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Developing a Body of Knowledge for Sustainability Engineering Using the Delphi Method: A Work in Progress

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Work in Progress: Developing a Body of Knowledge for Sustainability Engineering Using the Delphi Method

Abstract. As sustainability becomes increasingly essential to engineering education and practice, there is a need to formally define Sustainability Engineering as a distinct discipline. However, Sustainability Engineering, as a new and evolving field of study, still lacks a unified structure that can facilitate curricular coherence, guide the assessment of learning outcomes, and define professional competencies. As a means to develop this structure, and informed by other BoK's in engineering, as well as by the Engineering for One Planet (EOP) Framework, a preliminary model of a Sustainability Engineering Body of Knowledge ("SE-BoK") is proposed, containing five outcomes areas: Foundational, Engineering Fundamentals, Technical, Professional, and Mindsets and Values. To build a robust BoK, a multi-round Delphi study is proposed to acquire expert feedback and consensus on the contents and structure of the SE-BoK, using a survey based on the preliminary model as the basis of inquiry. The method of panel selection (from industry, academia, and other stakeholders) and the design of three iterative rounds of the Delphi study are described. Future work will report on the results of the Delphi study.

1. Introduction

As presented beautifully in *Braiding Sweetgrass* [1], many indigenous peoples were practicing sustainability for millenia as part of ritual and routine by managing resources in harmony with the natural biogeochemical cycles in their environments. Yet, many of these practices have been all but forgotten or displaced, particularly due to centuries of colonialism and resource extraction exerted by imperial powers, along with the emergence of the consumerism based economy, leading to the current environmental crisis that is now encountering not only global warming, but threats to several other planetary and social justice boundaries [2]. In response, the modern notion of "sustainability" has emerged to both acknowledge the unsustainability of current practices and to promote a host of solutions that attempt to maintain accepted standards of living within planetary and social justice boundaries.

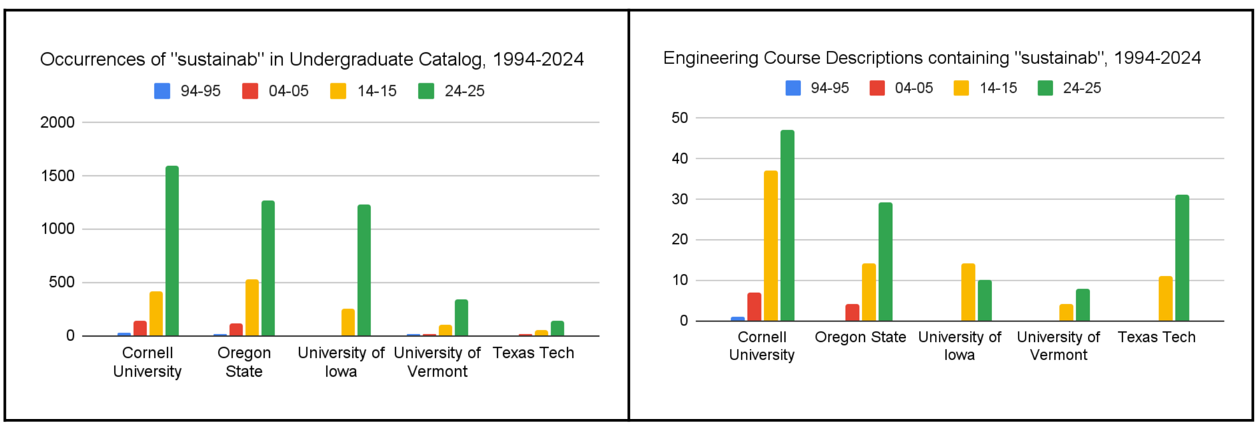
Acknowledging this context, the modern, internationally recognized sustainability movement emerged with a series of key initiatives and meetings organized through the United Nations over the last several decades, notably:

- the Brundtland Commission, formed in 1983, whose report established the widely acknowledged definition of sustainable development[1] as "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs" [3];
- the Rio Earth Summit in 1992 that established the United Nations Framework Convention for Climate Change (UNFCCC) and the annual Conferences of the Parties;

[1] The authors acknowledge that "sustainability" and "sustainable development" are not synonymous terms, at least due to the tension between "development" and "growth". But "sustainable development" has gained parlance in the context of the historical sketch.

