Sustainability Integration in Engineering Curricula of Selected Philippine State Universities and Colleges: Insights from a Systematic Thematic Analysis

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***Abstract*— Sustainability is now a globally mandated competency for engineering graduates, embedded in major frameworks such as UNESCO's Education for Sustainable Development (ESD), the Washington Accord, and the United Nations Sustainable Development Goals (SDGs). In the Philippines, engineering programs across State Universities and Colleges (SUCs) are governed by Commission on Higher Education Memorandum Orders (CMOs), which define the minimum curricular standards and intended learning outcomes that institutions operationalize in their program offerings. Building on this regulatory foundation, this study examined how sustainability competencies prescribed in CMOs are translated into practice through a systematic thematic analysis of engineering curricula across 66 selected SUCs. This was complemented by a cross-analysis of nine engineering CMOs and a mini-systematic literature review (~45 studies). Guided by a six-step systematic thematic analysis framework and anchored in a four-pillar, competency-based definition of sustainability, three dominant themes emerge. First, *Regulatory Compliance–Driven Integration* revealed that sustainability is incorporated primarily through standardized CMO outcome templates, resulting in highly uniform but superficial representations. Second, *Pillar Asymmetry and Environmental Bias* showed that the environmental dimension is substantively addressed in only 51.5% of programs, while the social and economic pillars remained largely absent. Third, the *Competency–Curriculum Disconnect* highlighted the complete absence of transformative sustainability competencies across all analyzed curricula. These findings culminated in the proposed conceptual model of the *Mimetic Sustainability Gap* which attempts to explain how regulatory compliance mechanisms could inadvertently substitute for authentic competency development. As a consequence, this study offers critical implications for policy reform, curriculum redesign, and accreditation practices, engineering faculty, and industry stakeholders, toward achieving genuinely sustainability-oriented engineering education.**

Keywords*— *sustainability integration, engineering education, Philippine SUCs, mimetic isomorphism

I. INTRODUCTION

The integration of sustainability into undergraduate engineering education has become a global imperative. Engineers are increasingly expected to design systems that are not only environmentally responsible but also economically viable, socially equitable, and ethically grounded—a mandate codified in major international frameworks such as UNESCO's Education for Sustainable Development (ESD) for 2030 [1], the Washington Accord graduate attributes [2], and the United Nations Sustainable Development Goals (SDGs) [3]. Collectively, these frameworks emphasize the development of transformative sustainability competencies, extending beyond mere awareness of environmental constraints toward the capacity to address complex, interconnected socio-technical challenges.

Within this global context, the Philippine higher education system—particularly its State Universities and Colleges (SUCs)—serves as the primary vehicle for delivering publicly accessible engineering education. Curricular structures across these institutions are governed by Commission on Higher Education Memorandum Orders (CMOs), which define the minimum standards, program outcomes, and competency expectations for each engineering discipline. Moreover, the country's accession to the Washington Accord through the Philippine Technological Council (PTC) further aligns local programs with international accreditation requirements, including the integration of sustainability-related graduate attributes. This dual regulatory environment—national standardization through CHED and international alignment through PTC—positions sustainability as both a mandated and benchmarked competency within engineering education.

Despite this strong regulatory and policy alignment, there remains a critical lack of system-level evidence on how sustainability is actually integrated within Philippine SUC engineering curricula [4]-[6]. In particular, it is unclear whether the competencies prescribed at the policy level are meaningfully translated into curricular structures and learning outcomes. Addressing this gap, the present study conducts a systematic thematic analysis of program outcomes, course descriptions, and course learning outcomes from 66 selected SUCs, with incomplete or unavailable institutional data supplemented through a cross-analysis of nine CMOs to ensure a comprehensive CMO-aligned corpus. Guided by this approach, the study is anchored on two research questions: (RQ1) *What is the nature and depth of sustainability integration mandated by CMOs?* and (RQ2) *What thematic patterns emerge, and what* *conceptual model best represents the current state of sustainability integration across Philippine SUC engineering curricula?*

II. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

A. Mini-Systematic Literature Review: Scope and Coverage

To ground the analysis in a defensible, engineering-specific definition of sustainability, a mini-systematic literature review was conducted across the following databases: Scopus, ScienceDirect (Elsevier), Springer Nature Link, Taylor & Francis Online, MDPI, and Frontiers in Education. Six primary search queries were applied: "sustainability in engineering education," "sustainability competencies undergraduate engineering," "Brundtland definition engineering curriculum," "triple bottom line engineering education," "education for sustainable development engineering," and "systematic review sustainability engineering curricula." The search covered publications from 1987 (the Brundtland Report) through 2025, with primary emphasis on peer-reviewed articles from 2006 to 2025. Of approximately 120 records identified through title-abstract screening, 45 papers were reviewed in full; 18 references were retained in the synthesis. Four foundational frameworks emerged as most directly relevant: (1) the Brundtland Commission definition [7]; (2) the Triple Bottom Line (TBL) framework [8]; (3) UNESCO's ESD competency model [1]; and (4) Wiek et al.'s sustainability competency framework [9].

B. Sustainability: From Foundational Definition to Engineering Application

The Brundtland Commission's canonical definition—"development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [7]—grounds sustainability in intergenerational equity and two foundational concepts: needs (particularly those of the world's most vulnerable) and limits (of technology and social organization to sustain the environment). While globally recognized, the definition has been widely critiqued as too broad for disciplinary application. Bithas and Christofakis [10] observed that there is no consensus on sustainability's operational content, and its vagueness allows diverse—often contradictory—interpretations. For engineering specifically, this creates a critical pedagogical risk: sustainability can be reduced to a checkbox on a design constraint list rather than a genuine professional competency.

Elkington's Triple Bottom Line (TBL) [8] addresses this by grounding sustainability in three interdependent pillars: environmental (ecological integrity, lifecycle stewardship), economic (long-term viability, circular economy), and social (equity, public health, inclusive design). In engineering contexts, Ram et al. [11] propose a fourth pillar—professional responsibility—encompassing engineering ethics, long-term accountability for the impacts of engineered systems, and alignment with professional codes of conduct. This four-pillar model is directly actionable at the curriculum level: each pillar maps to assessable course learning outcomes and disciplines-specific CLOs, converting the abstract Brundtland aspiration into measurable educational targets. UNESCO's ESD framework [1] adds a learning dimension structure—cognitive, socio-emotional, and behavioral—that situates these pillars not as inert knowledge domains but as the basis for agency, reflection, and action. Together, these frameworks define sustainability as a property of the curriculum's graduate outcomes, not merely its content. **Fig. 1** illustrates the synthesized framework.

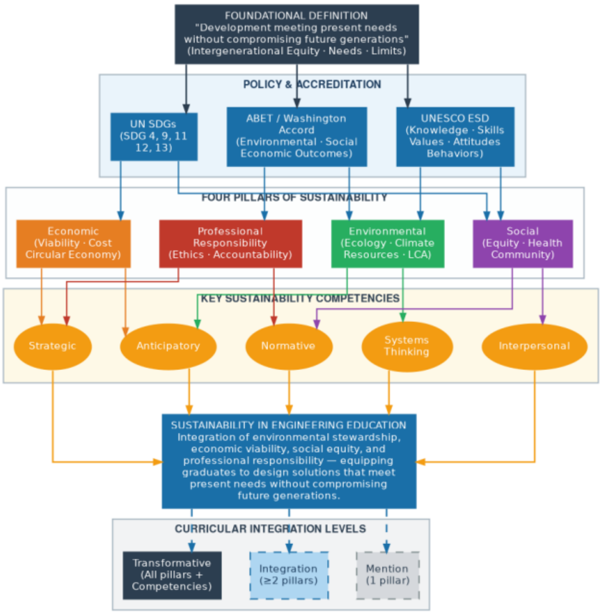

Fig. 1. Synthesized Conceptual Framework for Sustainability in Undergraduate Engineering Education.

