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Building Sustainability Competencies through Micro-Credentialing: A Transdisciplinary Life-Cycle Design Thinking Approach

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She is a co-developer of the micro-credential course ”Sustainability: Transdisciplinary Life-Cycle Design Thinking,” which operationalizes the Engineering for One Planet (EOP) framework through experiential learning and modular credentialing. Her broader educational mission focuses on embedding sustainability competencies into engineering curricula without increasing credit loads, fostering collaboration across disciplines, and preparing students with industry-relevant, data-driven design and life-cycle assessment (LCA) skills.

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Measuring the Impact of Micro-Credentials on Transdisciplinary Life-Cycle Thinking within the EOP Framework

Abstract

As engineering programs respond to rapidly evolving sustainability expectations, there is a growing need for flexible mechanisms that build Engineering for One Planet (EOP) competencies without adding credit-hour burdens or requiring program-level curricular restructuring. Micro-credentials and digital badges offer a promising pathway; however, stand-alone credentials often operate outside disciplinary contexts, limiting transfer, adoption, and equity of access. This paper reports the design and early evaluation of *Sustainability: Transdisciplinary Life-Cycle Design Thinking*, an EOP-aligned micro-credential intentionally embedded within existing credit-bearing courses to support authentic, systems-oriented learning.

Developed by faculty affiliated with Virginia Commonwealth University's Institute for Sustainable Energy and Environment, the micro-credential operationalizes core EOP principles (systems thinking, life-cycle assessment, stakeholder-informed decision-making, and ethical responsibility) through a transdisciplinary design lens. The credential is open to students across engineering, business, and arts disciplines, reflecting the EOP framework's emphasis on integrating technical, social, environmental, and economic dimensions in engineering practice. Embedding the micro-credential within credit-bearing courses reinforces disciplinary learning outcomes, reduces participation barriers associated with stand-alone offerings, and enables faculty adoption without disrupting existing curricula.

The micro-credential comprises three stackable modules: Introduction to Life-Cycle Thinking, Supply-Chain and Circular Systems Analysis, and Sustainable Design Assessment. Each module pairs concise instructional content with a rubric-scored assignment aligned to EOP learning outcomes and ABET-relevant competencies, including design under constraints, ethics, teamwork, experimentation and data analysis, and communication. Pilot implementation across multiple colleges engaged 175 students and indicated relevance, integration into course deliverables, and alignment with capstone work. Results suggest that embedded, transdisciplinary micro-credentials advance EOP-aligned sustainability education broadly.

Keywords: Engineering for One Planet (EOP); transdisciplinary design; systems thinking; life-cycle assessment (LCA); sustainable engineering education; micro-credentials and digital badges; ABET-aligned competencies; circular economy and supply-chain systems

1. Introduction

Institutions of higher education are increasingly expected to provide learning experiences that are flexible, relevant, and responsive to rapidly evolving workforce and societal needs. In this context, micro-credentials have emerged as a structured mechanism for recognizing the acquisition of specific competencies, skills, or knowledge that may not be fully represented through traditional academic transcripts.[1] Typically delivered as short, modular learning experiences and documented through digital badges or certificates, micro-credentials include transparent metadata describing learning outcomes, assessment criteria, and evidence of achievement. When faculty-designed and assessed, micro-credentials function as a formal and verifiable record of learning that can occur within, alongside, or beyond conventional credit-bearing coursework.

Over the past decade, micro-credentials have gained momentum across higher education, professional societies, and industry in response to increasingly non-linear student pathways and accelerated changes in skill demand.[2,3] Early adoption was concentrated in professional development and continuing education, particularly in information technology and workforce training contexts.[4] More recently, micro-credentials have been adapted for undergraduate and graduate education as tools for competency-based learning, curricular innovation, and employer signaling.[5] Their advantages include flexibility, scalability, and portability: students can document discrete, job-relevant skills without extending time to degree or accumulating additional credit hours, while institutions can introduce emerging topics without undertaking program-level curricular revisions. Importantly, micro-credentials also allow for more granular assessment of learning and can be updated as standards, tools, and societal priorities evolve.

