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Engineering Education for Sustainable Futures through Curriculum Renewal Aligned with the EAC Manual 2024

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ABSTRACT

Engineering education is undergoing rapid transformation driven by Industry 5.0, digitalisation, sustainability imperatives, and growing expectations for ethical and human-centred practice. This structured review examined how global curriculum-renewal trends align with the Engineering Accreditation Council (EAC) Manual 2024. A systematic search of Scopus, Web of Science, and Google Scholar covering 2015–2025 identified 423 records, of which 92 full-text articles were screened and 48 met the inclusion criteria for thematic synthesis. Five dominant domains emerge, namely digital and artificial intelligence fluency, sustainability and ethics, human-centred learning, interdisciplinary and entrepreneurial mindsets, and flexible micro-credential pathways. Mapping these domains to the eleven Programme Outcomes in the EAC Manual 2024 revealed strong alignment in sustainability, ethics, teamwork, and societal responsibility, but weaker integration of digitalisation, AI-enabled problem solving, and lifelong-learning structures. The review proposes guiding principles for strengthening curriculum renewal, emphasising ethical integration, sustainability orientation, digital empowerment, human-centred learning, interdisciplinary synergy, and reflective quality management. These insights provide an evidence-based foundation for Malaysian engineering programmes seeking coherent, future-ready curriculum transformation consistent with global developments and accreditation expectations.

Keywords: Engineering education, curriculum review, EAC Manual 2024, Industry 5.0, outcome-based education, ethics, sustainability, digital skills

1. INTRODUCTION

1.1 Engineering Education in a Period of Transformation

Rapid advances in artificial intelligence, automation, and data-driven technologies are reshaping the expectations placed on engineers in the twenty-first century. Jeon et al. [1] highlight that contemporary engineering practice increasingly depends on digital infrastructures and computational fluency, while Harden [2] emphasises that outcome-based education (OBE) remains the most reliable mechanism for sustaining coherence in rapidly changing environments. Global frameworks—including the Washington Accord and UNESCO's Engineering for Sustainable Development agenda—reinforce the need for ethical literacy, systems thinking, and sustainability competence as integral elements of engineering graduate preparation [3–5]. These developments have stimulated international discussions on "Engineering Education 5.0," a paradigm that integrates technological mastery with empathy, civic responsibility, and human-centred values [6–9]. Yet scholars such as Lozano et al. [5] warn that accreditation processes sometimes focus more on documentation than on meaningful transformation, signalling the need for continuous, evidence-informed curriculum renewal.

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1.2 Malaysian Context and Policy Landscape

Malaysia is situated within this global transition but operates under a distinct regulatory ecosystem governed by the Engineering Accreditation Council (EAC). The EAC Manual 2024 consolidates eleven Programme Outcomes (POs) aligned with the International Engineering Alliance (IEA) Graduate Attributes and Professional Competencies (2021) [11, 12]. These outcomes formalise expectations that engineers demonstrate ethical professionalism, sustainability awareness, problem-solving capability, teamwork, and lifelong learning. Azman and Yusoff [11] note that the Malaysian accreditation landscape has matured significantly, yet institutional practices often remain procedural rather than transformative. Local studies report persistent challenges including uneven mapping of Course Learning Outcomes (CLOs) to POs, partial integration of sustainability and ethical reasoning, and weak linkage between assessment data and Continuous Quality Improvement (CQI) cycles [13–18]. This situation creates a pressing need for curriculum-renewal frameworks that translate global trends into meaningful, locally relevant educational practice.

1.3 Research Gap and Purpose of the Study

Although numerous publications discuss engineering-curriculum reform, most are descriptive, single-institutional, or narrowly focused on specific pedagogical innovations [10–12]. Previous reviews have addressed sustainability competencies, accreditation compliance, and digital readiness [5, 14, 15], but few have explicitly analysed how global educational developments correspond to the EAC Manual 2024 and the IEA (2021) framework. Evidence also indicates inconsistent interpretation of the eleven POs and limited translation of accreditation principles into transformative teaching practice [13–18]. This review therefore aims to bridge that gap by synthesising global trends—digital and AI fluency, sustainability and ethics, human-centred learning, interdisciplinarity and entrepreneurship, and flexible learning pathways—and mapping them to the EAC 2024 Programme Outcomes. The study addresses three questions:

1. What global trends shape engineering-curriculum renewal?
2. How do these trends correspond to Malaysia's accreditation requirements?
3. What strategies can guide coherent and sustainable curriculum transformation?

