Education for Thriving in a Changing Climate: A Leadership Role for the American Academy of Environmental Engineers and Scientists

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Abstract

The objective of this current work is to align professional education with the systemic demands of Planetary Health as described in the most recent updated Body of Knowledge for Environmental Engineering (EEBoK2) published by the American Academy of Environmental Engineers and Scientists (AAEES) who hold the responsibility for defining the profession of environmental engineering. This paper addresses the continuous need to evaluate and update the EEBoK in response to emerging needs including climate change, growth in generative Artificial Intelligence, and continued growth in our understanding of social contracts. In particular, the ongoing work of the National Academies of Sciences, Engineering, and Medicine's project entitled, "Education for Thriving in a Changing Climate," offers a lens to consider the future of the EEBoK. Building upon prior published literature that cited the Grand Challenges and Opportunities of Environmental Engineering (2019), the objective of this current work is to align future versions of the EEBoK with the call to hold paramount the health, safety, and welfare of the public and the planet.

Relevance and Methodology: A continuous process of testing and improvement is a stated purpose of the EEBoK. The analysis in this current work employs a Large Language Model plus Human-in-the-Loop (LLM-HitL) approach. First, multiple reports were produced using a single prompt designed to produce a thematic analysis of provided data inputs. Second, a meta-analysis of the reports was produced. Third, a human compared the results of the six reports with the results of the meta-analysis to confirm validity. Fourth, original data inputs were searched to determine the rank abundance of the presence of the human verified results, and specific instances supporting the human verified results were identified in the original data inputs. The data input included a corpus of peer-reviewed literature from 2019 through June 2024, which cited the Grand Challenges and Opportunities in Environmental Engineering. This approach directly supports the updating of the outcomes to reflect the peer-reviewed literature.

Major Findings and Impact: We present actionable language for a future refresh of the EEBoK, which consider five areas. These include: 1) reconfirmation of the current 18 outcomes; 2) explicit consideration of environmental justice as part of societal impact and environmental policy; 3) explicit consideration of generative Artificial Intelligence as part of computational approaches; 4) the urgency to consider exceedance of planetary boundaries, including climate change; and 5) the expansion of multi-disciplinary teams to include "more than" adjacent scientists. The use of LLM-HitL described in this article provides a template for other professional societies seeking to integrate the results of peer-reviewed scholarship into updates of bodies of knowledge. This demonstrates the leadership of the American Academy of Environmental Engineers and Scientists to steward important aspects of the engineering body of knowledge, writ large, including topics such as professional ethics and planetary sustainability.

Introduction

Professions, including environmental engineering, are characterized by autonomous judgment over its work, a grounding in specialized knowledge, and self-governance by peer-defined standards [1]. Practically speaking, a profession includes a professional organization-prepared specialized body of knowledge (BoK), delivered through accredited programs of higher education and experiential learning, assessed through summative examination (e.g., often written and oral formats), and often protected through licensure and maintained through an obligation for continuing education. By this definition, environmental engineering is a profession.

The American Academy of Environmental Engineers and Scientists (AAEES) maintains a specialized Body of Knowledge, originally published in 2009 [2] and most recently updated and published as a second edition in 2025 [3]. The Engineering and Accreditation Commission of ABET Inc offers accreditation to approximately 125 baccalaureate programs of “Environmental Engineering and similarly named”, including more than 100 programs in the United States. The AAEES is identified by ABET as the “lead society” for environmental engineering [4], which means the AAEES is responsible both for proposing the “program specific criteria” as well as for proposing Program Evaluators (PEVs) to conduct accreditation visits using a six-year cycle.

The National Council of Examiners for Engineers and Surveying (NCEES) maintains a Fundamentals of Environmental Engineering as well as a Principles and Practice of Environmental Engineering exams, which are used by many jurisdictions in the United States (US) as a part of the licensure process (alongside an ABET accredited degree and 4 years of supervised work experience, in most jurisdictions). Although the AAEES is not formally responsible for maintaining the NCEES exam, in practice, many Board Certified Environmental Engineers (BCEEs) of the AAEES serve as part of the ad hoc NCEES exam preparation committee.

Furthermore, the AAEES offers an examination (written and oral) to obtain the BCEE to those licensed Professional Engineers who have 8 years of experience, 4 in responsible charge. And the quality of the Board Certification process employed by AAEES is ensured through independent accreditation by the Council of Engineering and Scientific Certification Boards (CESB). Thus, in summary, environmental engineering is a profession with a BoK, accredited programs of higher education, and license obtained through examination and experience. Plus, environmental engineering boasts an additional voluntary process of accredited Board Certification to demonstrate specialty knowledge at an advanced level.

In 2009, the AAEES published the first edition of the Environmental Engineering Body of Knowledge [2]. In 2025, the AAEES published an updated second Edition of the EEBoK [3]. Between 2009 and 2025, the National Academy of Engineering convened a group to prepare a report entitled, “Grand Challenges and Opportunities in Environmental Engineering and Science,” which was published in 2019 [5]. This report identified five areas where environmental engineering is uniquely equipped to offer major contributions, including:

1. Sustainably Supply Food, Water, and Energy
2. Curb Climate Change and Adapt to Its Impacts
3. Design a Future Without Pollution or Waste

4. Create Efficient, Healthy, Resilient Cities
5. Foster Informed Decisions and Actions

While not formally enumerated, a "sixth" grand challenge was also identified, specifically, "The Ultimate Challenge for Environmental Engineering: Preparing the Field to Address a New Future."

Between 2019 and June 2024, a total of 66 articles appeared in the peer reviewed literature, which cited the "Environmental Grand Challenges" report.