- the 2012 UN Conference on Sustainable Development (“Rio + 20”) that launched the creation of the 17 UN Sustainable Development Goals, which were adopted in 2015 at the UN Sustainable Development Summit.

This movement is reflected in the growing prominence of sustainability in university courses and curricula, including engineering, and has been championed in reports of the National Academies of Science, Engineering, and Medicine [4] and UNESCO [5]. To illustrate this impact, Figure 1 provides data showing that the occurrence of the keyword root “sustainab” in university catalogs and in engineering course descriptions has grown sharply over the last 30 years (based on snapshots at 10-year intervals from academic years 1994-95, 2004-05, 2014-15, and 2024-25). Acknowledging that this data might contain information that does not represent substantive growth of sustainability content in courses (e.g., “sustainability” might have been added to a course description without being deeply addressed), these trends, nevertheless, are likely representative of increasing, authentic attention of sustainability in many other universities, including within ABET accredited engineering programs. Indeed, other studies have also reported a notable increase of sustainability-related coverage in engineering courses and programs in the past two decades [6], [7]. For example, in a 2008 survey of over 300 engineering department heads, Murphy et al. reported that “more than 80% of the respondents reported some level of sustainable engineering course activity” [8].



(a) **(b)**

Figure 1. (a) Occurrence of ‘sustainab” in selected University Undergraduate Catalogs, 1994-2025. (b) Engineering Course Descriptions containing ‘sustainab” 1994-2025.

As the process to incorporate the principles and goals of sustainability as part of the training of engineers matures, a new engineering field called “Sustainability Engineering” is emerging, for which we propose the following definition:

> “Sustainability Engineering is a challenge-based field that applies the concepts and skills of mathematics, physical sciences, social sciences, economics, and

> ecology to use the resources of the Earth (materials and energy) for the well-being of present and future generations in balance with the Biosphere."

Sustainability engineers must be able to integrate social, ecological, and economic factors with technical/engineering considerations as routine. This requires a transdisciplinary and systems-thinking mindset, which is markedly different from the orientation of conventional engineering disciplines. The main goal of this work is to initiate the development of a new Body of Knowledge that establishes the required knowledge, skills, attitudes (KSAs)[2], and even behaviors (KSABs) for professional formation in Sustainability Engineering (SE-BoK).

2. Literature Review

Over the past three decades, educators and researchers have begun to articulate learning outcomes, competencies, knowledge, skills, abilities, behaviors, habits of mind, and mindsets that integrate sustainability into academic programs and the professions. Yet many questions remain regarding how to establish and measure corresponding learning outcomes, particularly in engineering.

In their study of the notion of a "sustainability mindset, Colón et al. [9] summarized leading research on sustainability competencies, as follows:

> Two extensive reviews of sustainability competencies were undertaken by Wiek, Withycombe, and Redman [10] and Redman, Wiek, and Barth [11]. Through these reviews, their notion of competence evolved from a "functionally linked complex of knowledge, skills, and attitudes that enable successful task performance and problem-solving" in the first review (p. 204), to a broader notion in the second review (p. 3), of a "complex combination of knowledge, skills, understanding, values, attitudes, and desire which lead to effective, embodied human action in the world, in a particular domain", directly quoting Crick (p. 313) [12]. The first review concluded that despite commonly held views that suggest a lack of consensus on sustainability competencies, after accounting for and synthesizing synonymous terminologies, a reasonable convergence can be captured by five competencies: systems thinking, anticipatory, normative, strategic, and interpersonal. The second review extended this framework by proposing three additional emerging competencies: implementation, intra-personal, and integration.

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[2] Perhaps the common interpretation of "KSA" is "knowledge, skills, and abilities", but the choice to replace "abilities" with "attitudes" better captures the totality of the broad scope of characteristics that is necessary for professional formation, as suggested by the literature.

Reviewing these and other studies, Colón et al. determined that a complete mindset is characterized by four components: knowledge, skills, behaviors, and attitudes (KSBAs), and is therefore similar to the broad notion of competency advanced by Wiek at al. [10], [11].

