2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #53854

Integrating Writing Across the Curriculum to Foster Ethical and Sustainability Reasoning in Engineering Design

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Work in Progress: Integrating Writing Across the Curriculum to Foster Ethical and Sustainability Reasoning in Engineering Design

Abstract

As engineering challenges become increasingly complex, future civil and environmental engineers must develop not only technical competence but also the ability to communicate, reflect, and reason ethically about sustainability trade-offs. Writing in engineering education, however, is often confined to formal reports rather than leveraged as a learning tool that supports professional judgment and design decision-making. This Work-in-Progress project integrates Writing Across the Curriculum (WAC) principles into a senior-level engineering design course to promote ethical and sustainability reasoning embedded within technical design. In collaboration with a campus writing support unit, the course was redesigned to replace a single major paper with multiple low-stakes, design-connected writing activities distributed across the semester. Preliminary qualitative findings suggest that scaffolded writing-to-learn activities enhance student engagement, deepen sustainability reasoning, and strengthen articulation of ethical considerations. This paper presents the course redesign, example writing prompts, assessment approach, and early evidence of impact.

Introduction

Engineering education has traditionally emphasized technical analysis and quantitative problem solving. While these competencies remain essential, current engineering practice requires professionals to navigate complex sociotechnical systems in which ethical responsibility, sustainability trade-offs, and communication are a part of technical design decisions. It has been strongly argued that engineering must move beyond purely technical judgement to include justice-oriented and socially responsive practices [1]. This shift aligns with accreditation expectations related to communication and ethical responsibility, however it has been challenging to integrate these outcomes meaningfully into design curricula.

Writing Across the Curriculum (WAC) scholarship promotes writing not merely as a reporting mechanism but as a cognitive tool that supports learning, reflection, and disciplinary thinking. Emig's foundational work established writing as a powerful mode of learning because it engages analysis, synthesis, and metacognitive processing in ways distinct from reading or discussion alone [2]. Research has shown that frequent low-stakes assessments are thought to be better than high-stakes assessments in multiple ways, that writing-to-learn activities promote conceptual understanding, critical thinking, metacognition, professional identity development and reflective judgment across disciplines [3], [4], [5]. In engineering education, however, writing is typically

concentrated at the end of design processes, limiting its potential to shape reasoning as decisions are made. This practice frames writing primarily as documentation rather than as a tool for shaping reasoning. Winsor's ethnographic study of engineers' rhetorical practices demonstrates that writing is central to how engineers construct knowledge, negotiate meaning, and develop professional identity [6]. Similarly, genre theory emphasizes that disciplinary genres are not neutral containers for information but socially situated forms that shape how professionals think and act [7], [8], [9]. When students engage in authentic disciplinary writing, they are not just communicating decisions but they are participating in the cognitive practices of the profession. Research in engineering education suggests that communication development in design courses strongly depends on situated learning, how instructors frame assignments, scaffold reflection, and connect writing to professional practice [10]. Without intentional integration into iterative design processes, writing tasks risk becoming isolated exercises rather than a mechanism for developing transferable reasoning skills.

Beyond communication skill development, structured writing has been shown to support ethical reasoning and reflective judgment. Reflection focused research in engineering education highlights the importance of intentional meaning-making processes that connect experience, values, and future action [11]. When students are encouraged to articulate and examine the assumptions underlying their design decisions, writing can make implied reasoning visible and available for assessment. Engineering ethics education research has also looked for approaches that move beyond rule-based instruction toward frameworks that support higher-order ethical reasoning. Reflexive and scaffolded pedagogies have shown measurable improvements in students' ethical reasoning abilities when supported by structured analysis and reflection [12]. Value-based approaches to ethics education emphasize the importance of connecting professional responsibility to personal commitments and broader societal impacts [13]. These approaches suggest that writing, especially when iterative and reflective, can serve as a bridge between technical analysis and moral reasoning. Another recent study suggests that a part of contemporary engineering responsibility is to integrate ethics with diversity, equity, and inclusion [14]. These arguments support the need for design education to embed ethical reasoning within complex social, environmental, and stakeholder contexts rather than treating it as an exercise to comply with accreditation expectations.