The purpose of this current article is to document the application of human expertise plus generative Artificial Intelligence - specifically the use of Large Language Models (LLMs) coupled with human-in-the-loop (HitL) - to evaluate the most recent EEBoK and identify specific recommendations for improvements based upon the results reported in these 66 articles.

Methods

The prompt used to execute the initial phase of this work is provided in Appendix A. This prompt was used with Gemini 3.0 and selections of the 66 articles (as input order and the total amount of data input to each prompt is known to impact the results).

A representative report (one of six) is included in Appendix B.

A second prompt was used to perform a meta-analysis of the six reports. The second prompt is provided in Appendix C. The prompt was used with Chat GPT 5.2 and the six reports produced using Gemini 3.0 and the prompt in Appendix A.

The full result of the meta-analysis is included in Appendix D.

Results and Discussion

Five results identified through the LLM-HitL approach will be discussed. These include:

1. The 18 outcomes included in the EEBoK2 [3] are necessary and sufficient;
2. Outcome 10: Societal Impact and Environmental Policy [3] is passive;
3. Outcome 3: Use of Computational Approaches [3] is insufficient;
4. Outcome 8: Sustainability [3] is insufficient and should be reframed to explicitly center the exceedance of planetary boundaries and climate change adaptation; and
5. Outcome 12: Multi-Disciplinary Teamwork to Solve Environmental Problems [3] is insufficient, and the ethic of care — holding paramount the health, safety, and welfare of the public and the planet — provides the directional framing for the evolution toward transdisciplinary convergence with the healthcare professions.

Result One. The American Society of Civil Engineers (ASCE) published one of the first Body of Knowledge documents among the engineering disciplines [6]. The CEBoK1, first edition, included 15 outcomes. The CEBoK2, second edition, expanded to 24 outcomes [7]. The CEBoK3, third edition, re-organized into 21 outcomes [8]. In contrast, the EEBoK1, first edition, included 18 outcomes [2], and the EEBoK2, second edition, reconfirmed these original 18 outcomes with important, yet relatively straightforward, modifications [3]. The results of the thematic analysis and meta-analysis reported in this article reconfirm the value of the 18 outcomes currently included in the EEBoK2, which strongly suggests that these 18 outcomes may be characterized as necessary and sufficient [9].

Result Two. In the current EEBoK2, Outcome 10: Societal Impact and Environmental Policy is elaborated as, “Incorporate societal impacts of environmental engineering issues and solutions; utilize engineering and communication skills to inform and implement environmental law and policy,” [3]. A question that may be raised in response to this definition is, “to what end?” In other words, while this outcome speaks to the importance of the interface of science, technology, engineering, math (STEM) and policies and regulations, it is unclear on the direction of the engagement - are environmental engineers to use their expert knowledge to promote regulatory frameworks and policy positions from the stance of advocacy for the public, a client, a personal point of view? Or is mere engagement sufficient? In contrast to the morally neutral approach to societal impact and environmental policy described in EEBoK2, the approach to “advocacy” included in similar guiding documents for healthcare professionals, such as the Code of Ethics for the American Medical Association or the Code of Ethics for the American Nurses Association require the healthcare provider to advocate for the wishes of the patient. Does Outcome 10 merely imply that environmental engineers should be active in public dialogue, or is there a particular position that environmental engineering should advocate (i.e., environmental justice, peace engineering, or similar) [10], [11]?

Result Three. In the current EEBoK2, Outcome 3: Use of Computational Engineering Approaches is elaborated as, “Utilize the techniques, skills and computational engineering methods and approaches necessary for engineering practice.,” [3]. While the use of Artificial Intelligence (AI) in the broadest sense is not new to environmental engineers, the widespread availability of generative AI, including Large Language Models (LLMs), creates what some consider to be new frontiers of human engagement with technology. Perhaps most importantly for environmental engineers, the resource intensity currently required for the computations systems needed to deliver LLMs - including electricity and water - present emerging challenges for environmental protection. On one hand, environmental engineers need to learn to use tools such as LLMs, and on the other hand environmental engineers have an obligation to sound a warning to society that the widespread use of these tools may have environmental consequence. An environmental engineer using LLMs inappropriately (i.e., “wasting compute cycles”) may be viewed similar to an environmental engineer who refuses to participate in local recycling programs (i.e., “wasting physical resources”). Should Outcome 3 specifically name “new tools” such as “AI” and “Big Data”, or remain focused on the general concepts without becoming overly focused on the newest “fad”?

Result Four. In the current EEBoK2, Outcome 8: Sustainability is elaborated as, “Integrate sustainability into the analysis and design of engineered systems and understand the use of methods for analyzing sustainability such as life-cycle analysis (LCA) and material or substance flow analysis,” [3]. While focused on a useful set of tools and fundamental approaches, Outcome 8 fails to mention the variety of areas where sustainability may be applied; specifically at the extreme of planetary boundaries, including the attainment of a thriving human population on a planet undergoing a changing climate. These concerns of planetary health could also appear in

Outcome 11: Contemporary and Global Issues. And here is the concern, by failing to “name and center” major environmental issues, the EEBoK2 may be missing an opportunity to protect the health, safety, and welfare of the public and the planet [12].