The Engineering for One Planet (EOP) initiative, supported by the Lemelson Foundation, has developed the EOP Framework for "supporting systems-level change in engineering education, centering sustainability as a core tenet of the engineering profession", and consists of a "curated list of core and supplemental sustainability-focused and professional/durable/leadership learning outcomes organized under nine topic areas" [13]. These nine areas are as follows: Systems Thinking, Environmental Literacy, Responsible Business and Economy, Social Responsibility, Environmental Impact Assessment, Materials Selection, Design, Critical Thinking, and Communication and Teamwork. Notably, at the center of these nine outcomes is "systems thinking", which corresponds with the first competency identified by Wiek et al. [10], [11]. The Framework "comprises 94 (47 core and 47 supplemental) vetted, foundational sustainability learning outcomes that hundreds of academics, engineering professionals, and subject matter experts, among others, have identified as necessary for preparing all graduating engineers — regardless of subdiscipline — with the skills, knowledge, mindsets, and understanding to practice engineering and build solutions in ways that protect and enhance our world." Notably, "[d]espite being listed under separate topics, the learning outcomes are interdependent and interconnected."

While the EOP Framework provides excellent guidance for integrating sustainability-focused learning outcomes in engineering curricula, it is not synonymous with a "Body of Knowledge" (BoK) of the type that has been developed in various engineering disciplines, in that it does not comprehensively address all of the KSA's required for entry to professional work. For example, the Civil Engineering BoK (CEBOK) is defined as the "knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level" [14]; it comprises 21 outcomes, four areas: Foundational Outcomes, Engineering Fundamentals Outcomes, Technical Outcomes, and Professional Outcomes. As with Civil Engineering, most of the BoK's from other engineering disciplines also extend beyond just "knowledge", and include skills, attitudes, abilities, and best practices. This is analogous to the broad scope of the definition of "competency" cited above, due to Crick [12]. Table 1 provides a summary of the BoK's from engineering disciplines whose BoK's were identified. As further reference, Appendix A shows an excerpt from the Professional Engineering Body of Knowledge, issued by the National Society of Professional Engineers (NSPE) [15], as an example of a BoK entry.

Notably, several of the engineering BoK's incorporate sustainability in a substantive manner. The CEBOK, for example, cites an ASCE-approved definition of sustainability for civil engineers, and includes Sustainability as one seven Technical Outcomes. Similarly, Sustainability is one of seven "Enabling Knowledge and Skill Outcomes" required in the Environmental

Engineering BoK (EEBoK2) [16], and is one of sixteen “Technical Capabilities” specified by the NSPE/Professional Engineering BoK. The Chemical Engineering BoK, issued by AiChE, lists Sustainability as one of six “Cross Functional Skills” [17].

Table 1. Summary of BoK’s from Engineering Disciplines

BoK	**Definitional Statements**
Chemical Engineering (AIChE, 1st ed., 2015) [17]	“encompasses the range of skills, knowledge, and abilities required of a chemical engineer professional for the purpose of providing guidance information to AIChE continuing education efforts”
Civil Engineering (ASCE, 3rd ed., 2019) [14]. Prior editions 2004, 2009. 4th edition forthcoming.	“knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level”
Ecological Engineering (AEES, forthcoming). [18]	“the knowledge, skills, and abilities that academic programs should incorporate into an undergraduate Ecological Engineering (EcoE) program … to support an engineering discipline in which the base science (ecology) is integrated throughout students’ engineering science and design experiences.”
Environmental Engineering (AAEES. 2nd ed., 2025) [16]. Prior edition 2009.	“top-level summary of knowledge and competencies, known as learning outcomes, for the understanding and practice of environmental engineering. It provides a current understanding of the breadth and the depth of the knowledge, skills, and attitudes, which are demonstrated across the diverse practice of environmental engineering at the professional level”
Industrial and Systems Engineering (IISE, 1st ed., 2021) [19]	“a taxonomy of relevant, I.E., concepts.”
Professional Engineering (NSPE, 1st ed., 2013) [15]	“common intellectual ground … shared by everyone in the profession regardless of employment or engineering discipline. … defined as the depth and breadth of knowledge, skills, and attitudes appropriate to enter practice as a professional engineer in responsible charge of engineering activities that potentially impact public health, safety, and welfare. … knowledge, skills, and attitudes are referred to as―capabilities … what an individual is expected to know and be able to do by the time of entry into professional practice in a responsible role.”
Software Engineering (IEEE, 4th ed., 2025) [20]. Prior editions 1999, 2004, 2014. Appears through a set of interpretive guides.	“the current state of generally accepted, consensus-based knowledge emanating from the interplay between software engineering theory and practice. … a common understanding of “generally accepted knowledge” in software engineering, defining the boundary between software engineering and related disciplines, and providing a foundation for certifications and educational curricula.”