1.4 Significance and Novel Contribution

The contribution of this study lies in constructing an integrated analytical framework that aligns global engineering-education developments with Malaysia's accreditation context. By examining 48 studies (from an initial pool of 92 screened between 2015 and 2025), the review identifies core domains that characterise contemporary engineering-education reform. Mapping these domains to the eleven POs articulated in the EAC Manual 2024 creates a structured matrix that links international expectations with measurable professional attributes. This framework provides a foundation for institutions seeking to strengthen ethical reasoning, sustainability orientation, digital competence, and lifelong-learning pathways within their curriculum-review processes. In doing so, the study offers a timely and evidence-based guide to support Malaysian engineering programmes as they transition from procedural accreditation compliance toward meaningful educational transformation.

2. LITERATURE REVIEW

2.1 Global trends in Engineering Education

Engineering education is undergoing a major shift driven by digitalisation, artificial intelligence, and sustainability imperatives. Harden [2] argues that outcome based education (OBE) provides a robust framework for aligning programmes with changing professional demands, while Merino Campos [3] and Zhou et al. [4] show that digital technologies and AI enabled learning environments are reshaping how students access and apply knowledge. At the same time, international initiatives such as the Washington Accord and UNESCO's Engineering for Sustainable Development agenda emphasise that technical competence must be complemented by social responsibility and sustainability awareness [3–5, 13]. These developments converge in the emerging notion of Engineering Education 5.0, which seeks to integrate technological mastery with empathy, civic responsibility, and ethical reflection [6–9, 13]. Together, these trends signal that curriculum renewal must address not only content but also the values, capacities, and dispositions required of future engineers.

2.2 Curriculum Review and Accreditation Frameworks

Curriculum review has become a central mechanism for ensuring that engineering programmes remain relevant and accountable. International accreditation models such as ABET, EUR ACE, and the Washington Accord link course learning outcomes to graduate attributes and formalised quality assurance processes [11, 12, 26–29]. Ramírez [12] and Vieira [13] highlight that these frameworks can drive systematic improvement when institutions use evidence from assessment to refine curriculum design. However, several authors caution that accreditation is sometimes treated as a periodic documentation exercise rather than an ongoing process of educational reflection [14, 15, 26]. In response, Tranfield et al. [16], Okoli [17], and Grant and Booth [18] recommend systematic and transparent review approaches that combine clear search strategies, explicit inclusion criteria, and structured synthesis. Snyder [21] further argue that literature reviews can function as a research methodology in their own right, supporting evidence informed curriculum decisions. These insights underscore the importance of structured reviews and continuous quality improvement (CQI) as foundations for sustainable curriculum renewal within accreditation systems.

2.3 Pedagogical Transformation

The move toward Engineering Education 5.0 has significant implications for pedagogy. Lozano et al. [5] and Zoltowski and Oakes [6] show that authentic, project based learning can cultivate systems thinking, ethical awareness, and social sensitivity alongside technical problem solving. Harden [2] emphasises that digital tools contribute most effectively when they are integrated within clear outcomes and assessment strategies rather than added as isolated innovations. Research by Lee et al. [7] and Crawley et al. [9] demonstrates that design projects, studio based learning, and systems oriented tasks promote holistic understanding and adaptability. Chew and Ng [10] illustrate how linking final year projects to current industry practice can support both employability and professional identity formation. Collectively, these studies suggest that pedagogical transformation requires deliberate alignment among learning outcomes, teaching methods, assessment, and real world contexts, rather than reliance on technology or isolated course level changes.

2.4 Sustainability and Ethics

Sustainability and ethics have moved from peripheral topics to core expectations within engineering education. Lozano et al. [5] conceptualise sustainability competence as a combination of systems thinking, critical reflection, and moral responsibility. Hardebolle and

Héder [24] show that integrating sustainability themes within engineering ethics courses can deepen students' understanding of professional responsibility, while Ng and Lee [25] find that community based service learning strengthens ethical competence and social awareness among engineering students. Despite these advances, Subri et al. [14] and Abd Rahman [15] report that sustainability and ethics are still often treated as separate modules, with limited integration into core technical subjects or assessment structures. This disconnect risks positioning ethics as an add on rather than a guiding principle. The literature therefore points to the need for models that embed ethical and sustainability considerations across design projects, laboratories, and capstone experiences, supported by common rubrics and coherent learning trajectories [5, 9, 24, 25].