Research on sustainability education identifies systems thinking, anticipatory reasoning, normative competence, and strategic decision-making as key competencies for addressing complex global challenges [15]. Engineering design involves trade-offs among environmental, economic, social, and technical criteria. However, while economic and technical feasibility are typically emphasized in design curricula, social and environmental dimensions are either addressed superficially or quite late in the process. Embedding writing-to-learn activities throughout the design process provides structured opportunities for students to articulate and

justify sustainability trade-offs as decisions unfold. This approach places sustainability reasoning not as an add-on section of a final report but as an essential component of iterative design thinking. By requiring students to articulate the ethical and sustainability implications of alternative solutions, writing serves as a mechanism for exploring value conflicts and stakeholder impacts.

This work addresses that gap by embedding writing-to-learn activities throughout a senior-level design course, intentionally aligning writing with design milestones to support ethical and sustainability reasoning as part of the engineering decision-making process. Ethical reasoning and sustainability trade-offs were selected as the primary writing focus areas because these aspects are frequently treated as add-ons rather than essential components of the technical design process. While technical and economic feasibility are often covered in traditional engineering design, the social and environmental pillars of sustainability require the reflective capacity that WAC activities can achieve. This focus on writing, ethical and sustainability reasoning also directly aligns with ABET Student Outcomes 2 (Sustainability), 3 (Effective communication) and 4 (Ethical and Professional Responsibility). Other parts of the design process were also supported through scaffolded WAC activities. The goal is not to replace technical rigor but to integrate ethical and sustainability reasoning alongside technical decision-making. Other components of the design process continue to be supported through scaffolded assignments.

Course activity redesign

The project was implemented in a senior-level core environmental engineering design course centered on a team-based, semester-long project addressing real-world engineering problems. Historically, the course included a single report component intended to capture ethical and sustainability considerations. While valuable, this approach put writing as an endpoint rather than a formative component of design reasoning. The redesigned activity replaced the major report component with multiple short, low-stakes writing activities distributed across the semester and aligned with project milestones. These writing activities were integrated into existing deliverables, such as problem definition, alternative evaluation, and final design justification. The redesign was developed in collaboration with a campus writing support unit and guided by WAC principles emphasizing writing as a tool for learning rather than assessment alone.

Writing activities were intentionally designed to align with key stages of the engineering design process. Early-semester prompts asked students to articulate problem framing, stakeholder perspectives, and initial constraints. Mid-semester writing focused on evaluating design alternatives, articulating ethical concerns and sustainability trade-offs, and justifying decisions using technical and contextual evidence. A reflective self-assessment prompted students to

synthesize their learning and evaluate how sustainability and ethics informed their final design. Below are the details about the projects and the writing assignments.

Approximately 45% of the course grade is associated with a semester-long team-based design project. Students work in teams of 3 to 5 and complete three major reports over a 15-week semester:

Report 1: Problem definition and literature review
Report 2: Development of viable solution alternatives + ethics and sustainability considerations
Report 3 (Final): Cost-benefit analysis (CBA), multi-criteria decision analysis (MCDA), and expanded final design

Historically, ethical and sustainability considerations were included primarily as a short section within Report 2, with limited prior scaffolding or formative writing. The WAC-integrated redesign distributed writing tasks across the first 10 weeks of the semester through structured, low-stakes individual deliverables aligned with project milestones.

The redesign introduced four scaffolded individual writing deliverables aligned with the engineering design process:

Week	Deliverable	Focus
2-4	Individual Deliverable 1	Technical solution research and design description
5-6	Individual Deliverable 2	Sustainability analysis (three pillars)
6-7	Individual Deliverable 3	Ethical and justice analysis
8-9	Individual Deliverable 4	Revision + integrated expansion for Report 2

Each individual deliverable was submitted separately to Canvas and added to a shared team document for peer review and cohesion. Students received written feedback from the teaching assistants and peers (via shared document comments). Students were asked to revise Deliverables 1-3 before incorporation into Report 2.