The EOP Framework and the SE-BoK are complementary tools that serve distinct yet interconnected roles in engineering education. The EOP Framework functions as an outcome-based curricular guide that supports the systematic integration of sustainability across engineering programs, with its many “core” and “supplemental” learning outcomes aligning with ABET criteria and the UN Sustainable Development Goals to enable program-level transformation. The Sustainability Engineering BoK builds upon these existing frameworks to establish the comprehensive intellectual and professional foundation of this transdisciplinary field. It seeks to define the core concepts, principles, analytical methods, tools, and competencies required for practice. Their relationship is both hierarchical and synergistic: the BoK seeks to define the scope and structure of the field, while EOP operationalizes that knowledge into broadly adoptable educational outcomes that prepare engineers. As a result, sustainability engineers will be prepared to promote equity, safeguard human well-being, and operate within ecological limits, integrating consideration of planetary boundaries, circular economy, well-being-centered economics, life-cycle assessment, governance and policy, applied across many sectors such as energy, water, transportation, materials, manufacturing, and the built environment. Together, the proposed BoK and existing frameworks will provide a coherent structure for accelerating the advancement of Sustainability Engineering education and professional practice.

3. Methodology

Research Approach and Justification

This study presents an iterative, Delphi-informed research framework to develop a Sustainability Engineering Body of Knowledge (SE-BoK). The Delphi approach was selected for this study because it is well-suited for developing consensus in emerging or ill-defined disciplinary areas where empirical standards and agreed-upon knowledge structures do not yet exist [21], [22], [23]. Sustainability Engineering represents an interdisciplinary and evolving field that spans multiple engineering domains, industry sectors, and societal contexts, making expert judgment essential for articulating a coherent and credible body of knowledge [24]. The structured, iterative nature of the Delphi process supports systematic refinement of expert input through controlled feedback while minimizing the influence of dominant individuals, thereby enhancing the reliability and validity of consensus outcomes [25], [26]. Additionally, the combination of open-ended exploratory rounds and subsequent quantitative rating rounds enables both knowledge generation and prioritization, aligning well with the formative objectives of this research and best practices in engineering education research methodology [27]. Defining consensus is challenging for Delphi studies, and achieving 100% agreement among all panelists in a Delphi study is mostly unattainable; however, most research studies report above 50% consensus [28]. As such, the Delphi approach provides a rigorous and transparent methodological foundation for the initial development of the SE-BoK.

The proposed framework builds on the structure of existing engineering bodies of knowledge, and integrates sustainability education frameworks with structured expert consensus methods to ensure rigor, relevance, and applicability to sustainable engineering education and practice. Since this is a work-in-progress paper, it describes the overall methodology and progress to date.

Research Phases

The process is broken into three phases (Figure 2). This study reports tasks completed in phases 1 and 2. The first phase began with a comprehensive review of established engineering bodies of knowledge (BoKs) to identify foundational concepts and competencies relevant to sustainability engineering. In parallel, the EOP Framework [13] was analyzed to ensure alignment with contemporary sustainability principles, systems thinking, and global engineering education priorities. Insights from these reviews informed the development of an initial SE-BoK draft, which was then subject to initial review by sustainability experts in academia and industry to refine its scope, terminology, and organizational structure.