Environmental engineers have no difficulty naming and centering fecal pollution of surface waters as a health threat. Do environmental engineers see the emission of greenhouse gases from combustion as a similar threat to health? While some might argue that considering a human exhaling carbon dioxide as a danger is an overreach, environmental engineers already recognize that the natural human biological process of expelling feces must be engineered so as to prevent fecal to oral transmission of illness. A central question that must be addressed in the future development of the EEBoK includes, “what level of settled science is needed for engineers to design interventions?” The example of disrupting fecal-oral transmission of illness - including the now famous construction of the Thames embankment (sewers) in London by Joseph Bazalgette - began in 1862. Louis Pasteur had only performed his famous swan-neck flask experiments in 1859, and it wasn’t until 1876 that Robert Koch developed the “germ theory.” Clearly engineers were willing to make massive investments to improve human health; even when the science was not yet settled (i.e., “miasma” theory was the dominant notion of illness transmission in the early years of the Great Sanitary Awakening).

Result Five. In the current EEBoK2, Outcome 12: Multi-Disciplinary Teamwork to Solve Environmental Problems is elaborated as, “Involve the skills and expertise of multiple disciplines to address complex engineering problems as a team,” [3]. But are these skills and expertise reserved to cognitive and psychomotor domains, or do they extend also to the affective domain [13]? For example, similar concerns could also appear in Outcome 13: Professional and Environmental Ethics, where environmental engineers may benefit from collaboration with other healthcare professionals such as physicians and nurses. If “multi-disciplinary teamwork” is limited to “engineers working with chemists and biologists” then a range of diverse skills, knowledge, and attitudes may be missed. Environmental engineering is widely recognized as an inclusive and collaborative profession - the nature of environmental health demands as much. But the question is, “which other disciplines are welcomed, and which other disciplinary partners are required?” Is multi-disciplinary teamwork “essential” and is the current inclusion of scientists “sufficient” to achieve the goals of applying, “…engineering principles to improve and maintain the environment for the protection of human health, for the protection of nature’s beneficial ecosystems, and for environment-related enhancement of the quality of human life,” [3]. And how does this match to the calls for the evolution towards “environmental engineering 3.0?” [14]. The ethic of care, drawn from collaboration with healthcare professionals such as physicians and nurses, supplies the directional content that a value-neutral framing of "teamwork" lacks — it specifies why convergence matters, not merely that it is desirable. In this sense, the evolution of Outcome 12 is inseparable from the reframing of professional identity toward holding paramount the health, safety, and welfare of the public and the planet.

Limitations

While some readers may be skeptical of the value of the LLM-HitL approach, other readers may see the methods outlined in this article and assume that “anyone” can complete this work following a similar approach. While the overall approach may be replicated, it is important to note that both the LLM as well as the HitL aspects of this method may be highly dependent on the user, which necessitates that best practice for articles such as this include principles such as transparency, accountability, and verifiability [15].

For example, it is known that different LLMs provide different levels of "veracity versus hallucination". Similarly, it is known that different humans have different levels of tacit knowledge. In the case of this article, the author was part of the team that helped to update the EEBoK2 and was therefore highly familiar with the document. Furthermore, the author invested the time and effort to read both the abstract and the conclusion of every paper included in the corpus - the papers that cited the Grand Challenges report. While "reading" is not the same as "thematic analysis", a human author is perhaps more likely to spot errors in an LLM response when there is a high degree of familiarity with the content that is being evaluated using an LLM. Therefore, the caution to those who would "replicate" this method is to be sure that the use of the LLM is as a "side car" - to supplement; not replace - the role of the human author. LLM technology offers tremendous opportunity to gain insight into large quantities of data (i.e., a machine may read and recall nearly 3,000 pages of text more effectively than a human), and yet the human brain is highly evolved at pattern recognition as a survival skill.

A further limitation follows from the epistemic status of the LLM outputs themselves. The six thematic reports (Appendix B) and the meta-analysis (Appendix D) are secondary sources, not primary evidence; the primary evidence remains the 66 peer-reviewed articles in the corpus. The LLM-HitL workflow is therefore best understood as a structured triangulation among primary sources, professional judgment, and LLM-generated summaries rather than as a direct analysis of the literature [16]. This framing matters because it locates the burden of validity on the human reader rather than on the model: the author's prior familiarity with the EEBoK2 and with the abstracts and conclusions of each article in the corpus is what allows the LLM output to function as a credible secondary source, and a replication attempt lacking that prior familiarity would not be epistemically equivalent.

A related limitation concerns the nature of the tool. An LLM is not a calculator; it is a sociotechnical mediator of the flow of data, information, knowledge, and wisdom (DIKW) among people [17]. A calculator acts on data and returns a deterministic result. An LLM, by contrast, shapes how knowledge is produced, shared, and validated - and it does so while consuming electricity, water, and embedded carbon, and while carrying the biases of its training data and prompt framing. Treating LLM-HitL corpus synthesis as if it were a calculation would understate these risks; treating it as a mediated sociotechnical process makes the obligations of transparency, accountability, and verifiability [15] visible and auditable. For future EEBoK updates and for other professional bodies of knowledge, this framing implies that LLM-HitL should be adopted with the same governance infrastructure that is expected of other sociotechnical systems affecting professional formation - including documented prompts, preserved intermediate outputs, multiple independent human reviewers with relevant tacit knowledge, and explicit labeling of model versions and run dates.