2.5 Malaysian Context

Within Malaysia, the Engineering Accreditation Council (EAC) Manual 2024 formalises eleven Programme Outcomes aligned with the International Engineering Alliance Graduate Attributes and Professional Competencies (2021) [11, 12]. These outcomes frame expectations for problem analysis, design, modern tool usage, ethics, sustainability, teamwork, communication, project management, and lifelong learning. Azman and Yusoff [11] notes that university–industry collaboration has improved programme relevance, while Subri et al. [14] and Abd Rahman [15] highlight positive effects of curriculum review on graduate attributes. At the same time, local studies identify persistent challenges: uneven mapping of course learning outcomes to Programme Outcomes, limited interdisciplinary collaboration, modest involvement of industry in curriculum design, and weak linkage between attainment data and CQI cycles [14, 15, 22, 23]. Abdullah and Rahman [22] and Ismail and Lim [23] report that digital readiness and AI integration vary widely across institutions, suggesting that the potential of Programme Outcomes related to modern tools and lifelong learning is not yet fully realised. These findings indicate that Malaysian programmes require clearer frameworks for aligning global trends with national accreditation priorities.

2.6 Identified Gaps and Synthesis

Across global and Malaysian literature, several consistent gaps emerge. First, curriculum reform often prioritises compliance with accreditation requirements over educational innovation, leading to surface level changes rather than deep pedagogical transformation [13–15, 26, 29]. Second, the integration of sustainability and ethics remains uneven, with limited evidence of systematic embedding across design, laboratory, and project based courses [5, 14, 15, 24, 25]. Third, the mechanisms linking Programme Outcomes to CQI are frequently underdeveloped, with attainment data used primarily for reporting rather than as a basis for reflective action [16–18, 21, 30]. Finally, studies on digital and AI readiness in Malaysian engineering programmes reveal fragmented approaches to digital competence and lifelong learning [22, 23]. These gaps highlight the need for a coherent framework that connects global trends in digitalisation, sustainability, and human centred learning with the eleven Programme Outcomes in the EAC Manual 2024. The present review responds to this need by synthesising evidence from 48 studies and mapping their key themes to the national accreditation framework, providing a structured basis for curriculum renewal and accreditation aligned with Engineering Education 5.0.

3. METHODOLOGY

3.1 Search Strategy

This study employed a structured qualitative review guided by systematic review principles. A comprehensive search was undertaken across Scopus, Web of Science, and Google Scholar to identify peer-reviewed publications related to engineering education, curriculum renewal,

accreditation, sustainability, ethics, digitalisation, interdisciplinary learning, and Engineering Education 5.0. The search covered the period from 2015 to 2025 and applied combinations of controlled keywords and Boolean operators such as "engineering education," "curriculum review," "outcome-based education," "EAC Manual," "sustainability," "ethics," "digital skills," "Industry 5.0," and "artificial intelligence," with modifications made to accommodate the indexing structures of each database. The search yielded 423 records, which formed the initial dataset for screening.

3.2 Inclusion and Exclusion Criteria

Studies were included if they were peer-reviewed, published between 2015 and 2025, written in English, and explicitly addressed engineering curriculum design, accreditation frameworks, sustainability, ethics, digitalisation, or related pedagogical transformation. Excluded studies comprised non-engineering research lacking educational relevance, opinion pieces, grey literature, papers without methodological clarity, and duplicate records. After removing 137 duplicates through automated and manual checks, 286 unique records remained for further assessment.

3.3 Screening and Selection Process

The screening process followed a multi-stage procedure. Titles and abstracts of the 286 unique records were independently screened by two coders, resulting in 92 articles selected for full-text review. Full-text assessment focused on relevance to engineering-education reform and alignment with the thematic domains of sustainability, ethics, digitalisation, human-centred learning, and interdisciplinary competencies. Forty-eight studies met all inclusion criteria and were retained for the final synthesis. Disagreements during screening were resolved through discussion, and inter-rater reliability was calculated using McHugh's kappa statistic, which yielded $\kappa = 0.82$, indicating strong agreement.

A PRISMA-style flow narrative summarises the process: 423 records were identified, 137 duplicates were removed, 286 titles and abstracts were screened, 194 were excluded, 92 full texts were assessed, 44 were excluded due to insufficient relevance or methodological rigour, and 48 studies were included for synthesis.