These characteristics make micro-credentials particularly well suited for sustainability education**,** which presents persistent challenges for traditional curricula. Sustainability is inherently broad, systems-oriented, and transdisciplinary, encompassing environmental stewardship, social responsibility, economic viability, and ethical decision-making.[6] Addressing sustainability meaningfully requires competencies such as systems thinking, trade-off analysis, stakeholder engagement, and long-term impact assessment—skills that cut across disciplinary boundaries. Consequently, sustainability content is often unevenly distributed across programs, confined to electives, or addressed in isolated courses with limited integration into core disciplinary learning.[7] Stand-alone sustainability credentials may further limit access by competing with crowded degree plans or attracting only self-selected student populations.

To address the challenges of integrating sustainability across diverse programs, a unifying framework is needed that articulates competencies in ways that are both outcomes-oriented and adaptable across disciplines. The Engineering for One Planet (EOP) Framework, launched in 2020 by The Lemelson Foundation in partnership with the VentureWell Foundation, advances sustainability and climate literacy by emphasizing systems thinking, life-cycle–informed analysis, ethical responsibility, stakeholder-aware decision-making, and the integration of environmental, social, and economic considerations into practice.[8] Although rooted in engineering education, EOP is intentionally transdisciplinary, reflecting the reality that sustainability challenges extend beyond technical domains and require collaboration among engineers, designers, business professionals, policymakers, and communities. These competencies also align with sustainability principles in other fields, including Environmental, Social, and Governance (ESG) frameworks used to assess organizational sustainability performance across environmental impacts, social responsibility, stakeholder relations, and governance practices, as well as human-centered design approaches. EOP was therefore selected as the organizing framework for this micro-credential because it provides a competency-based structure that translates effectively across technical and non-technical domains, enabling shared sustainability literacy while allowing discipline-specific interpretation. Alternative frameworks were considered, including reporting-focused business models and design-thinking approaches; however, these tend to privilege either managerial metrics or creative processes in isolation. By contrast, EOP's integrated competency model offers a stronger foundation for a transdisciplinary educational intervention bridging engineering, business, and arts contexts while maintaining conceptual coherence and rigor.

Against this context, this study describes the design and implementation of an EOP-aligned, transdisciplinary micro-credential embedded within credit-bearing courses across multiple colleges, including its modular structure, assessment strategy, and evaluation methods. It is worthwhile to note that this approach supports accreditation alignment by embedding Accreditation Board for Engineering and Technology (ABET) student outcomes such as design under constraints, ethical and professional responsibility, teamwork, experimentation and data analysis, and effective communication—within course-based sustainability learning.

2. Methods

2.1 Design of Micro-credential

The *Sustainability: Transdisciplinary Life-Cycle Design Thinking* micro-credential was developed through a coordinated collaboration among faculty from Virginia Commonwealth University's College of Engineering, School of Business, and School of the Arts. Engineering faculty emphasized life-cycle assessment (LCA), systems modeling, and trade-off analysis; business faculty contributed expertise in supply-chain management, risk, and sustainability metrics; and arts faculty foregrounded design thinking, material context, and human-centered problem framing.The primary design objective was to embed EOP aligned sustainability competencies within existing credit-bearing courses across multiple colleges without increasing credit-hour requirements or requiring curricular restructuring, Fig 1.**Error! Bookmark not defined.** Accordingly, the micro-credential was designed as a modular, stackable experience adaptable to senior design courses, project-based electives, and interdisciplinary studios. It consists of three short modules that progressively build sustainability competencies, each following a consistent instructional structure: **(1)** a concise video primer, **(2)** a guided applied task, and **(3)** a rubric-scored assignment that generates an assessable learning artifact. A brief description of this module is provided below:

1. The "*Introduction to Life-Cycle Thinking"* module introduces the LCA framework, including system boundaries, functional units, and cradle-to-cradle perspectives, with emphasis on problem framing and impact identification.
2. The "*Supply-Chain Management"* module applies life-cycle concepts to sourcing, logistics, manufacturing pathways, and end-of-life strategies, incorporating circular economy options through scenario-based analysis.
3. The *"Sustainable Design Assessment"* module integrates prior skills into a structured decision brief or sustainability design canvas, requiring students to document assumptions, evaluate trade-offs, and justify decisions using environmental, social, and economic criteria.