C. Wiek et al. Sustainability Competency Framework

The most influential scholarly operationalization for teaching sustainability in higher education is Wiek et al.'s competency framework [9], identified in meta-analyses as the most cited paper in the field. The framework identifies five key competencies: (1) systems-thinking—analyzing complex socio-technical-environmental interdependencies and feedbacks; (2) anticipatory—envisioning, evaluating, and designing for long-term sustainability futures; (3) normative—identifying and negotiating sustainability values, ethical trade-offs, and intergenerational obligations; (4) strategic—designing and implementing sustainability interventions and transitions; and (5) interpersonal—facilitating collaborative, cross-cultural, multi-stakeholder sustainability processes. Recent literature further extended the framework to eight competencies, adding integration (connecting competencies in practice) and implementation (executing interventions, not merely planning them) [12], [13]. These eight competencies define "transformative" sustainability education and represent the gold standard against which curricular integration is assessed in this study.

D. CHED Engineering Program Outcomes and Sustainability Alignment

CMOs mandate thirteen standard Program Outcomes (POs a–m), adapted from Washington Accord graduate attributes [14]-[24]. **Table I** presents the full set, with sustainability pillar alignment and Wiek competency correspondence. As the table shows, only three POs carry any sustainability relevance: PO(c) (design within constraints including sustainability), PO(f) (ethical and professional responsibility), and PO(h) (understanding the global, economic, environmental, and societal impact of engineering solutions). Critically, even these three address sustainability partially and without the competency depth that transformative sustainability education requires: PO(c) lists sustainability as one of eight co-equal design constraints; PO(f) addresses ethics generically; and PO(h) requires understanding of impact without requiring the capacity to analyze, anticipate, or act upon it.

E. *Working Definition and Integration Levels*

Synthesizing these four frameworks, the working definition for this study is: *sustainability in undergraduate engineering education is the integration of environmental stewardship, economic viability, social equity, and professional responsibility into engineering knowledge, skills, and dispositions—equipping graduates to design, analyze, and implement solutions that meet present needs without compromising future generations' ability to do the same, through systems-thinking, anticipatory, normative, strategic, and interpersonal competencies*. Three integration levels are operationalized: *Mention-level* (sustainability appears only as a design constraint in generic outcome statements; one pillar referenced superficially); *Integration-level* (two or more pillars addressed through explicit sustainability-focused courses and CLOs); and *Transformative-level* (all four pillars developed with at least three Wiek competencies embedded as assessed outcomes).

III. METHODOLOGY

A. *Data Source*

Primary institutional data were collected through a systematic manual review of the official websites of 78 Philippine SUCs (excluding both private higher education institutions and SUCs with engineering programs granted autonomous status to maintain consistency in regulatory context). From these sources, all publicly available program descriptions, Program Educational Objectives (PEOs), POs, and course-level information—including course descriptions and, where available, course learning outcomes—were extracted through structured manual compilation. Of the 78 SUCs reviewed, 66 were confirmed to offer engineering programs and were therefore included in the analytical sample.

To address gaps arising from incomplete or unavailable institutional data, secondary data were drawn from nine CMOs corresponding to the most prevalent engineering disciplines [14]-[23]. These CMOs define the minimum curricular standards and intended learning outcomes that SUCs are mandated to implement. Accordingly, all 66 SUCs were assumed to align with the relevant CMO-prescribed baseline, enabling the construction of a comprehensive and policy-grounded analytical corpus. This assumption is grounded in the regulatory requirement for SUCs to adhere to CHED-prescribed minimum standards, even as institutions retain limited flexibility in curricular implementation.

TABLE I. STANDARD CHED ENGINEERING PROGRAM OUTCOMES AND THEIR SUSTAINABILITY FRAMEWORK ALIGNMENT

PO	Program Outcome (Standard Across All CMOs)	Sustainability Pillar	Wiek Competency	Relevance
(a)	Apply mathematics and sciences to solve complex engineering problems	None	None	None
(b)	Design and conduct experiments; analyze and interpret data	None	None	None
(c)	Design systems within constraints: economic, environmental, social, ethical, health & safety, sustainability	Env·Econ·Soc·Prof	Strategic (partial)	Moderate
(d)	Function in multidisciplinary and multi-cultural teams	Social (partial)	Interpersonal (partial)	Low
(e)	Identify, formulate, and solve complex engineering problems	None	Systems (partial)	Low
(f)	Practice the engineering profession ethically and responsibly	Prof. Responsibility	Normative (partial)	Moderate
(g)	Communicate effectively with a range of audiences	None	Interpers. (partial)	Low
(h)	Understand the impact of engineering solutions in a global, economic, environmental, and societal context	Env·Econ·Social	Anticipatory (partial)	Moderate
(i)	Recognize the need for, and engage in lifelong learning	None	None	Low
(j)	Know and act on contemporary issues	Env (implicit)	Anticipatory (partial)	Low
(k)	Use modern engineering tools and techniques	None	None	None
(l)	Know engineering and management principles as member and leader	Prof. Resp. (partial)	Strategic (partial)	Low
(m)	Understand at least one specialized field of practice (discipline-specific)	Varies	None	Varies

