative case study, a pedagogical activity, and a targeted learning outcome.

Table 1. Mapping governance concepts to case studies, pedagogical recommendations, and learning outcomes.

Governance concept	**Case study**	**Pedagogical activity**	**Learning outcome**
Tragedy of the Commons	Sunset Valuation [19] [20]	Resource valuation exercise	Visualize total cost curves and the interaction between engineering decisions and economic incentives.
Shared Governance (Ostrom)	COAST Fisheries [26] [27]	Parametric Trigger Modeling	Design technical thresholds (e.g., wave height) that serve social safety nets; connect modeling to policy.
Precautionary Principle	Wildfire/ Prescribed Burns [9]	Multi-stakeholder negotiation	Balance immediate health risks (smoke/PM2.5) against long-term catastrophic risk; practice "Garden" management.
Interdependent Systems	Water/ GRoWES [23] [24]	Stakeholder Mapping / Mastery Learning	Analyze how technical water solutions rely on local governance and community maintenance to prevent stunting.
Indigenous Stewardship	Prescribed burns as indigenous land-management practice [15] [17] [28]	Layered multi-framework pedagogy	Integrate exclusion, management, and kinship perspectives into engineering design reasoning; validate indigenous knowledge as a form of engineering.

Key educational strategies include policy literacy, ethical reasoning, interprofessional collaboration, and experiential learning. The goal of these pedagogical interventions is to produce engineers who are technically proficient, socially aware, and governance-literate. Furthermore, validating indigenous knowledge systems in the engineering curriculum supports the professional identity development of indigenous students, reinforcing that their traditional knowledge is a vital form of engineering [28]. Integrating convergence education and V-shaped professional frameworks helps students understand their role as ethical, policy-informed actors in complex socio-technical systems.

Curricula should frame challenges along a local-to-global continuum, enabling students to translate localized interventions into broader climate adaptation strategies. Local case studies, such as wildfire management or water governance, can illustrate universal governance principles applicable to other socio-technical systems globally.

This work is intended to align with the forthcoming consensus study by the National Academies of Sciences, Engineering, and Medicine (NASEM), Education for Thriving in a Changing Climate [29], which is anticipated to address the preparation of engineers and allied professionals for climate-adaptation decision-making across K–12, higher education, and workforce development. The pedagogical approaches proposed above – resource-valuation exercises, role-play and negotiation simulations, scenario-based cross-framework comparisons, and layered multi-framework pedagogy that includes indigenous stewardship – are intended as concrete curricular examples aligned with the NASEM agenda. Specifically, these interventions operationalize three cross-cutting priorities commonly identified in climate-education frameworks: (i) developing policy literacy alongside technical competence, (ii) validating multiple knowledge systems (including indigenous knowledge) in engineering reasoning, and (iii) preparing engineers to function as ethical actors within multi-actor governance contexts rather than as neutral technical implementers. Situating this work within the NASEM agenda is intended to help connect institution-level pilots at Missouri University of Science and Technology to a national research and practice community, and to invite collaboration on the research questions identified in the Introduction.

Limitations

While the case studies presented – ranging from wildfire management in North America to water quality in Guatemala and fisheries governance in the Caribbean – provide a robust conceptual foundation, several limitations must be acknowledged.

The pedagogical interventions identified in this study, such as the “Modified Mastery Learning” and specific simulation exercises, have primarily been implemented and refined at a single institution (Missouri University of Science and Technology). Future effort should confirm the scalability of these methods to institutions with different student demographics or departmental structures.

The background presented in this article focuses on a select triad of philosophical foundations: exclusionary conservation, Ostrom’s shared management, and indigenous stewardship. While these provide a significant contrast to traditional “command-and-control” engineering models, they do not encompass the full spectrum of global regulatory and legal frameworks. Future effort should expand the background, including approaches outside of the “Western” and “Indigenous” approaches such as including specific Asian or African communal resource models to offer additional insights into climate thriving.

Much of the evidence for the effectiveness of these pedagogical tools is qualitative, relying on case study data and pilot course results. There is currently a lack of longitudinal data to confirm whether students maintain this “policy literacy” and “ethical reasoning” as they transition into professional practice or if these competencies significantly alter their technical design choices over a career. Future work should explore these longitudinal aspects of the work.

While the Nurse+Engineer model and V-shaped professionalism are proposed as useful prototypes, the paper does not fully account for the administrative and accreditation barriers (i.e., for engineering or for nursing) that may create practical difficulties for the widespread adoption of such deeply interdisciplinary convergences (i.e., how many classroom, laboratory, and clinical experiences may be “double counted”).

Finally, while the “sunset valuation” exercise shows tremendous promise as a useful pilot for teaching the Tragedy of the Commons, additional – more rigorous – quantitative assessment – especially longitudinal – is needed to measure student mastery of complex economic incentives in engineering decision-making.

Conclusions

Based upon limited case study data, we propose that integrating philosophy, policy, and practice can prepare engineering students for careers that include climate-adaptation challenges. Case studies in wildfires, water governance, and fisheries insurance illustrate how governance-informed design affects health, ecology, and equity. The four pedagogical recommendations developed in this paper – environmental valuation exercises, role-play and negotiation simulations, scenario-based cross-framework comparisons, and layered multi-framework pedagogy that includes indigenous stewardship – are summarized in Table 1 and are offered as concrete contributions to the NASEM *Education for Thriving in a Changing Climate* agenda [29]. The four research questions articulated in the Introduction define a research agenda for evaluating whether these interventions build durable policy-literacy competencies, which strategies are most effective, whether those competencies persist into professional practice, and whether they transfer across institutional contexts. Addressing these questions would help position engineering graduates as ethical, governance-literate actors in a changing climate.

Declaration on use of Generative Artificial Intelligence

Consistent with the recommendation of transparency, accountability, and verifiability (as described in [30]), Google Gemini version 3 Pro was used during the drafting phase of this manuscript. Claude Opus 4.7 was used during final editing, specifically to produce a structural review and suggest surgical edits (cut and paste) that the author reviewed independently. The following prompt was used with Claude: "Assume you are a program chair for the annual meeting of the American Society for Engineering Education. Evaluate the near final draft of the manuscript being submitted by corresponding author Professor Daniel Oerther of the Missouri University of Science and Technology (attached) and offer specific recommendations to improve the manuscript given the following: 1) instructions to authors for the meeting as originally published by ASEE (attached); 2) call for papers as originally published by ASEE (attached); 3) feedback from reviewers and program chair on the original abstract and subsequent draft versions of the manuscript." The author takes full responsibility for the content of the article.

Author approved TL;DR

Author approved TL;DR (as recommended by [31]): By synthesizing theory and practice from wildfires, water, and fisheries governance, this work proposes a best-practice approach for educating engineers as V-shaped professionals capable of protecting public health in a changing climate. While current results rely on pilot data from a single institution, the study outlines a path for future innovation in engineering ethics and commons management.

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