During the pilot phase, the micro-credential modules were embedded within existing courses rather than offered as standalone instruction. Implementation contexts included senior design courses in engineering programs, project-based electives in business, and studio-based coursework in the arts. Faculty incorporated the modules at points where sustainability framing or decision analysis was already pedagogically relevant, allowing the credential to function as an overlay rather than a curricular replacement. This embedded approach ensured alignment with course learning outcomes while maintaining consistent assessment artifacts across programs.

It is important to realize that the micro-credential was intentionally designed to provide foundational sustainability literacy rather than discipline-specific technical mastery**.** The modules emphasize conceptual framing, systems thinking, and structured decision-making approaches that enable students to identify sustainability tradeoffs within their disciplinary contexts. Rather than attempting comprehensive technical coverage of every sustainability method, the micro-credential focuses on equipping learners with transferable analytical frameworks (e.g., boundary definition, circularity pathways, trade-off justification) that can be applied within subsequent discipline-specific coursework. In this sense, the credential functions as an enabling layer of sustainability cognition, upon which deeper technical competencies may be developed through domain-specific instruction, research, or professional practice.

Table 1. Alignment of the *Sustainability: Transdisciplinary Life-Cycle Design Thinking* micro-credential modules with Engineering for One Planet (EOP) outcomes.

Module	Primary EOP Outcomes Addressed
Introduction to Life-Cycle Thinking	• Systems thinking across product and process life cycles • Life-cycle–informed problem framing • Awareness of environmental and societal impacts
Supply-Chain Management	• Integration of environmental, social, and economic considerations • Stakeholder-informed decision-making • Circular economy and resource stewardship
Sustainable Design Assessment	• Trade-off analysis and decision justification • Ethical and professional responsibility • Evidence-based sustainability assessment

Table 2. Alignment of micro-credential modules with Accreditation Board for Engineering and Technology (ABET) student outcomes and associated assessment artifacts.

Module	ABET Student Outcomes	Primary Assessment Artifacts
Introduction to Life-Cycle Thinking	• Identify, formulate, and solve complex engineering problems • Consider global, environmental, and societal factors	• Life-cycle system boundary diagram • Functional unit definition • Reflective memo
Supply-Chain Management	• Engineering design under constraints • Teamwork	• Supply-chain scenario analysis • Circularity decision matrix • Design justification
Sustainable Design Assessment	• Communication • Ethical and professional responsibility • Data analysis and interpretation	• Sustainability Design Canvas or decision brief • Quantified trade-off analysis • Assumptions and uncertainty documentation