B. *Implemented Systematic Thematic Analysis*

This study employed a systematic thematic analysis following the six-step framework of Naeem et al. [25] to examine sustainability integration across Philippine SUC engineering curricula. The analysis began with iterative familiarization of CMO documents and institutional program records, from which sustainability-relevant textual segments were selectively extracted. Keywords were then inductively identified based on recurring patterns and salient expressions, guided by the 6Rs criterion to ensure analytical depth and contextual fidelity. These keywords were subsequently transformed into codes through an inductive–deductive approach, anchored in both the four-pillar sustainability framework and the Wiek competency framework (see **Fig. 1**). Codes were iteratively synthesized into higher-order themes using the 4Rs criterion, enabling the transition from descriptive categorization to interpretive analysis. Finally, the relationships among keywords, codes, and themes were conceptually integrated to develop the *Mimetic Sustainability Gap* model, which served as a theoretical representation of the observed patterns of sustainability integration.

IV. RESULTS

A. Program Distribution and CMO Sustainability Depth

Out of 78 Philippine State Universities and Colleges (SUCs) reviewed, 66 (84.6%) were found to offer engineering programs. The distribution of these programs across SUCs is presented in **Table II**. Civil Engineering (BSCE) is the most widely offered program, present in 56 SUCs (84.8%), followed by Electrical Engineering (66.7%) and Mechanical Engineering (54.5%). In contrast, Environmental Engineering (BSEnE)—identified as the most sustainability-intensive discipline based on curricular content—is offered by only 2 SUCs (3.0%), indicating limited institutional presence despite its strong sustainability orientation.

A cross-disciplinary comparison of CMO-mandated sustainability content is summarized in **Table III**. The results showed clear variation in both the presence and depth of sustainability integration across engineering programs. Agricultural and Biosystems Engineering (BSABE) and Environmental Engineering (BSEnE) exhibit the highest level of integration, characterized by multiple dedicated sustainability-related courses and broader coverage across environmental, economic, and social pillars.

In contrast, Chemical Engineering (BSChE) and Civil Engineering (BSCE) demonstrated moderate inclusion, where sustainability is incorporated through selected core or supporting courses, primarily emphasizing environmental aspects with limited representation of other pillars. Mechanical (BSME) and Electrical Engineering (BSEE) showed minimal integration, with sustainability-related content largely confined to elective offerings or indirectly embedded topics.

Programs such as Computer Engineering (BSCpE), Industrial Engineering (BSIE), and Geodetic Engineering (BSGE) exhibited the lowest level of integration, with no dedicated sustainability courses and reliance limited to general program outcomes (e.g., PO(c) and PO(h)). Overall, the results indicated a heterogeneous distribution of sustainability content across disciplines, with substantial differences in both curricular structure and pillar coverage.

B. Keywords, Codes, and Themes Derived

The analysis identified a limited but consistent set of sustainability-related keywords across CMOs and program-level documents. Frequently occurring terms include "sustainable production" (BSABE), "climate change mitigation" (CMO 94), and "renewable energy systems" (CMOs 94, 97, and 88). More generalized formulations such as "environmental and societal context" (embedded in Program Outcome [PO(h)]) and "sustainability, in accordance with standards" (PO(c)) were observed uniformly across all nine CMOs, reflecting a standardized regulatory phrasing.

In contrast, several critical sustainability concepts were entirely absent from both CMO and institutional documents. These include systems thinking, intergenerational equity, circular economy, life cycle analysis, carbon footprint, SDGs, and stakeholder engagement. The absence of these terms constitutes negative evidence, indicating the lack of explicit articulation of higher-order or transformative sustainability constructs within the analyzed corpus.