Writing assignments

Individual Deliverable 1 – Environmental Issue Exploration and Technical Solution Development

A minimum 300-word technical description including:

- The overview of the environmental issue (impacts on human health, environment, stakeholders).
- A list of all solution alternatives identified by the team (one per member to develop further).
- Conditions under which the solution is appropriate (considering environmental regulations)
- Expected/required pollutant removal efficiency
- Design constraints (e.g., hydraulic retention time, reactor size, operational limitations)
- Factors affecting performance
- A brief justification for why the option is viable based on current research.
- APA-formatted references.
- A link to the shared team document.
- Students were instructed to avoid opinion and maintain objective synthesis.

Individual Deliverable 2 – Sustainability Analysis

A minimum 300-word analysis addressing:

- Environmental sustainability aspects of their design alternative
- Social sustainability aspects of their design alternative
- Economic sustainability aspects of their design alternative
- A reflective paragraph on trade-offs identified
- Students were explicitly required to address all three sustainability pillars.

Individual Deliverable 3 – Ethical and Justice Analysis

Minimum 300-word discussion addressing:

- Equity and justice implications
- Stakeholder impact
- Community voice and participation
- Potential unintended consequences
- A reflective closing paragraph

Students were prompted to explicitly identify:

- Who benefits?
- Who bears burdens?
- Whose input shapes implementation?

Individual Deliverable 4 – Revision and Integration

Students revised Deliverables 1-3 based on feedback and expanded:

- Technical depth
- Sustainability trade-offs
- Ethical and justice considerations

They ensured distinct approaches among team members and cohesive cross-team integration before submission as part of Report 2.

The writing tasks were aligned to the design process:

Design Stage	**Writing Function**
Problem framing	Literature review and synthesis
Alternative generation	Technical articulation
Alternative evaluation	Sustainability reasoning
Stakeholder analysis	Ethical reasoning
Decision refinement	Reflective integration

Assessment instrument

Rubrics were adapted from existing grading structures and modified to explicitly evaluate:

- Ethical reasoning depth
- Sustainability integration across pillars
- Evidence-based justification
- Clarity of articulation

Each dimension was scored on a 4-level scale:

- Exemplary (100%)
- Proficient (75%)
- Developing (50%)
- Needs Revision (25%)

Rubric criteria was aligned with:

- ABET Student Outcome 2: Sustainability considerations and trade-offs in design
- ABET Student Outcome 3: Effective communication
- ABET Student Outcome 4: Ethical and professional responsibility

Rubric 1 – Environmental Issue Exploration and Technical Solution Development

Level	Descriptor
4 – Exemplary	Clearly and accurately frames the environmental issue, including impacts on human health, environment, and stakeholders. Identifies multiple solution alternatives. Provides required pollutant removal efficiency to meet regulations, operational parameters (e.g., HRT, reactor size), constraints, and external factors. Synthesizes peer-reviewed evidence objectively (APA format). Demonstrates strong research-grounded justification without opinion language.
3 – Proficient	Adequately describes the issue and solution. Includes most required technical elements (efficiency, constraints, conditions). Uses credible sources, though integration may be descriptive rather than analytical. Justification present but could be more explicit or quantitative.
2 – Developing	Provides partial or generalized description. Technical parameters vague or incomplete. Limited quantitative data. Sources cited but weakly integrated. Justification superficial.
1 – Needs Revision	Issue poorly framed or incomplete. Minimal technical depth. Lacks required parameters or credible sources. Claims unsupported.