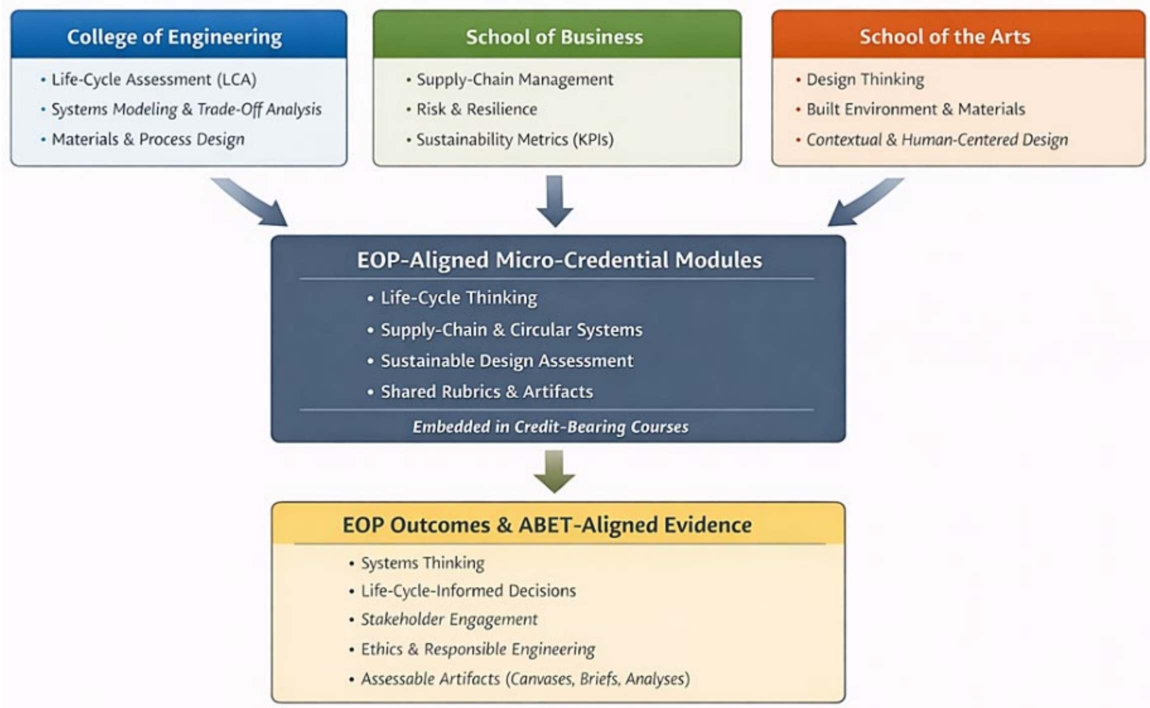

Figure 1. Transdisciplinary collaboration model for the EOP-aligned micro-credential. Faculty from the College of Engineering, School of Business, and School of the Arts contribute disciplinary expertise that converges through shared, EOP-aligned micro-credential modules embedded within credit-bearing courses, resulting in assessable sustainability competencies and ABET-aligned evidence.

2.2 Digital Badge Design and Earning Criteria

Completion of the micro-credential was recognized through a digital badge titled *Sustainability: Transdisciplinary Life-Cycle Thinking*, issued by Virginia Commonwealth University.[9] The badge serves as a portable, verifiable credential with embedded metadata describing learning outcomes, associated skills, and earning criteria. Skills associated with the badge include life-cycle thinking, systems and contextual awareness, design thinking, creative problem solving, circular economy principles, sustainable supply-chain management, and sustainability measurement using key performance indicators (KPIs). To earn the badge, learners were expected to complete all three modules and demonstrate competency through a final rubric-scored assessment, with a minimum performance threshold of 80%, ensuring that badge issuance reflects demonstrated competency rather than participation alone.

2.3 Evaluation Instruments and Data Collection

The sustainability micro-credential was offered to undergraduate and graduate students across engineering, business, and arts programs at [institution], with a total participation of n = 281 students. Following completion of the instructional modules, student learning and perceptions were evaluated using a two-part assessment approach consisting of (1) a required summative knowledge assessment and (2) an optional post-credential survey. Both instruments were administered electronically using an online data collection platform.

The summative assessment included a combination of multiple-choice and scenario-based questions designed to evaluate student learning across multiple dimensions of sustainability. The optional post-credential survey consisted of five items, including three Likert-scale questions and two open-ended questions, and was designed to capture students' prior familiarity with key sustainability concepts and their perceived ability to transfer learning to real-world contexts. The Likert-scale items asked students to report: (1) their familiarity with life-cycle analysis prior to taking the course; (2) their familiarity with the concept of sustainable supply chains prior to the course; and (3) the likelihood that they would apply the skills and knowledge gained from the micro-credential to real-world scenarios. The two open-ended questions invited students to describe (1) the most valuable aspects of the micro-credential and (2) suggested improvements for future iterations of the course.

Quantitative responses from the Likert-scale items were analyzed using descriptive statistical methods (e.g., means and standard deviations) to characterize trends across disciplinary groups. Qualitative responses were analyzed using thematic content analysis to identify recurring themes related to perceived value, learning transfer, and opportunities for course refinement. Together, these mixed-methods data provided both summative evidence of learning outcomes and formative feedback to support continuous improvement of the micro-credential.

3. Results and Discussion

The study cohort comprised students from engineering, business, and arts disciplines, representing academic programs with substantial differences in curricular structure, technical emphasis, and prior exposure to sustainability concepts. This disciplinary breadth provides a strong foundation for examining how students engage with multiple dimensions of sustainability learning within a shared micro-credential framework. Because the modules were integrated into existing coursework across multiple colleges rather than delivered through a single course, student exposure to the credential occurred within varied instructional contexts, reflecting the intended distributed implementation model.