TABLE II. ENGINEERING PROGRAM DISTRIBUTION ACROSS 66 SELECTED SUCS

Engineering Program	No. of SUCs	% of 66	CMO (s. 2017) [14]-[24]
BS Civil Engineering	56	84.8%	CMO 92
BS Electrical Engineering	44	66.7%	CMO 88
BS Mechanical Engineering	36	54.5%	CMO 97
BS Agricultural & Biosystems Engineering	32	48.5%	CMO 94
BS Computer Engineering	31	47.0%	CMO 87
BS Electronics Engineering	28	42.4%	CMO 101
BS Industrial Engineering	16	24.2%	CMO 96
BS Geodetic Engineering	13	19.7%	CMO 89
BS Chemical Engineering	9	13.6%	CMO 91
BS Environmental Engineering	2	3.0%	CMO 98*

**Note: As no CMO currently exists for BS Environmental Engineering, the CMO for Sanitary Engineering (CMO 98 s. 2017) was used as the closest available proxy.*

TABLE III. CMO-MANDATED SUSTAINABILITY CONTENT BY ENGINEERING DISCIPLINE

Program	Dedicated Sustainability Courses	Pillar Coverage	Level
BSABE	Renewable Energy Systems; Environmental & Waste Mgmt; Climate Change & Natural Resources; Soil & Water Conservation	Env (H), Econ (M), Soc (L)	Integration
BSEnE	Environmental Impact Assessment; Sanitation Engg; Ecological Engg; Environmental Modeling	Env (H), Soc (M), Econ (M)	Integration
BSChE	Chemical Process Safety & Environment; Environmental Engineering	Env (H), Econ (L)	Mention
BSCE	Environmental Engineering (core); Water Resources; River Engineering (elective)	Env (M), Soc (L)	Mention
BSME	Thermal & Energy Systems; Renewable Energy (elective)	Env (L), Econ (L)	Mention
BSEE	Renewable Energy Systems (elective); Power Systems	Env (L)	Mention
BSCpE / BSIE / BSGE	No dedicated sustainability courses	PO(c) & PO(h) only	Mention

From the keyword analysis, six codes were derived. C1 (Regulatory Compliance Language) captured the verbatim uniformity of PO(c) across all CMOs. C2 (Disciplinary Selectivity) reflected the concentration of sustainability depth within specific programs, particularly BSABE and BSEnE. C3 (Environmental Dominance) denoted the presence of substantive environmental course learning outcomes (CLOs) in 34 out of 66 SUCs (51.5%). C4 (Social–Economic Superficiality) indicated that social and economic dimensions appear only as co-listed constraints without substantive curricular elaboration. C5 (Competency Silence) highlighted the complete absence of Wiek sustainability competencies across all CMOs. Finally, C6 (Ethical–Professional Proxy) captured the reliance on PO(f) as an indirect surrogate for sustainability accountability. These codes were then synthesized into three higher-ordered themes. Theme 1 (Regulatory Compliance–Driven Integration) emerged from C1 and C5, reflecting the dominance of standardized language without corresponding competency depth. Theme 2 (Pillar Asymmetry and Environmental Bias), derived from C2, C3, and C4, captured the uneven representation of sustainability pillars, with environmental aspects prevailing over social and economic dimensions. Theme 3 (Competency–Curriculum Disconnect), formed from C5 and C6, reflected the absence of explicit competency-based sustainability integration despite the presence of related ethical and professional constructs. Consequentially, across the 66 SUCs, no programs (0%) demonstrated transformative sustainability integration. Instead, 32 SUCs (48.5%) exhibited moderate integration, characterized by partial curricular inclusion, while 34 SUCs (51.5%) reflected minimal integration, limited to nominal or outcome-level mentions.

C. *Practical Implications of the Findings*

The central contribution of this study is the *Mimetic Sustainability Gap* model (see **Fig. 2**), which emerged from the observed alignment between regulatory structures and curricular practices. Rather than being externally imposed, the model represents an analytically derived explanation of the structural and conceptual distance between the sustainability competencies prescribed in international frameworks and those reflected in Philippine CMO-baseline curricula. The term mimetic is drawn from DiMaggio and Powell's theory of institutional isomorphism [26], which suggested that organizations tend to adopt the language and formal structures of legitimate models as a means of securing institutional credibility, even in the absence of substantive transformation. In this context, the convergence of identical Program Outcome (PO[c]) formulations across all nine CMOs and their consistent reproduction across 66 SUCs can be understood as an expected manifestation of such mimetic processes within a highly standardized regulatory environment.