Rubric 2 – Sustainability Analysis

Level	Descriptor
4 – Exemplary	Clear integration of environmental, social, and economic sustainability pillars. Demonstrates systems thinking by articulating measurable trade-offs across pillars. Reflective paragraph shows understanding of competing priorities.
3 – Proficient	Addresses all three pillars, though depth varies. Trade-offs discussed but may lack quantitative or stakeholder specifications. Reflection is provided but somewhat descriptive.
2 – Developing	Addresses only 1-2 pillars or treats pillars unevenly. Trade-offs minimally explored. Reflection superficial.
1 – Needs Revision	Minimal or vague sustainability discussion. Pillars missing or mischaracterized. No meaningful trade-off analysis.

Individual Deliverable 3 – Ethical and Justice Analysis

Level	Descriptor
4 – Exemplary	Clearly identifies multiple stakeholders, equity considerations, and justice implications. Explicitly addresses: Who benefits? Who bears burdens? Whose voice shapes implementation? Discusses unintended consequences and proposes mitigation strategies. Demonstrates depth beyond compliance-level ethics.
3 – Proficient	Identifies stakeholders and ethical concerns. Addresses equity and stakeholder participation but analysis may lack depth or strong mitigation strategies.
2 – Developing	Mentions ethical issues superficially. Stakeholder analysis limited. Justice implications underdeveloped.
1 – Needs Revision	Ethical dimension minimal or absent. Stakeholders not clearly identified. No justice reasoning.

Individual Deliverable 4 – Revision and Integration

Level	Descriptor
4 – Exemplary	Demonstrates substantial revision based on feedback. Expands technical depth, sustainability trade-offs, and ethical reasoning. Writing shows integration across technical, sustainability, and justice domains.
3 – Proficient	Evidence of revision and integration present. Improvements visible but may not fully deepen analysis.
2 – Developing	Limited revision effort. Minimal expansion beyond earlier draft.
1 – Needs Revision	Little to no revision. No meaningful integration of feedback.

Professional Communication

Level	Descriptor
4 – Exemplary	Clear, organized, objective technical writing. Avoids opinion. Proper APA formatting. Logical flow aligned with design stage. Professional tone throughout.
3 – Proficient	Generally clear and professional. Minor organization or formatting issues.
2 – Developing	Organization inconsistent. Tone sometimes informal. Formatting errors.
1 – Needs Revision	Disorganized, unclear, or nonprofessional tone. Formatting missing or incorrect.

Assessment and evaluation plan

As a work-in-progress, this study employs a mixed-methods assessment approach emphasizing formative evaluation. Data sources include student writing artifacts, rubric scores, instructor observations, and qualitative student feedback collected through reflections. Rubrics assessed dimensions such as ethical reasoning, sustainability integration, clarity of justification, and connection to technical analysis. Qualitative analysis focuses on identifying patterns in how students articulate ethical and sustainability considerations over time. Quantitative summaries of rubric scores are used to examine trends across assignments. Assessment criteria are aligned with ABET outcomes related to ethical responsibility, communication, and consideration of societal and environmental impacts, supporting program-level evaluation while informing iterative course refinement.

Preliminary analysis of student writing suggests that distributing writing across the design process supports deeper engagement with ethical and sustainability reasoning. Students increasingly articulated explicit trade-offs among technical, environmental, and social factors, and demonstrated greater confidence in justifying design decisions. Reflections indicate that writing prompts helped students clarify assumptions, recognize stakeholder impacts, and connect sustainability concepts to concrete design choices. Student feedback also suggests increased appreciation for writing as a professional engineering skill rather than a purely academic requirement. Several students noted that short, focused writing tasks felt more relevant and manageable than a single large paper, and that writing supported team discussions and decision-making.

Evidence of Ethical and Sustainability Reasoning

Rubric-based assessment of student work further supported the role of design-connected writing in promoting ethical and sustainability reasoning. Student submissions were evaluated using an ABET-aligned rubric assessing discussion of ethical and justice-related concerns as well as consideration of sustainability across the three pillars: society, environment, and economy. At the highest performance level, students demonstrated the ability to identify relevant ethical and justice concerns associated with multiple design alternatives and to articulate potential mitigation strategies. These responses reflected an understanding of how engineering decisions can differentially impact human health, environmental systems, and economic conditions.

