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Integrating Leadership Attributes into Environmental Engineering Education: A Framework for Developing Future Leaders in Sustainability and Public Service

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[Integrating Leadership Attributes into Environmental Engineering Education: A Pilot Program Conceptual Framework for Developing Future Leaders in Sustainability and Public Service]: A Work in Progress

Abstract

Addressing today's complex environmental challenges requires engineers who are not only technically proficient but also equipped with strong leadership skills. Environmental engineers make decisions which impact public health, ecosystems, and long-term sustainability. Many projects involve regulatory agencies, policies, and collaborating with multidisciplinary groups. Attributes including integrity, critical thinking, resiliency, and supporting skills, such as systems thinking, communication, and innovation, not only impact the success of a project but also the growth of the profession. However, traditional environmental engineering undergraduate programs often do not adequately cover leadership development. The purpose of this paper is to provide a framework to integrate leadership development into environmental engineering education, while delivering the required technical knowledge needed in the profession. This will include mapping attributes to existing environmental engineering courses, adding leadership modules and activities, as well as implementation strategies for faculty development, assessment methods, and collaboration with industry and government. The framework will be evaluated in a future pilot program. The paper calls for curriculum reform in engineering education to develop leadership attributes.

Introduction

The environmental engineering profession faces increasingly complex technical, social, and ethical challenges in its mission to protect public health and the environment. Emerging issues, including climate change adaptation and mitigation, sustainable and resilient infrastructure, decarbonization, water and energy nexus management, ecosystem restoration, and environmental justice, introduce problems that are multiscale, multifaceted, and deeply interconnected [1]. These challenges rarely present themselves as well-bounded technical problems; rather, they demand systems thinking, interdisciplinary collaboration, ethical judgment, and the ability to communicate and lead across organizational, cultural, and institutional boundaries [2]. Traditional undergraduate engineering curricula provide a rigorous and structured foundation in mathematics, science, and core engineering principles, guided by accreditation criteria such as those established by ABET [3]. While necessary, this focus is insufficient to prepare graduates for the leadership demands they encounter early in professional practice [4].

A review of literature by the authors reveals a lack of published undergraduate leadership programs designed specifically for environmental engineering students, despite the field's distinctive professional demands. This paper describes the design and development of a pilot technical leadership program tailored to undergraduate environmental engineering students. The program responds to student interest and employer expectations, and proposes a scalable framework that complements, rather than displaces, existing technical curricula.

Student Perspectives on Leadership Preparation

A survey was conducted at Stevens Institute of Technology, a medium-sized private university located in the New York tri-state metropolitan area. As of the 2025–2026 academic year, the institution enrolls approximately 2,200 undergraduate engineering students. Given the small, institution-specific sample, the results are not intended to be broadly generalizable to all environmental engineering students nationally or internationally. Instead, the findings should be interpreted as exploratory and contextual, offering insight into student familiarity within a specific institutional and programmatic setting that may inform future, larger-scale investigations.

An anonymous electronic survey was distributed to second-, third-, and fourth-year environmental engineering students to assess their interest in and perceptions of leadership. Twenty-five students responded, with a 69% response rate. The survey included Likert-scale and open-ended questions addressing familiarity with leadership, perceived importance of leadership skills, self-reported preparedness, and interest in a leadership-focused elective. Its purpose was to gauge student attitudes and willingness to enroll in a leadership elective, rather than to assess detailed leadership competencies; a more comprehensive, theory-based assessment will be conducted during the program's pilot phase.

Results indicate that 48% of environmental engineering students reported moderate familiarity with engineering leadership, while only 16% felt very familiar. Leadership skills were widely regarded as important, with 68% rating them as extremely important, yet relatively few students felt fully prepared to demonstrate these skills. A strong majority, 76%, expressed willingness to enroll in a leadership-focused elective. Responses are summarized by academic level in Table 1.

Table 1. Responses to Survey by Academic Year

Academic Year in Environmental Program	Total Responses (n)	Leadership Familiarity	Leadership Importance	Willingness to Enroll
Sophomore	5/6 (83.33%)	2/5 (40%)	2/5 (40%)	2/5 (40%)
Junior	5/10 (50%)	2/5 (40%)	3/5 (60%)	4/5 (80%)
Senior	10/15 (66.67%)	6/10 (60%)	8/10 (80%)	9/10 (90%)
Fifth Year	5/5 (100%)	2/5 (40%)	4/5 (80%)	4/5 (80%)
Total	**25/36 (69.44%)**	**12/25 (48%)**	**17/25 (68%)**	**19.25% (76%)**

Responses to other questions show that students are favoring hands-on, project-based or case study/discussion-based delivery formats and valuing interaction with practicing professional engineers. Students expressed greatest interest in negotiation and conflict resolution, project leadership, and mentoring and delegation. Overall, these findings highlight strong student interest in practical, ethically informed leadership instruction that emphasizes skill development, collaboration, and professional engagement.