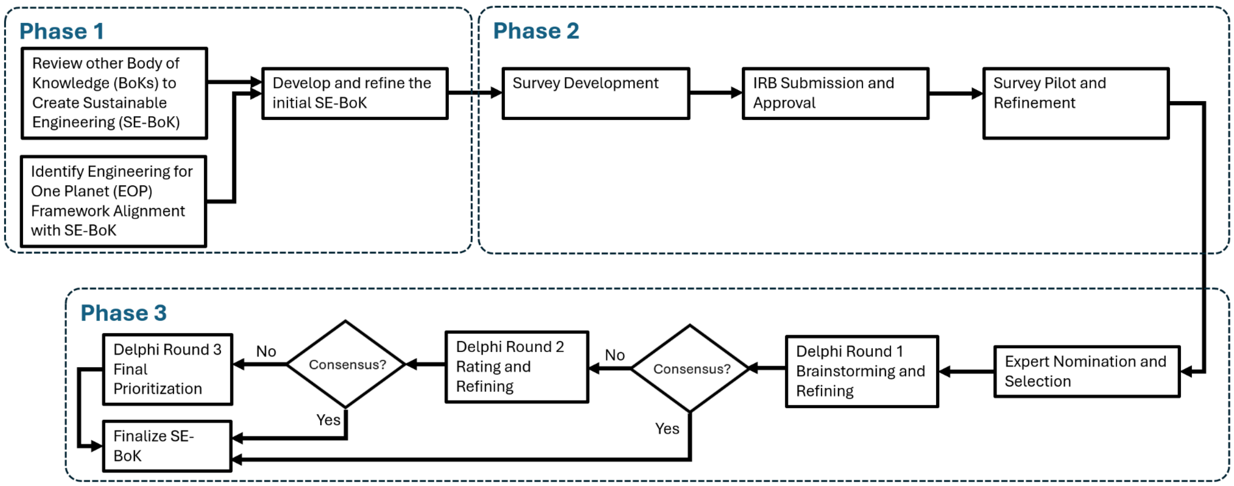

Figure 2. Iterative, Delphi-informed framework for the development and validation of a Sustainability Engineering Body of Knowledge (SE-BoK), integrating existing engineering BoKs, alignment with the EOP Framework, and multi-round expert consensus surveys.

To evaluate and refine the proposed SE-BoK, a multi-round Delphi study was proposed with subject-matter experts. A structured survey instrument was developed to elicit both qualitative feedback and quantitative ratings related to the relevance, clarity, and prioritization of SE-BoK elements. The first draft of the survey questions was created based on student profiles and program outcomes from the emerging Sustainability Engineering program at the University of Puerto Rico, Mayagüez (UPRM) and the Sustainable Systems Engineering Program at University of Calgary. It also drew upon the EOP Framework, the National Academies report *Strengthening Sustainability Programs and Curricula at the Undergraduate and Graduate Levels* [4], and *Closing the Sustainability Skills Gap* [29] report by Microsoft and Boston Consulting Group. The structure and organization of the survey was modeled after the ASCE CEBOK [14].

The draft was then updated and reorganized to improve the flow. This included the creation of an introduction outlining the purpose and use of the survey, section introductions and directions, defining abbreviations that may be unclear to participants, and creating a new section for final insights and concluding thoughts. A section of open-ended questions was added at the beginning of the survey to ensure unbiased responses from the participants. Demographic questions and informed consent were incorporated in the final pilot survey.

The survey questions were administered through Qualtrics™, an online survey platform, and was reviewed by experts in sustainable engineering and related disciplines (within the EOP network) for completeness and rigor prior to soliciting informative responses for the first round of the Delphi studies. The reviewers have documented expertise in sustainability-focused engineering curriculum development or practice, including at least one of the following: (a) peer-reviewed scholarship in sustainability engineering or education, (b) leadership in sustainability curriculum reform, or (c) industry experience in sustainability-driven engineering practice exceeding five years. This approach was used to enable confidentiality, controlled iteration, and systematic data collection. The study protocol and survey instruments received Institutional Review Board (IRB) approval prior to deployment. Following the initial review, the survey instrument was subject to external expert review and pilot testing to establish content validity and usability.