The resulting gap was observed to operate across three interconnected layers. At the regulatory layer, CMOs translate the Washington Accord Graduate Attribute 11 (sustainability and environment) into a constraint-oriented outcome (PO[c]) rather than a competency-based domain. This translation is structurally significant: while constraints function as design considerations, competencies represent enduring capabilities that inform decision-making across contexts. The absence of outcomes requiring systems-level reasoning, anticipatory thinking, or socio-technical analysis suggested a narrowing of sustainability from a transformative competency into a bounded parameter within engineering design. Moreover, at the institutional layer, SUCs are observed to reproduce CMO-prescribed language with high fidelity. This pattern is consistent with an outcomes-based education (OBE) framework in which compliance is evaluated primarily through the presence of prescribed outcomes, rather than the depth or mode of their curricular enactment. In the absence of explicit sustainability benchmarks or capacity-building requirements from CHED or the PTC, institutional variation beyond the prescribed baseline remains limited.

Lastly, at the competency layer, neither CMOs nor institutional curricula specify sustainability competencies in explicit or operational terms (e.g., those articulated in established competency frameworks). As a result, the observed pattern suggested that while sustainability is present at the level of terminology, it is not consistently translated into demonstrable competencies. Graduates, therefore, may exhibit awareness of sustainability as a concept but lack the integrated capabilities associated with systems thinking, anticipatory analysis, normative reasoning, strategic action, and stakeholder engagement.

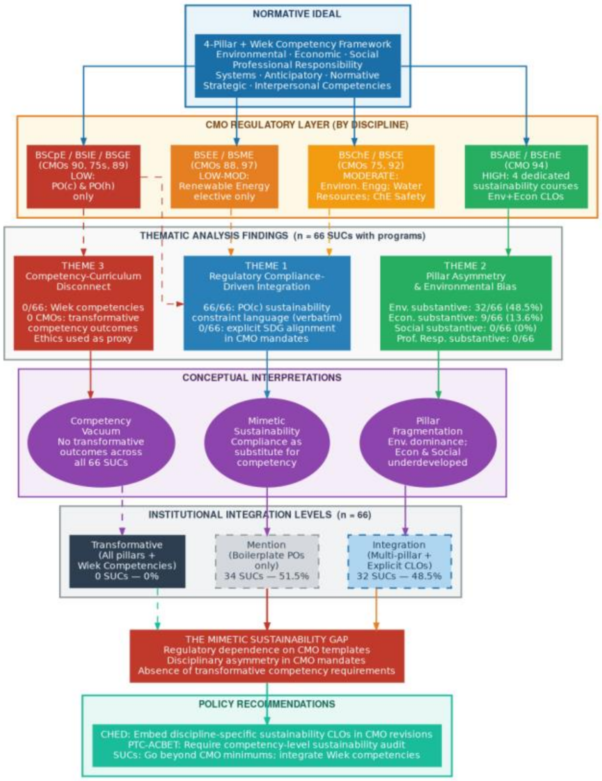

Fig. 2. The Mimetic Sustainability Gap: Conceptual Model of Sustainability Integration in Philippine SUC Engineering Curricula.

V. LIMITATIONS AND FUTURE WORK

While the present work presented the first CMO-enriched, system-level thematic analysis of sustainability integration across 66 Philippine SUC engineering programs, it is subject to several limitations. First, the analysis assumes baseline alignment of all 66 SUCs with CMOs; however, actual institutional implementation may vary in ways not fully captured by publicly available program documents. Second, the study is confined to program-level artifacts and does not examine instructional practices, faculty sustainability competencies, or student learning outcomes, which may diverge from formal curricular representations. Third, while nine CMOs representing the most prevalent engineering disciplines were analyzed, less common specializations were not included, potentially limiting disciplinary completeness. Future research should therefore extend this work through multi-level empirical validation, including classroom-level observations, faculty capability assessments, and direct measurement of student sustainability competencies.

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