Descriptive results from the pilot implementation (n = 191) are summarized in Table 3 and illustrated in Figure 2.

Table 3. Summary of Student Outcomes by Discipline

Discipline	No. of Students	*Foundational LCA Understanding** Mean Score (SD)	*Supply Chain Sustainability Understanding** Mean Score (SD)	*Likelihood of Application in Real-World Contexts** Mean Score (SD)
Business	54	3.30 (1.09)	3.67 (1.10)	4.27 (0.88)
Mechanical Engineering	81	3.28 (1.10)	3.30 (1.09)	3.90 (0.85)
Electrical Engineering	46	3.56 (1.15)	2.88 (1.09)	3.80 (1.00)
Chemical Engineering	30	3.20 (1.37)	3.20 (0.96)	4.13 (0.86)
Arts	40	3.53 (1.18)	3.40 (1.01)	4.10 (0.93)

Weighted scores**	3.36 (1.15)	3.31 (1.09)	4.01 (0.90)

Notes: **All measures used a five-point Likert scale (1 = very low, 5 = very high); ** Weighted SDs reflect pooled within- and between-discipline variance using discipline sample sizes as weights.*

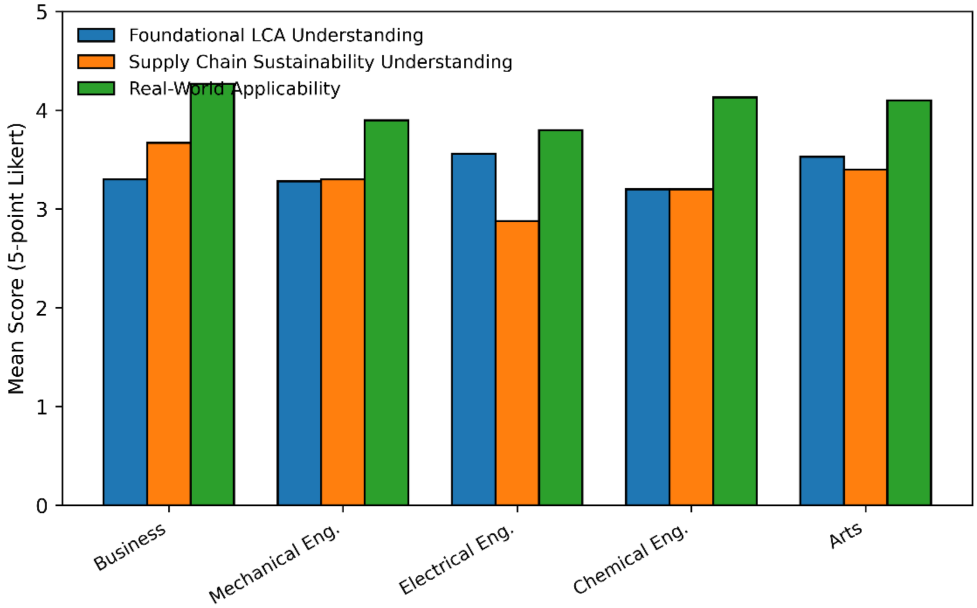

Figure 2. Mean student self-reported scores for foundational life-cycle analysis (LCA) understanding, supply chain sustainability understanding, and real-world applicability across disciplines. Scores are reported on a five-point Likert scale.

Across all disciplines, students demonstrated a generally consistent understanding of foundational life-cycle analysis (LCA) principles. Mean scores exceeded the midpoint of the five-point Likert scale, ranging from M = 3.20 to 3.57, with moderate variability (SD = 1.09–1.37). Although the full response range (1–5) was observed within each disciplinary group—reflecting heterogeneity in incoming knowledge—the similarity of mean values and overlapping distributions suggest only modest disciplinary differences in foundational LCA understanding. In contrast, greater disciplinary variation emerged in students' understanding of supply chain sustainability. Mean scores ranged from M = 2.88 to 3.67, indicating differences in conceptual familiarity that appear sensitive to curricular emphasis and prior disciplinary exposure. Business students reported the highest average understanding (M = 3.67), followed by Arts (M = 3.40), Mechanical and Nuclear Engineering (MNE; M = 3.30), and Chemical and Life Science Engineering (CLSE; M = 3.20), while Electrical and Computer Engineering (ECE) students reported the lowest mean score (M = 2.88). Standard deviations were comparable across disciplines (approximately SD ≈ 1.0), indicating similar response dispersion within each group despite differences in central tendency. These patterns suggest that while foundational life-cycle concepts are broadly accessible across disciplinary contexts, understanding of supply chain sustainability is more strongly shaped by disciplinary training and curricular focus.