This study conceptualizes Sustainability Engineering as a transdisciplinary domain situated at the intersection of traditional engineering disciplines and sustainability science. Accordingly, the target panel includes experts whose work demonstrably integrates engineering design, systems thinking, and sustainability principles in either academic, research, or industry contexts. Panel selection is crucial and requires careful consideration. The BoKs of the established engineering disciplines have been developed many years after the disciplines were established, making the selection of disciplinary experts a relatively straightforward process. In contrast, in the case of such a new, unique, and continuously evolving field of Sustainability Engineering, identifying experts is a challenging proposition. To ensure rigor and credibility, it was decided that panelists had to meet at least two of the following qualification criteria: (a) a doctoral degree in engineering, sustainability science, or a closely related field, (b) a minimum of five years of professional experience integrating sustainability into engineering practice or education, (c) authorship of peer-reviewed publications in sustainability engineering or engineering education, (d) leadership roles in sustainability-focused initiatives (e.g., curriculum reform, industry sustainability programs, professional societies), (e) or recognized expertise through invited talks, funded research, or policy contributions in sustainability engineering [30].

Recruitment of the initial panel of experts was conducted by the authors who are members of the Engineering for One Planet (EOP) Network. The EOP Network is committed to authentic inclusion, and currently spans 35 states, Washington DC, and Puerto Rico, and brings together over 65 disciplines across 10 different sectors. The authors leveraged the EOP network to identify an initial sample of respondents outside of the network. Snowball sampling will then be used strategically to identify additional experts meeting the predefined qualification criteria, particularly in emerging subdomains where formal disciplinary boundaries are not yet established. All potential experts will be screened against the inclusion criteria prior to invitation. The initial target sample size is 15 to 20 participants, as mentioned in prior research, to prioritize the inclusion of well-qualified and interested panelists [25]. This step will help refine the expert panel members. The demographic questions in the survey will additionally enable the authors to track the diversity and expertise of the panelists.

The Delphi process will consist of three rounds. Round 1 will emphasize open-ended brainstorming and refinement and closed-ended responses, allowing experts to suggest modifications, additions, and clarifications to the SE-BoK. Qualitative responses will be thematically analyzed and used to revise SE-BoK. Round 2 will focus on quantitative rating and prioritization of SE-BoK elements using Likert-scale measures and Round 3 will support final prioritization and confirmation of consensus. The results of rounds 1 and 2 will be anonymized and shared with the panelists for the next round. The final draft of the SE-BoK will be shared with the panelists on completion of the study. Consensus will be evaluated after each Delphi round using predefined quantitative and qualitative criteria. For Likert-scale items, consensus is defined as ≥70% agreement (ratings of 4 or 5 on a 5-point scale) combined with an interquartile range (IQR) ≤ 1.0, indicating convergence of expert opinion. Items failing to meet these thresholds will be revised based on qualitative feedback and re-evaluated in subsequent rounds. Stability of responses across rounds will also be examined to confirm the attainment of consensus prior to finalizing the SE-BoK. The expert nomination and external review of the survey instrument are ongoing tasks reflecting the near completion of phase 2 and the start of phase 3, indicating our progress to date.

4. Preliminary Results: Refined Survey Design

The initial draft of the Delphi survey instrument was refined to ensure alignment with the proposed SE-BoK. The reviewed instrument includes demographic items to characterize anticipated expert panel composition, followed by a combination of closed-ended five-point Likert-scale questions focusing on assessing the level of agreement with proposed SE-BoK outcomes and open-ended prompts spanning the four areas of Foundational Outcomes, Engineering Fundamentals Outcomes, Technical Outcomes, and Professional Outcomes, adopted from the CEBOK, plus a fifth category on Mindsets and Values, motivated by several of the studies reviewed (Table 1). According to the CEBOK [14], Foundational Outcomes are the core intellectual, ethical, and societal foundations necessary for engineering practice; Engineering Fundamentals Outcomes are the core engineering sciences, analytical tools, and modeling foundations required across the discipline; Technical Outcomes are domain-specific technical mastery, design capability, analysis tools, and specialized competencies; Professional Outcomes include non-technical competencies enabling leadership, teamwork, communication, lifelong learning, and public responsibility.