3.4 Data Extraction and Coding Procedure

For each included study, key information such as authorship, year of publication, research context, methodological design, thematic focus, and connection to accreditation or competency frameworks was recorded in an evidence table to facilitate systematic comparison. The analysis followed inductive thematic coding based on Braun and Clarke's six-phase approach. Initial open codes generated from repeated reading were grouped into categories and refined through iterative comparison to identify patterns across studies. This process produced five dominant themes representing global trends shaping engineering education: digital and AI fluency, sustainability and ethics, human-centred learning, interdisciplinary and entrepreneurial mindsets, and flexible learning pathways.

3.5 Analytical Framework

The five emergent themes were then mapped onto the eleven Programme Outcomes outlined in the Engineering Accreditation Council (EAC) Manual 2024 and the International Engineering Alliance (IEA) Graduate Attributes (2021). This mapping enabled systematic evaluation of the coherence between international educational developments and Malaysia's accreditation framework, forming the analytical foundation for interpreting curriculum renewal within the context of Engineering Education 5.0.

4. FINDINGS AND THEMATIC ANALYSIS

The thematic synthesis of 48 included studies revealed five intersecting domains that characterise contemporary developments in engineering education: digital and artificial intelligence fluency, sustainability and ethics, human-centred learning, interdisciplinary and entrepreneurial mindsets, and flexible learning pathways. These domains collectively reflect how global engineering education is transitioning toward models that integrate technical excellence with ethical, social, and digital competencies. Each domain was examined for its alignment with the eleven Programme Outcomes (POs) articulated in the Engineering Accreditation Council (EAC) Manual 2024 and the International Engineering Alliance (IEA) Graduate Attributes (2021).

4.1 Digital and AI Fluency

Across the literature, digital competence is recognised as a foundational requirement for contemporary engineering practice. Jeon et al. [1] and Zhou et al. [4] highlight that automation, computational modelling, and data-driven design now underpin engineering workflows, while Harden [2] notes that outcome-based frameworks ensure these skills remain anchored in conceptual understanding. Most studies caution, however, that digitalisation is unevenly integrated across curricula, with AI-related content still limited or isolated in many programmes. Within the EAC 2024 framework, digital fluency corresponds primarily to PO2 (problem analysis), PO3 (design and development of solutions), and PO5 (use of modern tools). The findings suggest that Malaysian programmes have incorporated digital tools into selected courses but have not yet embedded structured progressions for AI literacy, data analytics, or automation across the curriculum. Strengthening this integration would better align graduate capabilities with global expectations for Industry 5.0.

4.2 Sustainability and Ethics

Sustainability and ethics emerged as the most consistently emphasised domain across the reviewed studies. Lozano et al. [5] conceptualise sustainability competence as an integration of systems thinking, foresight, and moral responsibility, while Hardebolle and Héder [24] and Ng and Lee [25] show that experiential and community-engagement approaches enhance ethical judgement. Despite this consensus, several studies report that sustainability and ethics remain siloed within specialised courses rather than embedded across design, laboratory, and capstone projects. Under the EAC 2024 framework, these aspects correspond to PO6 (environment and sustainability) and PO7 (ethics), with related implications for PO8 and PO9 (individual, team, and societal responsibilities). The thematic synthesis indicates that although Malaysian programmes recognise sustainability and ethical professionalism, their implementation would benefit from more coherent, cross-curricular embedding supported by common rubrics and reflective assessment.

4.3 Human Centred Learning

Human-centred learning emerged as a significant theme in the literature, reflecting the shift toward engineering education that prioritises empathy, social context, and user-centred design. Zoltowski and Oakes [6] and Crawley et al. [9] demonstrate that project-based and service-learning approaches cultivate deeper understanding of societal impact while strengthening communication and teamwork. Braun and Clarke [19] further emphasise reflective inquiry as a driver of meaningful learning. Studies from the Malaysian context indicate growing interest in human-centred pedagogies, although these practices often remain limited to capstone projects or co-curricular initiatives. Alignment with EAC 2024 is evident through PO8 (individual and teamwork), PO9 (communication), and indirectly PO6 and PO7. The literature synthesis therefore suggests an opportunity for institutions to embed human-centred design more systematically across foundational and disciplinary courses.