Despite these differences in conceptual familiarity, students across all disciplines reported a consistently high likelihood of applying the skills and knowledge gained through the micro-credential to real-world contexts. Mean scores for perceived applicability ranged from M = 3.80

to 4.27, with all groups reporting averages well above the midpoint of the scale. Business students again reported the highest likelihood of application (M = 4.27), followed by CLSE (M = 4.13) and Arts (M = 4.10), while MNE (M = 3.90) and ECE (M = 3.80) students also expressed strong intentions to apply course concepts. The relatively low and consistent variability (SD ≈ 0.85–1.00) indicates broad agreement regarding the practical relevance and transferability of the micro-credential content.

Taken together, the quantitative results (Table 3; Fig. 2) reveal a coherent pattern across disciplinary contexts. Foundational LCA understanding was relatively uniform across engineering, business, and arts students, whereas understanding of supply chain sustainability exhibited greater disciplinary variation. Importantly, these differences did not translate into diminished perceived applicability. Students across all disciplines reported similarly strong intentions to apply micro-credential knowledge in real-world settings, underscoring the potential of a transdisciplinary sustainability micro-credential to bridge disciplinary differences, reinforce shared foundational literacy, and support the transfer of sustainability concepts from coursework to applied practice.

Qualitative responses further contextualize and reinforce these findings. Students consistently identified life-cycle thinking, supply chain sustainability, and holistic design perspectives as the most valuable components of the micro-credential. Many emphasized gaining a systems-level understanding of products and processes—from raw material extraction through end-of-life—highlighting considerations such as energy use, emissions, and waste. Themes related to supply chain risk, logistics, and uncertainty emerged prominently, particularly in relation to real-world constraints and decision-making tradeoffs. Students also highlighted the value of circular economy concepts, including cradle-to-cradle design and material reuse, as well as real-world case studies that helped connect theoretical concepts to practice.

Building on these strengths, student feedback pointed to opportunities for enhancing interactivity, applied learning, and instructional clarity in future iterations of the micro-credential. Common suggestions included incorporating additional real-world case studies, hands-on or scenario-based exercises, and interactive elements within videos, such as embedded questions or short quizzes. Students also requested clearer organizational scaffolding, including end-of-video summaries, grouped assessment questions, and access to slides or transcripts. Several responses indicated interest in deeper coverage of select topics—particularly supply chain sustainability—supported by additional examples and quantitative scenarios. Collectively, these recommendations identify pathways for strengthening engagement and applied learning while preserving the micro-credential’s foundational, discipline-agnostic scope. At the same time, they highlight the importance of ensuring that foundational sustainability concepts remain adaptable to diverse disciplinary contexts. Although the micro-credential delivers shared core competencies, it is intentionally designed for discipline-specific contextualization at the assignment level. For example, materials engineering students may apply life-cycle principles to recyclability, alloy selection, and remanufacturing pathways, while mechanical engineering students may analyze energy efficiency and system integration tradeoffs. This modular structure allows instructors to align sustainability analysis with disciplinary learning outcomes without modifying the core instructional content. In this way, the micro-credential operates as a scaffold rather than a prescriptive curriculum, supporting both consistency of foundational literacy and flexibility of disciplinary application.