Quantitative questions were designed to support future descriptive and consensus analyses across Delphi rounds, while qualitative questions capture feedback on clarity, relevance, and completeness of proposed focus areas and learning outcomes. The outcomes of this initial review informed revisions to question wording, domain organization, and response scales, resulting in a survey instrument prepared for external pilot testing.

The Technical and Professional outcomes (Table 2) are strongly informed by the EOP Framework [13], which was developed through extensive collaboration across academic and industry stakeholders. For example, the EOP focus areas such as material selection and design are reflected in each of the SE-BoK technical outcomes such as technical breadth and depth. Similarly, the EOP focus areas such as communication and teamwork are reflected in each of the SE-BoK professional outcomes such as communication, teamwork, and ethical leadership among others.

Table 2. Summary of Survey Structure Aligned to the SE-BoK Focus Areas

Survey Section	Focus Area	Item Types and Number of Questions	Planned Analysis
Demographic Questions	Expert background and expertise	Multiple choice, short response (9)	Descriptive statistics; categorical distributions
Opening Questions	Conceptual framing of sustainability engineering	Open-ended (5)	Thematic coding; concept frequency analysis
Section A: Foundational Outcomes	Ethical, societal, and systems foundations, experiential learning, critical thinking and problem solving	Likert-scale (6); open-ended (3)	Descriptive statistics, thematic coding, and frequency analysis
Section B: Engineering Fundamental Outcomes	Core engineering sciences and analytical tools, design fundamentals and risk	Likert-scale (9); open-ended (2)	
Section C: Technical Outcomes	Domain-specific technical competencies, project management, systems design, risk and resilience	Likert-scale (8); open-ended (3)	
Section D: Professional Outcomes	Leadership, teamwork, policy, communication, and ethics, responsible business and economy	Likert-scale (8); open-ended (2)	
Section E: Mindset and Values	Affective and dispositional outcomes	Likert-scale (9); open-ended (1)	
Section F: Overall Insights	Meta-level feedback and future directions	Open-ended (5)	Thematic coding; concept frequency analysis

5. Discussion and Lessons Learned

The primary objective of this work is to develop an initial Body of Knowledge (BoK) for Sustainability Engineering that defines the knowledge, skills, and abilities/attitudes (KSAs) required of engineers who design solutions that promote human well-being for present and future generations while remaining within biospheric limits. Sustainability engineers must be capable of integrating social, ecological/environmental, and economic considerations with rigorous engineering analysis and design. Achieving this integration requires sustainability-focused education and a fundamentally transdisciplinary mindset integrated with values that augments the traditionally siloed engineering paradigms.

Historically, engineering disciplines developed their BoKs many years after the establishment of the field, relying on expert consensus to reflect prevailing professional practices and educational standards. In contrast, the development of a Sustainability Engineering BoK presents several unique and complex challenges:

A. Sustainability Engineering transcends conventional engineering education and practice.

B. The field itself and the knowledge base are emerging and rapidly evolving, and practitioners and educators are continuously developing and adopting new methods, tools, and conceptual frameworks.

C. Most experts originate from traditional engineering disciplines and are effectively relearning engineering through a sustainability lens, often carrying forward disciplinary biases and paradigms.

D. Critical expertise derives from non-engineering domains (e.g., economics, policy, social sciences, ecology), requiring the integration of external knowledge into engineering decision-making.

Such challenges result in two central challenges:

(i) Defining an appropriate initial set of KSAs to serve as a starting point for structured deliberation and consensus-building.

(ii) Identifying and assembling a sufficiently diverse expert panel spanning academia, industry, NGOs, and government – a level of cross-sector representation uncommon in the development of prior engineering BoKs.

As discussed, the initial SE-BoK was developed through a careful literature review, but going forward, expert feedback will surely modify its structure and content. Recognizing that reliance on self-reported survey data may introduce bias stemming from the interpretation of survey items and from individual perceptions of importance or relevance, the use of multiple Delphi rounds, open-ended responses, formal consensus thresholds, and controlled feedback can help mitigate individual bias by emphasizing convergence across expert judgments rather than isolated opinions. To address the need for a broad base of experts, panelists will be purposefully selected to ensure that diverse perspectives relevant to sustainability engineering are captured.