Conclusions

The EEBoK2 is a strong document. The 18 outcomes first set in EEBoK1 survived the second edition largely intact, and the corpus analyzed here does not argue for adding a nineteenth or dropping any of the existing 18. What the corpus does argue for is sharper content in four of them. That gives five findings in total:

- The 18 outcomes are necessary and sufficient. The scaffold from 2009 continues to hold. Modernization should happen inside existing outcomes, not by restructuring the list.
- Outcome 10 (Societal Impact and Environmental Policy) should name environmental justice. The present wording asks engineers to inform and implement policy but does not say whose interests the engineer serves when those interests conflict. Healthcare professions answered that question long ago; environmental engineering has yet to name and address this issue head on.
- Outcome 3 (Use of Computational Engineering Approaches) should explicitly name important terms of art, including “AI” and “Big Data”. Students will use these tools whether the EEBoK names them or not. Naming them lets the outcome also name the obligation that comes with them, namely the electricity, water, and carbon costs of computation and storage (i.e., digital pollution).
- Outcome 8 (Sustainability) should name planetary boundaries and climate change adaptation. While life-cycle analysis and material flow analysis are important tools, naming the tools is not the same as naming the reason why the tools exist. A graduate should be able to say what sustainability is for – to answer the question “why” as well as the question “how”.
- Outcome 12 (Multi-Disciplinary Teamwork) should include partners from outside the physical and biological sciences, including healthcare. The goals in the EEBoK2 preamble - protecting human health, ecosystems, and quality of life - already require those partners. The outcome should say so clearly as a way to invite others into partnership.

The four content changes above have direct curricular consequences. Naming environmental justice in Outcome 10 means a course on environmental law is no longer sufficient without a companion unit on who bears environmental burdens and who does not. Naming AI in Outcome 3 means AI literacy belongs in a design course, not only a tools course. Naming planetary boundaries in Outcome 8 means life-cycle analysis assignments should include a boundary-exceedance scenario, not just a baseline case. Naming the healthcare professions in Outcome 12 means capstone teams should sometimes include a nurse or a public health student, not only a chemist and a biologist.

Other engineering lead societies face the same pressures identified here. The LLM-HitL approach described in this article, including the prompts in Appendices A and C, is offered as a roadmap that other societies can adapt for their own BoK reviews.

Ultimately, the AAEES holds the responsibility to define the profession. This includes now, as well as what it must look like in the future to ensure a thriving society. By integrating these competencies - environmental justice, AI ethics, planetary health, and convergence - into a future iteration of the EEBoK, AAEES can ensure that future environmental engineers are equipped to hold paramount the health, safety, and welfare of the public and the planet.

Declaration on use of Generative Artificial Intelligence

Consistent with the recommendation of transparency, accountability, and verifiability (as described in [15]), Google Gemini version 3 Pro was used in the original drafting and editing of the manuscript. Specifically, the following prompt was used to improve the draft: "Assume you are the program chair for the American Society for Engineering Education. Evaluate the attached draft article considering the attached call for papers and the attached author kit. Identify any errors and evaluate if the paper should be accepted."

Subsequently, Claude Opus 4.7 was used in editing the final version of the manuscript. The following prompt was used with Claude: "Assume you are a program chair for the annual meeting of the American Society for Engineering Education. Offer any final feedback on the accepted paper - in final format - from corresponding author Professor Daniel Oerther of the Missouri University of Science and Technology (attached). Recommendations for improvements should include internal consistency of abstract, introduction, methods, results, discussions and conclusions; citations; and any additional bullet proof improvements as identified from the following: 1) instructions to authors for the meeting as originally published by ASEE (attached); 2) call for papers as originally published by ASEE (attached); 3) feedback from reviewers and program chair on the original abstract and subsequent draft versions of the manuscript."

In addition, as described in the Methods section and Appendix C, ChatGPT version 5.2 was used to perform the meta-analysis of six reports produced using Gemini 3.0 (the output is reproduced verbatim in Appendix D). The author takes full responsibility for the content of the article.

Author approved TL;DR

Author approved TL;DR (as recommended by [18]): "The EEBoK2's scaffold is right - don't rebuild it. But four of its 18 outcomes should stop dancing around AI, planetary boundaries, environmental justice, and the healthcare professions and just name them."

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Appendix A. Prompt used to perform the initial six analyses.

You are a senior environmental engineering professor at an ABET-accredited baccalaureate program with national recognition in curriculum design and environmental engineering education.

Your task is to propose evidence-informed updates to the **Environmental Engineering Body of Knowledge, Second Edition (EEBOK2)**, focusing primarily on its **18 existing outcomes**.

You have three attached documents:
- EEBOK.pdf - the current Body of Knowledge (Second Edition)
- corpus.pdf - a selection of peer-reviewed articles that cite the NAE Grand Challenges and Opportunities in Environmental Engineering
- EAC - the current Engineering Accreditation Criteria for ABET including Environmental Engineering and Similarly Named Programs

Use ONLY information extractable from these three attachments. Do NOT use external knowledge, standards, or documents.

CONFIRM that you have received all pages from each of the three documents:
- EEBOK.pdf - 94 pages
- corpus.pdf - 2,317 pages
- EAC.pdf - 53 pages

Core Evaluation Structure

1. Overall Adequacy (one concise paragraph)
   - Do the 18 outcomes collectively cover the contemporary scope of environmental engineering practice as reflected in the corpus?
   - Highlight the strongest and weakest areas of coverage.