Several limitations should be acknowledged when interpreting these results. The study reflects a pilot implementation at a single institution and relies in part on self-reported measures of familiarity and perceived applicability, which do not capture long-term retention or demonstrated sustainability-informed design performance. Disciplinary participation levels and instructional contexts varied across courses, and the competencies addressed represent a foundational subset of sustainability practice rather than a comprehensive treatment. Accordingly, the findings should be viewed as exploratory, establishing proof of concept rather than definitive evidence of impact. To this end, ongoing work is focused on strengthening the evidence base for the micro-credential's effectiveness through implementation in authentic, project-based learning environments. At VCU, Vertically Integrated Projects (VIP),[10] Senior Capstone Design, and Independent Study courses provide natural settings for students to apply sustainability and life-cycle principles. One representative example is the Middle of Broad (mOb) Studio, a transdisciplinary initiative engaging undergraduate and graduate students from VCUarts and affiliated programs, in partnership with VCU Sustainability.[11] In this ongoing effort, students collaborate with university sustainability staff to develop strategies for recycling and reusing cardboard waste from the VCU College of Engineering, supporting School of the Arts' material needs while reducing institutional waste hauling costs. Pilot experience further suggests that the micro-credential is most effective when introduced at curricular transition points—such as late sophomore or junior courses involving open-ended design, or capstone and project-based experiences where sustainability trade-offs can be applied, indicating that distributed integration across the curriculum may offer the strongest pedagogical benefit.

The *Sustainability: Transdisciplinary Life-Cycle Design Thinking* micro-credential underpins this work by providing foundational competencies in life-cycle assessment, circularity, and systems thinking, with learning transfer evaluated through a structured, sustainability-focused student competition aligned with Engineering for One Planet (EOP) outcomes. In parallel, the micro-credential will be released as open courseware through the Virtual Library of Virginia (VIVA), a statewide academic consortium supporting the creation and dissemination of openly licensed educational resources.[12] Although designed for adaptation across institutions, the model preserves its value through standardized competency definitions, shared assessment artifacts, and performance thresholds for badge issuance. Instructors may contextualize assignments to local disciplinary needs, but credentialing remains tied to demonstrated achievement of common outcomes. By balancing implementation flexibility with consistency of competency verification, this approach reduces the risk of credential dilution while enabling broader adoption. Making the micro-credential publicly available through this platform further extends access beyond institutional boundaries and supports adaptation, reuse, and replication across engineering and allied disciplines, strengthening both the empirical foundation and scalability of curriculum-embedded sustainability micro-credentials in engineering education.

4. Conclusion

This study examined early outcomes of a transdisciplinary sustainability micro-credential focused on life-cycle analysis, supply chain sustainability, and systems-level design thinking. Results from a diverse cohort spanning engineering, business, and arts disciplines indicate that foundational life-cycle concepts are broadly accessible, while understanding of supply chain sustainability varies with prior curricular exposure. Despite these differences, students across disciplines reported high perceived relevance and strong intentions to apply micro-credential learning in real-world contexts, supporting the value of embedding sustainability education within credit-bearing coursework. Collectively, these findings provide early evidence that the micro-credential operationalizes key Engineering for One Planet (EOP) outcomes, including systems thinking, life-cycle–informed reasoning, and integration of environmental, social, and economic considerations. The transdisciplinary structure—supported by shared modules, rubric-scored artifacts, and a performance-gated digital badge—enabled consistent assessment of sustainability competencies while reducing participation barriers and supporting alignment with ABET student outcomes.

Recent national initiatives further highlight the growing role of micro-credentials in sustainability education. For example, ABET's Sustainability Microcredential is designed as a fully online, self-paced certificate to support flexible, lifelong learning for STEM students and professionals.[13] In contrast, the VCU sustainability micro-credential was intentionally embedded within existing degree programs. Integrating the credential into credit-bearing coursework enables structured faculty mentorship, discipline-specific performance assessment, and curricular coherence—positioning sustainability not as an optional enrichment activity, but as a core expectation of engineering practice. From an engineering education perspective, this embedded model represents a scalable and pedagogically rigorous approach for advancing sustainability learning while preserving academic standards and program accountability.

The Sustainability: Transdisciplinary Life-Cycle Design Thinking micro-credential provides foundational competencies in life-cycle assessment, circularity, and systems thinking, with learning transfer evaluated through a structured, sustainability-focused student competition aligned with Engineering for One Planet (EOP) outcomes. Efforts are underway to release the credential as open courseware through the Virtual Library of Virginia (VIVA), extending access beyond institutional boundaries and supporting adaptation, reuse, and replication across disciplines.[14] Although designed for adaptation across institutions, this proposed initiative will preserve its value through standardized competency definitions, shared assessment artifacts, and performance thresholds for badge issuance. Instructors may contextualize assignments to local disciplinary needs, but credentialing remains tied to demonstrated achievement of common outcomes. By balancing implementation flexibility with consistency of competency verification, this approach reduces the risk of credential dilution while enabling broader adoption.