Hence, the unique characteristics of Sustainability Engineering call for an adaptive and inclusive approach to developing its Body of Knowledge rather than serving as impediments. By establishing an initial outline, the BoK can provide a starting point while remaining open to evolution. Additionally, traditional engineering perspectives can be leveraged as strengths when examined explicitly through a sustainability lens, supporting professional rigor while enabling paradigm shifts. Integrating critical knowledge from non-engineering domains can be addressed by clearly defining interfaces and collaborative competencies rather than absorbing entire disciplines. Finally, although assembling a diverse, cross-sector expert panel is more complex than in past BoK efforts, phased and tiered engagement models can ensure both feasibility and legitimacy, reflecting the realities of sustainability practice, while minimizing bias.

6. Conclusions, Challenges and Future Work

This paper argues for the development of a new professional domain called Sustainability Engineering, addressing a documented gap in sustainability engineering education. A rigorous process is presented as a means to develop the corresponding Body of Knowledge (SE-BoK) that would be necessary for professional formation in this field. The primary contribution of this work is the articulation of a transparent, replicable, consensus-driven methodology for developing the disciplinary knowledge in the context of an emerging engineering field. A pilot survey instrument designed to acquire expert feedback is proposed, informed by existing engineering BoK's as well as the EOP Framework. Although the survey captures open feedback at the outset, so that no biases of any proposed model is introduced, subsequent segments of the survey presume a working structure of a future SE-BoK, consisting of areas for Foundational Outcomes, Engineering Fundamentals Outcomes, Technical Outcomes, Professional Outcomes, and Mindset and Values. A set of participant criteria are also presented. Expert consensus will be generated through a multi-round Delphi process in which empirical evaluation will lead to future refinement of the SE-BoK through expanded expert participation and longitudinal validation. Ongoing and future work will involve full deployment of the Delphi study, analysis of expert responses, and translation of the resulting SE-BoK into curricular guidance for sustainability engineering programs.

Even for mature disciplines, developing a BoK is a lengthy process that must be iterative and continuous. For Sustainability Engineering – an emerging transdisciplinary field – additional complexity is introduced due to the need to recruit experts and attempt to establish outcomes in a context that does not have a traditionally established professional base. The present work builds the foundation for managing that evolution. The initial BoK is not a final product, but serves as a governance framework for continuous learning and refinement. By intentionally positioning the SE-BoK as iterative, the current Delphi-based effort establishes a credible and transparent starting point while acknowledging the evolving nature of the field. Similarly, while self-reported data introduce inherent subjectivity, the structured use of multiple Delphi rounds, consensus thresholds, and qualitative feedback provides a disciplined mechanism for surfacing shared priorities rather than individual preferences.

Future work will incorporate additional validation mechanisms – such as alignment with practice outcomes, accreditation needs, or case-based review – to further strengthen robustness. Future work will also seek to integrate the most recent version of the EOP Framework. In this way, the present effort creates both an initial consensus and a repeatable process through which the Sustainability Engineering BoK can evolve with the field itself.

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APPENDIX A

Excerpt from NSPE Professional Engineering Body of Knowledge [15]

Chapter 4

The Engineering Body of Knowledge

Definition of Entry into Professional Engineering Practice

This report uses expressions such as "practice of engineering as a professional engineer," "entry into the professional practice of engineering," "practice as a professional engineer," and "practice of engineering at the professional level." For the purpose of this report, all of these expressions are equivalent to entry into practice as a licensed professional engineer in responsible charge of engineering activities (i.e., projects or components of projects) that potentially impact public health, safety, and welfare.

In this context, responsible charge means activities such as carrying out assignments, making project plans, directing engineering designs, writing specifications, preparing engineering reports, or deciding methods of execution or suitability of materials, all without referring to a higher authority other than for collaborative and/or checking purposes. We are attempting to describe the capabilities and abilities of a professional engineer at the time in their career when they are just beginning to assume responsible charge, perhaps with straightforward project components. According to the NCEES Model Law, responsible charge means "direct control and personal supervision of engineering work." NSPE defines responsible charge as an engineer providing "supervisory direction and control authority."