2. Structural Critique of the 18 Outcomes
   For each outcome (or logical groups of outcomes), concisely evaluate:
   - Redundancy / significant overlap with other outcomes
   - Scope problems (too narrow, too vague/broad, outdated framing)
   - Missing critical contemporary competency (if any)

   Use a compact format, e.g.:
   Outcome X: [very brief current wording]
   → Assessment: [redundant / too narrow / missing X / good as is]
   → Evidence from corpus: [1-3 key recurring themes or representative citations]

3. Proposed Revision Package (choose ONE coherent strategy)
   - Option A: Retain all 18 outcomes largely unchanged → strong justification required
   - Option B: Consolidate 2-4 outcomes into fewer statements
   - Option C: Keep most, refine wording of several, add 1-2 new outcomes
   - Option D: More substantial restructuring (explain why necessary)

   Present your recommended set of outcomes (number them clearly).
   For every change (addition, deletion, merge, rewording) provide:
   - Precise proposed text
   - Primary evidence from the corpus
   - Whether the change is (a) necessary for ABET alignment or (b) aspirational / forward-looking

4. Attainment Level Guidance
   For each **proposed** outcome (not necessarily the original 18), give brief attainment expectations at three career stages described in the EEBOK:

- At completion of baccalaureate degree in Environmental Engineering
- At completion of master's degree or 30 semester credits or equivalent post baccalaureate
- After four years of professional experience

Flag when your recommendation meaningfully exceeds current typical ABET expectations.

Guardrails & Transparency
- Ground every substantive claim in specific recurring themes or clusters of findings from the 66-article corpus.
- Explicitly label interpretive judgments or areas of weak/ambiguous evidence in the corpus.
- If a major recommendation rests on uncertain interpretation of the corpus, mark it:
  [HUMAN REVIEW RECOMMENDED] and explain why.
- Maintain a professional, evidence-driven, forward-looking tone.

Desired Output Organization (follow this structure)

1. Executive Summary (150-250 words)
2. Structural Assessment Summary Table or bulleted list
3. Recommended Revised Set of Outcomes (numbered list with proposed text)
4. Attainment Expectations (table or clearly sectioned per outcome)
5. Points Requiring Human Confirmation (if any)

Appendix B. An example of one of six reports generated with the prompt included in Appendix A using Gemini 3.0.

Executive Summary

The Second Edition of the Environmental Engineering Body of Knowledge (EEBOK2) provides a robust foundational framework for the profession, aligning well with historical sanitary engineering roots and the general ABET criteria. However, based on a review of the provided corpus of 66 peer-reviewed articles citing the NAE Grand Challenges, the EEBOK2 requires targeted updates to address the rapidly evolving complexity of the 21st century. While the current 18 outcomes adequately cover traditional technical competencies, they insufficiently address three critical, emergent themes omnipresent in the contemporary literature: (1) the **Data Revolution** (Artificial Intelligence, Machine Learning, and Big Data); (2) **Environmental Justice and Equity**, moving beyond general "societal impact" to active engagement with marginalized communities; and (3) **Convergence and the Nexus**, specifically the Food-Energy-Water (FEW) nexus, which demands a transdisciplinary approach beyond standard multi-media interactions.

This proposal recommends **Option C: Refine and Expand**, maintaining the 18-outcome structure to preserve continuity with ABET accreditation but significantly renaming and rescoping four key outcomes (Outcomes 3, 8, 10, and 12) to bridge the gap between current education and future professional needs. These changes are evidence-based, drawing directly from the corpus's emphasis on "intelligent computation," "social justice," and "systems thinking."

Structural Assessment Summary

The following assessment evaluates the existing 18 outcomes against the themes extracted from the *Environmental Engineering Science* corpus and the ABET EAC.

- **Outcome 3: Use of Computational Engineering Approaches**
    - *Critique:* **Too Narrow / Outdated.** The current focus on "computer-aided design" and "numerical models" misses the paradigm shift toward "Big Data" and AI.
    - *Evidence:* The corpus highlights "Artificial Intelligence," "Machine Learning," and "Data Science" as essential for tracing pollutants and optimizing systems.
- **Outcome 8: Sustainability**
    - *Critique:* **Scope Problem.** While strong on general principles, it lacks explicit reference to the **Food-Energy-Water (FEW) Nexus**, a dominant theme in contemporary research.
    - *Evidence:* Multiple articles cite the FEW nexus as a critical framework for resource security.
- **Outcome 10: Societal Impact and Environmental Policy**
    - *Critique:* **Missing Critical Competency.** "Societal impact" is too passive. The corpus demands a shift toward **Environmental Justice (EJ)** and equity, specifically regarding marginalized communities.
    - *Evidence:* Literature emphasizes "environmental racism," "social justice," and the disproportionate burden on "historically marginalized communities".
- **Outcome 12: Multi-Disciplinary Teamwork**
    - *Critique:* **Outdated Framing.** "Multi-disciplinary" implies working *next* to others. The corpus argues for **"Convergence"** or "Transdisciplinary" approaches where disciplines merge to solve complex problems.
    - *Evidence:* Research calls for "deep integration" and "convergence research" to address Grand Challenges.
- **Outcomes 1, 2, 4, 5, 9, 13-18**
    - *Critique:* **Adequate / Good as Is.** These outcomes align well with ABET EAC general criteria (e.g., Outcome 1 maps to ABET SO 1; Outcome 13 maps to ABET SO 4) and standard practice.

Recommended Revised Set of Outcomes (Option C)

Strategy: Retain the 18-outcome structure to ensure stability for ABET program evaluators but **rename and expand the scope** of four outcomes to reflect the urgency of the NAE Grand Challenges.

Outcome 3 (REVISED): Data Science and Computational Intelligence

- *Current Text:* Use of Computational Engineering Approaches
- *Proposed Text:* **Utilize techniques, skills, and modern engineering tools, including data science, machine learning, and artificial intelligence, to analyze complex environmental systems and predict future trends.**
- *Evidence:* The corpus explicitly states that environmental engineering must move "from slide rule to big data" and utilize "artificial intelligence... to optimize performance".
- *Type:* (b) Aspirational / Forward-looking (exceeds typical ABET "modern tools" requirement).