Future research will also examine how institutionally issued, EOP-aligned micro-credentials compare with established sustainability credentials—including ABET's Sustainability Microcredential,[13] LEED,[15] Envision,[16] or Certified Sustainability Professional certifications, with respect to accessibility, disciplinary scope, pedagogical integration, and demonstrated impact on student learning and professional preparation. Such comparisons will clarify the role of curriculum-embedded micro-credentials as complements—not replacements—to established certifications and help determine how they can scale across institutions. Ultimately, this work suggests that embedded micro-credentials may provide a practical pathway for normalizing sustainability as an integrated, assessable, and cross-disciplinary dimension of engineering education rather than a peripheral or optional component.

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References:

[1] R. Ward, S. Grant, M. W. Larsen, and K. Giovacchini, "The universal micro-credential framework: The role of badges, micro-credentials, skills profiling, and design patterns in

developing interdisciplinary learning and assessment paths for computing education", *IEEE Transactions on Education*, *67*(6), 897-906, 2024

[2] R. Raj, A. Singh, V. Kumar, and P. Verma, "Achieving professional qualifications using micro-credentials: a case of small packages and big challenges in higher education", *Int. J. Educ. Manage.*, *38*(4), 916-947, 2024

[3] K. L. Keeley, "The scope and depth micro-credential framework: Aligning education with evolving industry demands,", *Innovative Approaches in Vocational and Regional Education*. IGI Global Scientific Publishing, 2025. 49-86.

[4] D. Parsons, "Design and implementation of a postgraduate micro-credential in software development," in *Science and Information Conference*, pp. 853-864. Cham: Springer Nature Switzerland, 2023.

[5] M. Alenezi, M. Akour, and L. Alfawzan, "Evolving microcredential strategies for enhancing employability: Employer and student perspectives", *Education Sciences* 14(12), 1307, 2024

[6] D. L. Zelinka, "*Systems approaches to transdisciplinary sustainable development issues*" Doctoral dissertation, University of Colorado at Boulder, 2019

[7] M. Ward, B. Bowen, S. Burian, A. Cachelin, and D. McCool, "Institutionalizing interdisciplinary sustainability curriculum at a large, research-intensive university: Challenges and opportunities," J. Environ. Stud. Sci., 6(2), 425–431, 2016.

[8] C. Anderson and C. Cooper, "Infusing sustainability into diverse courses and programs using open source Engineering for One Planet (EOP) teaching resources," in Proc. of the 2024 ASEE Annu. Conf. Expo., Jun. 2024.

[9] Institute for Sustainable Energy and Environment (ISEE), "Digital badge program," Virginia Commonwealth University. [Online]. Available: https://isee.vcu.edu/education-and-outreach/digital-badge/ [Accessed Feb 21, 2026]

[10] Virginia Commonwealth University, "Vertically Integrated Projects (VIP)," [Online]. Available: https://vip.vcu.edu/ [Accessed Feb 21, 2026]

[11] Virginia Commonwealth University School of the Arts, "Middle of Broad community engagement," [Online] Available: https://arts.vcu.edu/community-campus/middle-of-broad/ [Accessed Feb 21, 2026]

[12] Virtual Library of Virginia (VIVA),[Online] Available https://vivalib.org/va/open/vivaopen, [Accessed Feb 21, 2026]

[13] ABET, "Sustainability micro-credential," [Online]. Available: https://www.abet.org/sustainability-microcredential/ [Accessed Feb 21, 2026]

[14] Virtual Library of Virginia (VIVA) [Online]. Available: https://vivalib.org/va/open/vivaopen [Accessed Feb 21, 2026]

[15] U.S. Green Building Council, "LEED rating system," [Online] Available: https://www.usgbc.org/leed [Accessed Feb 21, 2026]

[16] Institute for Sustainable Infrastructure, "Envision sustainable infrastructure framework," [Online] Available: https://www.envisionenvironmental.com/ [Accessed Feb 21, 2026]