At the satisfactory level, students generally acknowledged ethical or justice-related concerns but provided more limited discussion of how those concerns influenced design decisions. Lower-performing responses tended to reference ethics or sustainability in vague or surface-level terms, or treated these considerations as secondary to technical performance. This pattern suggests that

while most students recognized the importance of ethical and sustainability issues, the depth of reasoning varied across teams.

Analysis of sustainability-related rubric dimensions indicates that students who engaged more fully with the structured writing prompts were more likely to address all three sustainability pillars in a coherent and integrated manner. In contrast, weaker responses often emphasized a single pillar, most commonly economic feasibility, without explicitly addressing environmental or social implications.

Comparison to prior course iterations

To evaluate whether the WAC-integrated approach represents an improvement over the previous course design, further work will include comparison to archival student work from prior iterations of the course. In the previous format, ethical and sustainability considerations were addressed primarily within a single report section without any prior feedback or iteration. Writing served largely as documentation rather than a formative tool for improvement and deeper dive.

Student artifacts from both course formats will be evaluated using the same ABET-aligned rubric assessing 1) identification of ethical concerns, 2) discussion of sustainability trade-offs across environmental, social, and economic dimensions, and 3) justification of design decisions.

Comparative indicators will include:

- Mean rubric scores across ethical reasoning
- Mean rubric scores across sustainability considerations
- Communication of sustainability trade-offs

Qualitative coding will also be used to identify the themes in student reflection papers to determine improved sustainability and ethics considerations. This comparison will allow evaluation of whether distributing writing throughout the design process produces more sustained and integrative reasoning than a single summative writing task.

Even though this approach removes the challenge of a larger writing task for the seniors, our observations have been so that students delay the work or underestimate the writing tasks without a structured process and tend to rush through the writing process closer to the deadline. Through structured smaller writing tasks, they may be able to continue building on their work, developing a well-developed artifact.

Preliminary quantitative findings

Preliminary rubric analysis (n = 52 students) indicates that 78% of students clearly articulated trade-offs across at least two sustainability pillars, compared to 67% (n = 41) in the previous course iteration. 83 % of the students (n = 52) identified ethical and justice concerns related to their alternative designs and identified potential ways to mitigate them, compared to 79% (n = 41) in the previous course iterations.

Work-in-progress

This work-in-progress demonstrates how WAC principles can be operationalized within an engineering design course to support ethical and sustainability reasoning. By embedding writing throughout the design process, the approach reframes writing as an integral component of engineering judgment rather than a documentation task. The model is scalable and adaptable, requiring minimal restructuring of existing courses while supporting multiple ABET-aligned outcomes. The findings suggest that writing-to-learn activities can strengthen students' ability to articulate and defend design decisions in complex, value-laden contexts, an essential competency for contemporary engineering practice.

As a work-in-progress, the study is limited by its reliance on early findings and a single course context. Ongoing work includes expanding data collection, refining rubrics, and examining changes in student perceptions of writing over time. Future iterations will incorporate more systematic quantitative analysis and potentially explore transferability across courses and programs. This project suggests framework for integrating writing as a reflective and analytical tool in engineering design education, supporting efforts to prepare engineers who are both technically proficient and ethically grounded.

Although the primary goal of the intervention was to enhance ethical and sustainability reasoning, attention was also given to improving students' writing clarity and structure. Students were provided with rubric transparency, examples of high quality responses, and feedback on their writing assignments for improvement. Future iterations may incorporate structured peer review and targeted feedback processes to further improve writing quality.

Acknowledgements

Many thanks go to CSU Writing Across the Curriculum Grant and Ms. Annie Halseth for the support for this work.

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