Outcome 8 (REVISED): Sustainability and the Food-Energy-Water (FEW) Nexus

- *Current Text:* Sustainability
- *Proposed Text:* **Integrate sustainability and the Food-Energy-Water (FEW) Nexus principles into the analysis and design of engineered systems to ensure resource security and minimize unintended cross-sectoral consequences.**
- *Evidence:* The corpus dedicates entire special issues to the "Food-Energy-Water Nexus" and "systems perspectives," identifying it as critical for resource security.
- *Type:* (b) Aspirational / Forward-looking.

Outcome 10 (REVISED): Environmental Justice, Equity, and Policy

- *Current Text:* Societal Impact and Environmental Policy
- *Proposed Text:* **Incorporate principles of environmental justice, equity, and social inclusion into engineering solutions; utilize communication and policy frameworks to address the needs of historically marginalized and underserved communities.**
- *Evidence:* The corpus highlights "environmental racism" and the need to "cultivate diversity and engage collaboratively" with communities to achieve "social justice".
- *Type:* (a) Necessary for ABET alignment (ABET SO 2 requires consideration of "cultural, social... and economic factors").

Outcome 12 (REVISED): Transdisciplinary and Convergence Teamwork

- *Current Text:* Multi-Disciplinary Teamwork to Solve Environmental Problems
- *Proposed Text:* **Collaborate effectively within transdisciplinary and convergence research teams, integrating knowledge from diverse fields (including social sciences and health) to address complex, grand challenge-scale problems.**
- *Evidence:* The corpus argues that "convergence research" (deep integration) is required to solve problems like stunting and sanitation, moving beyond simple multi-disciplinary work.
- *Type:* (b) Aspirational / Forward-looking.

(Outcomes 1, 2, 4, 5, 6, 7, 9, 11, 13, 14, 15, 16, 17, and 18 remain unchanged in title, though their descriptions should be updated to reflect the new emphases above.)

Attainment Level Guidance

The following table provides attainment guidance for the **four revised outcomes**.

Outcome	Baccalaureate (B.S.)	Master’s (M.S.) / 30 Credits	Professional Practice (4 Years)
3. Data Science & Computational Intelligence	**Apply** basic statistical and data visualization tools to interpret environmental data. Recognize the utility of AI/ML in engineering.	**Analyze** large environmental datasets using machine learning algorithms or advanced statistical models to identify patterns and predict system behavior.	**Evaluate** the validity and ethical implications of AI-driven models in engineering decision-making. Integrate big data analytics into project management.
8. Sustainability & FEW Nexus	**Explain** the interconnections between food, energy, and water systems. Apply life-cycle principles to simple design components.	**Analyze** trade-offs within the FEW nexus for complex systems. Design systems that optimize resource recovery and minimize waste across sectors.	**Synthesize** nexus thinking into large-scale infrastructure planning. Lead projects that explicitly address cross-sectoral sustainability goals.
10. Environmental Justice (EJ) & Policy	**Recognize** historical inequities in infrastructure placement and environmental risk. Describe relevant environmental policies and EJ frameworks.	**Integrate** EJ principles into site assessment and solution design. Analyze the social and economic impacts of engineering decisions on marginalized groups.	**Create** and advocate for engineering solutions that actively remediate environmental injustices. Engage directly with stakeholders to co-design equitable infrastructure.
12. Transdisciplinary & Convergence Teamwork	**Function** effectively on teams with diverse technical backgrounds. Identify the roles of non-engineering experts (e.g., social scientists) in projects.	**Collaborate** in transdisciplinary teams to frame research or design problems. Integrate methods from other disciplines (e.g., public health) into engineering work.	**Lead** convergence teams that bridge the gap between technical engineering, public policy, and community needs to solve grand challenges.

Flag: The expectation for Master's/Professional levels in **Outcome 3 (AI/ML)** and **Outcome 12 (Convergence)**meaningfully exceeds current typical ABET expectations, which focus more on standard multidisciplinary teams and modern tools rather than convergence and artificial intelligence.

Points Requiring Human Confirmation

[HUMAN REVIEW RECOMMENDED] regarding the specific inclusion of **"Artificial Intelligence"** in Outcome 3.

- *Reasoning:* While the provided corpus (corpus1.pdf) strongly advocates for the inclusion of "intelligent computation," "machine learning," and "AI" as emerging essentials, the current ABET criteria (EAC.pdf) do not yet explicitly require AI. Adding this as a core competency is a significant "future-proofing" step that may require curriculum overhaul (e.g., new CS requirements) that some programs may not yet be resourced to deliver.

[HUMAN REVIEW RECOMMENDED] regarding the shift from "Multi-disciplinary" to **"Transdisciplinary/Convergence"** in Outcome 12.

- *Reasoning:* The corpus distinguishes between "multi-disciplinary" (working side-by-side) and "convergence" (deep integration). However, ABET Criterion 3.5 only requires an ability to function on a team that creates a "collaborative and inclusive environment". While "convergence" is the academic gold standard per the NAE Grand Challenges, it may be a high bar for undergraduate attainment without specific university-wide structures (e.g., joint courses with social sciences).

Appendix C. Prompt used to perform the meta-analysis.

If you find yourself attempting to reconcile disagreements, select a "best" position, merge findings, or propose changes to EEBOK2 / ABET / any source document — STOP immediately and instead analyze why the disagreement exists.

You are an expert in rigorous comparative qualitative meta-analysis and AI-assisted pattern detection across parallel expert interpretations.