Industry Perspectives in Leadership

To provide an industry perspective, an electronic survey was administered to environmental engineering professionals, targeting middle- and upper-level managers. While this sample is not representative of all environmental engineering employers nationally or globally, it seeks to provide insights from industry perceptions of entry-level environmental engineers' leadership preparedness, the importance of leadership skills, and the value of undergraduate leadership training of entry-level engineers. Thirteen respondents, including alumni, external advisory board members, and senior design sponsors, participated. Respondents represent a mix of organizations, including consulting firms, private companies, and public sector entities. They span a range of firm sizes and are located across multiple regions, primarily within the New York tri-state metropolitan area. Respondents held a variety of positions, including leadership roles such as vice presidents and directors, as well as senior technical roles such as senior engineers and project managers. Specific company names and identifying details have been omitted to protect anonymity.

Survey responses indicate that recent environmental engineering graduates are generally perceived as requiring substantial mentoring across multiple professional competencies. For example, 69.23% of respondents reported that graduates are only partially prepared to communicate complex technical concepts to non-technical stakeholders, and 23.08% indicated they are not prepared. Similarly, 69.23% noted graduates require significant mentoring to collaborate effectively on multidisciplinary teams. In project management, 46.15% rated graduates as not prepared and 30.77% as partially prepared. Leadership-related skills showed similar trends: 38.46% reported graduates are not prepared to provide mentorship, and 38.46% rated their leadership potential as below average, with 46.15% rating as average. Additionally, 76.92% indicated graduates are only partially adaptable to changing project conditions, 53.85% reported they struggle to manage conflict independently, and 53.85% described their problem-solving in ambiguous situations as moderate. Overall, the data suggest that while graduates demonstrate baseline technical capability, employers perceive notable gaps in leadership, adaptability, communication, and professional readiness.

Pilot Program Design and Development

The pilot program is grounded in the recognition that technical competence and leadership capability develop complementary but distinct pathways. Technical knowledge, skills, and abilities (T-KSAs) are systematically cultivated through accredited engineering curricula. In contrast, leadership skills, attributes, and qualities (L-SAQs) are often left to informal experiences or post-graduate development. The design acknowledges common academic constraints, curricular overload, faculty expertise, and assessment challenges, and addresses them through integration, scaffolding, and experiential learning.

A progressive "crawl–walk–run" model underpins the program, introducing leadership concepts early, developing them explicitly at the junior level, and reinforcing them through coached practice in the senior capstone experience. A summary of the three phases is listed in Table 2.

Table 2. Summary of Three Phase Model

Phase	Description	Examples
1: Early Exposure (Crawl)	Embed leadership exposure into first- and second year existing courses, focusing on team-based projects with modules on team roles, communication, conflict management, and self-assessment.	Reflective journaling, peer and self-assessments, structured rubrics aligned with learning outcomes.
2: Junior Level Leadership Course (Walk)	Standalone leadership course titled, *Leadership Skills, Attributes and Qualities for Environmental Professionals*, organized into five progressive modules.	1. Foundations of Leadership for Environmental Engineers 2. Communication with Diverse Audiences and Stakeholders 3. Interdisciplinary Collaboration and Teamwork 4. Leadership Projects and Decision-Making Under Uncertainty 5. Personal Leadership Development Planning
3: Leadership Integration with Senior Capstone (Run)	Embed leadership as an explicit learning outcome into a year-long senior capstone course, with industry-sponsored projects.	Structured leadership coaching; role rotation; peer evaluations. Industry sponsors provide feedback, reinforcing professional relevancy.

Program Outcomes Assessment

The program outcomes and assessment framework will be fully developed upon commencement of the pilot program and will be guided by the principles outlined below in Table 3. The pilot is expected to be fully implemented within two years, with the primary delay attributable to course approval processes through departmental and university curriculum committees.

Table 3. Outcomes and Assessments

Outcome	Example Assessment Tools
Self-Awareness and Emotional Intelligence	Pre- and post-program surveys; reflective journals; team feedback

Critical and Systems Thinking	Rubric-based evaluation same case studies; capstone deliverables
Resilience and Teaming Skills	360-degree peer evaluations; faculty observations; documented team performance
Project Success and Client Satisfaction	Capstone course performance; sponsor feedback; post-project evaluations

Conclusion

The proposed pilot technical leadership program addresses a documented and growing gap between undergraduate preparation and professional expectations in environmental engineering. By integrating leadership development across the curriculum, grounding instruction in discipline-specific contexts, and emphasizing experiential learning and assessment, the program prepares graduates to lead ethically, communicate effectively, and navigate complexity. The model offers a scalable and evidence-informed framework with the potential to enhance both student outcomes and the societal impact of the environmental engineering profession.

References

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