TASK
Analyze the six independent expert reports attached in a single file.
Each report was generated using the identical core prompt but with different ordering/sequencing of the source materials.
Treat them strictly as six parallel, good-faith expert viewpoints — never as drafts to merge, reconcile, improve, or vote on.

SCOPE & HARD CONSTRAINTS
• Use ONLY content explicitly present in the six reports.
• Do NOT introduce external knowledge, new interpretations, or judgments about EEBOK2, ABET criteria, the source corpus, or "correctness".
• Focus exclusively on patterns of (dis)agreement among the reports themselves.
• If a requested category has no clear examples, state explicitly: "None identified" and give a one-sentence reason.

Analytical Objectives — Answer ALL of these in order

1. Strong Convergence (≥5/6 reports)
List only areas where ≥5 reports show substantial agreement (even if phrased differently).
For each:
• Concise shared finding/critique/recommendation
• Agreement level (6/6, 5/6) + brief evidence (which reports)
• One-sentence interpretation: what this high convergence implies about robustness of evidence, issue clarity, or confidence a human can place in the point

2. Partial / Conditional Agreement (3-5/6 reports generally aligned)
List areas showing directional agreement but clear variation in:
• emphasis • severity • framing • priority • recommended action
For each:
• Nature of the shared direction
• Main dimensions & examples of variation
• One-sentence implication for corpus ambiguity, ordering sensitivity, or interpretive latitude

3. Meaningful Divergences (material conflicts, ≥2 opposing substantive positions)
List only significant disagreements (conflicting judgments, mutually exclusive recommendations, starkly different adequacy assessments).
For each:
• Position A summary + supporting reports
• Position B summary (if more than two, group minor variants) + supporting reports
• Most plausible primary cause (choose one): weak/diffuse corpus evidence • differing interpretive lenses • prompt structural ambiguity • ordering effect
• Implication for a human decision-maker

4. Notable Outliers & Singular Insights
Findings/critiques/recommendations appearing in ≤2 reports (especially strong singles).
For each significant outlier:
• Description of the unique insight

• Assessment (choose & justify one): plausibly valuable but under-recognized • appears speculative/weakly supported • likely ordering/priming artifact
• Recommendation: merits human follow-up? (Yes/No + one-sentence reason)

5. Meta-pattern Analysis: Robustness vs Fragility
Synthesize ONLY the overall pattern of agreement/disagreement (do NOT synthesize report content).
Explicitly answer:
• Which major aspects of the analysis appear highly robust to source ordering perturbation?
• Which aspects appear fragile / highly order-sensitive?
• Implications for reliability of LLM-assisted expert analysis in this domain
• Where human SME judgment remains most essential
• One or two concrete ways future prompts might reduce unproductive variance

6. Confidence-stratified Guidance for Human Reviewer
Three short, bulleted lists (no new content claims):
• High-confidence findings (can be accepted with high trust; ≥5/6 convergence)
• Medium-confidence areas (directionally consistent but variation warrants discussion; 3-5/6 partial agreement)
• Low-confidence / disputed areas (major divergences or outliers needing essential human expertise)

OUTPUT STRUCTURE — Use these exact headers and keep prose concise & analytical

1. Executive Overview (~150-200 words)
High-level summary of overall pattern strength, dominant sources of variation, and most important takeaway for using these reports.

2. Strong Convergence

3. Partial / Conditional Agreement

4. Meaningful Divergences

5. Notable Outliers & Singular Insights

6. Meta-pattern Analysis: Robustness vs Fragility

7. Confidence-stratified Guidance for Human Reviewer

Distinguish clearly:
[Observation] — what the reports literally say
[Interpretation] — what the pattern reasonably suggests

Reports are attached in a single file.

Appendix D. The report produced using Chat GPT 5.2 and the prompt included in Appendix C.

Below is a **comparative qualitative meta-analysis strictly across the six reports as artifacts**, following your constraints.
No reconciliation, correction, or judgment about EEBOK2/ABET is attempted; only **patterns among the reports themselves** are analyzed.

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1. Executive Overview (~150-200 words)

[Observation]
Across six independent expert reports generated from identical prompts but different source orderings, there is **strong structural convergence** on a small number of critiques and modernization themes, paired with **substantial divergence**on scope boundaries, adequacy judgments, and professional identity framing. Most reports treat EEBOK2 as structurally sound yet substantively lagging emerging emphases evident in the corpus. However, the *degree* of lag, *which outcomes are deficient*, and *how aggressively they should be reframed* vary meaningfully.

[Interpretation]
High convergence clusters around *where* modernization pressure exists (data/AI, justice/equity, climate/resilience), while divergences emerge around *how far* such pressures justify renaming outcomes, merging outcomes, or reframing professional identity. Ordering sensitivity appears strongest when reports encountered literature emphasizing care ethics, decision-making, or resilience early. The most important takeaway is that **LLM-assisted expert synthesis is reliable for identifying pressure points**, but **fragile for defining boundaries, necessity vs aspiration, and institutional feasibility**—precisely where human judgment is most required.

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2. Strong Convergence

2.1 Outcome 3 is substantively under-specified relative to corpus emphasis on data/AI

- **Shared finding:** Outcome 3 (“Computational Engineering Approaches”) is described as too narrow or outdated relative to corpus emphasis on data science, AI/ML, or advanced analytics.
- **Agreement level:** 6/6 (Reports 1-6)
- **Evidence:** All six explicitly critique Outcome 3 scope and propose expansion or reframing.
- **Interpretation:** High robustness; the corpus signal here is strong and ordering-insensitive.

2.2 Outcome 10 framing (“Societal Impact”) is viewed as passive or insufficient

- **Shared finding:** Outcome 10 inadequately captures justice, equity, or active engagement emphasized in the corpus.
- **Agreement level:** 6/6 (Reports 1-6)
- **Evidence:** Each report uses language such as “too passive,” “missing critical competency,” or “needs explicit EJ/equity.”
- **Interpretation:** Very high confidence that the reports detect a shared semantic mismatch.

2.3 The 18-outcome structure itself should be retained

- **Shared finding:** Retaining the existing 18-outcome scaffold is preferable to wholesale restructuring.

- **Agreement level:** 5/6 (Reports 1-5 explicitly; Report 6 mostly retains but also merges outcomes)
- **Interpretation:** Strong convergence that structural continuity is valued, even amid content pressure.

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3. Partial / Conditional Agreement

3.1 Sustainability framing requires modernization

- **Shared direction:** Outcome 8 ("Sustainability") is under-specified relative to corpus themes.
- **Variation:**
    - Reports 1, 2, 4, 5 emphasize circular economy, planetary health, decarbonization.
    - Report 3 emphasizes FEW nexus.
    - Report 6 explicitly judges Outcome 8 "good as is."
- **Implication:** Indicates corpus breadth allows multiple legitimate focal interpretations; ordering sensitivity likely.

3.2 Climate change as a distinct competency

- **Shared direction:** Climate adaptation/resilience is prominent in the corpus.
- **Variation:**
    - Reports 1, 2, 6 argue for explicit climate-focused outcomes.
    - Report 3 embeds climate within other revised outcomes.
    - Report 4 emphasizes decarbonization more than adaptation.
- **Implication:** Ambiguity exists over whether climate is a *cross-cutting lens* or a *stand-alone outcome*.

3.3 Teamwork reframing (multi- vs trans-disciplinary)

- **Shared direction:** Current teamwork framing is limited.
- **Variation:**
    - Reports 1, 3 advocate "convergence/transdisciplinary."
    - Reports 2, 5 cautiously elevate but flag feasibility.
    - Report 6 explicitly says Outcome 12 is "good as is."
- **Implication:** Interpretive latitude driven by differing readings of ABET constraints and corpus emphasis.

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4. Meaningful Divergences

4.1 Adequacy of several existing outcomes ("good as is" vs deficient)

- **Position A:** Many outcomes (e.g., 8, 12, 13) are adequate and aligned (Report 6).
- **Position B:** Same outcomes require reframing or renaming (Reports 1-5, variably).
- **Primary cause:** Differing interpretive lenses (compliance-oriented vs identity-oriented reading).
- **Implication:** Human decision-makers must decide whether the goal is *alignment* or *transformation*.

4.2 Ethics as standard professionalism vs "Ethic of Care"

- **Position A:** Ethics outcome is largely sufficient (Reports 2, 3, 6).
- **Position B:** Ethics requires reframing around care work and professional identity (Report 4; partially Report 5).
- **Primary cause:** Ordering effect (early exposure to care-focused literature).

- **Implication:** This is a value-laden divergence unsuitable for automated resolution.

4.3 Merging or restructuring outcomes

- **Position A:** Maintain all outcomes distinctly (Reports 1-5).
- **Position B:** Merge problem formulation with design; restructure numbering (Report 6).
- **Primary cause:** Prompt structural ambiguity combined with ordering sensitivity.
- **Implication:** Structural changes are highly fragile and require human governance.

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5. Notable Outliers & Singular Insights

5.1 "Care penalty" and professional identity reframing

- **Appears in:** Report 4 (strong), Report 5 (weak echo)
- **Assessment:** Plausibly valuable but under-recognized
- **Recommendation:** Yes — merits human follow-up due to conceptual impact.

5.2 Explicit outcome merging (Problem formulation + design)

- **Appears in:** Report 6 only
- **Assessment:** Likely ordering/priming artifact
- **Recommendation:** No — insufficient corroboration.

5.3 Internal inconsistency of Outcome 17 naming

- **Appears in:** Report 5 primarily
- **Assessment:** Plausibly valuable but narrow
- **Recommendation:** Yes — factual verification warranted.

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6. Meta-pattern Analysis: Robustness vs Fragility

Robust to ordering:

- Identification of pressure points (data/AI, justice, climate).
- Recognition that Outcome 3 and 10 are focal stressors.

Fragile / order-sensitive:

- Degree of renaming vs reframing.
- Ethics and professional identity narratives.
- Structural changes (merging, re-sequencing outcomes).

Implications for LLM-assisted analysis:

- Reliable for *where tension exists*.
- Unreliable for *how far reform should go*.

Where human SME judgment is essential:

- Normative scope decisions.
- Accreditation feasibility.
- Professional identity framing.

Prompt improvements:

- Explicitly separate “diagnostic” vs “normative” tasks.
- Constrain structural edits unless explicitly requested.

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7. Confidence-stratified Guidance for Human Reviewer

High-confidence findings (≥5/6)

- Outcome 3 scope is widely viewed as insufficient.
- Outcome 10 framing is consistently seen as passive.
- Retaining the 18-outcome scaffold is broadly favored.

Medium-confidence areas (3-5/6)

- Sustainability reframing direction.
- Climate change as distinct vs embedded outcome.
- Elevation of teamwork to convergence.

Low-confidence / disputed areas

- Ethics as “care profession.”
- Outcome merging or renumbering.
- Strength of aspirational vs necessary labeling.

If you want, next we can **map which disagreements are epistemic vs normative**, or **trace which corpus subsets most strongly drive divergence**—without reconciling any positions.