4.4 Interdisciplinary and Entrepreneurial Education

Interdisciplinary and entrepreneurial competencies were consistently highlighted as essential for preparing engineers capable of addressing complex global challenges. Lee et al. [7] and Merino Campos [3] show that interdisciplinary collaboration enhances creative problem solving and adaptability, while Vieira [13] links entrepreneurial exposure to employability and lifelong learning. Malaysian studies, however, report that engineering programmes remain predominantly discipline-centric, with limited integration of interdisciplinary studios, cross-faculty collaboration, or entrepreneurship modules. Within the EAC 2024 framework, these attributes relate to PO8 (teamwork), PO9 (communication), and PO10 (project management and finance), with additional implications for PO11 (lifelong learning). The findings indicate that structured interdisciplinary experiences and entrepreneurship-oriented projects could significantly strengthen alignment with these outcomes.

4.5 Flexible Learning Pathways

Flexible learning pathways, through micro credentials, modular structures, and recognition of prior learning, are becoming important internationally in supporting lifelong learning. Snyder [21] notes that flexible structures allow learners to personalise their pathways and respond to emerging professional needs. Although national policy in Malaysia supports micro credentialing, the adoption of flexible structures varies across institutions. Many programmes lack clear mechanisms for stacking micro credentials, integrating industry certifications, or supporting alternative learning routes. This domain is strongly connected to Programme Outcome 11, which emphasises the ability to engage in independent and lifelong learning. The synthesis points to a need for institutions to create clearer pathways that support flexible progression without compromising accreditation requirements.

Globally, universities have moved toward hybrid curricula combining traditional engineering foundations with AI-driven design thinking, exemplified by MIT's "Computing Across Curriculum" initiative and the UK's "AI for Engineers" framework. To remain competitive, Malaysian institutions must reposition digital literacy as a transversal outcome, linked not only to tool use (PO5) but also to lifelong learning (PO12) and problem solving (PO2). The EAC 2024's open interpretation of "modern engineering tools" provides sufficient latitude for such expansion, provided institutions embed structured digital-skills progressions and cross-disciplinary computing modules.

4.6 Integrated Synthesis

Overall, the five domains show broad conceptual alignment with the EAC Manual 2024. Sustainability, ethics, teamwork, and communication are strongly represented, while digital fluency, interdisciplinary collaboration, and flexible learning require further development. The review indicates that the EAC framework already accommodates the essential attributes for future ready engineers, but realising its full potential depends on deeper integration of digital competence, ethical reasoning, and flexible learning structures throughout the curriculum.

The mapping confirms that while the EAC framework already encompasses most global priorities, its implementation across universities remains uneven. Strengthening linkages among digitalisation, sustainability, and lifelong learning would allow the framework to function not only as an accreditation instrument but also as a strategic guide for transformative curriculum renewal.

Table 1 Alignment of Global Trends with EAC 2024 Programme Outcomes

Global Trend	Primary EAC PO Alignment	Strength of Alignment	Identified Gap
Digital & AI Fluency	PO2, PO3 and PO5	Moderate	Lack of AI modules; limited computational integration
Sustainability and Ethics	PO6 and PO7	Strong	Fragmented application across disciplines
Human-Centred Learning	PO8 and PO9	Moderate	Service learning not mainstreamed
Interdisciplinary and Entrepreneurship	PO8 and PO9 and PO10	Moderate	Limited cross-faculty integration
Flexible Pathways and Micro-Credentials	PO11	Weak	Policy framework ahead of practice

5. IMPLICATIONS AND RECOMMENDATIONS

The review highlights that the EAC Manual 2024 provides a comprehensive foundation for producing graduates who are technically competent, ethically responsible, environmentally aware, and prepared for continuous learning. However, the thematic evidence suggests that several areas require more deliberate institutional attention. The emphasis on digital and artificial intelligence fluency calls for structured progression of digital skills from early years to advanced courses, including the integration of data analytics, automation, and artificial intelligence driven design. Sustainability and ethics should be strengthened through embedding within design studios, laboratory practice, fieldwork, and assessment rubrics to ensure that students internalise these values across learning experiences. Human centred learning requires wider adoption of authentic projects that engage real communities and users, supported by reflection based assessment tools.

Interdisciplinary and entrepreneurial competence can be enhanced through collaborative studios that bring together students from engineering, business, social sciences, and design. These collaborations should be supported by industry partners who provide relevant problems and insights. Flexible learning pathways demand institutional mechanisms that recognise micro credentials, industry certifications, and prior learning while maintaining alignment with Programme Outcomes. Finally, continuous quality improvement requires that attainment data, stakeholder feedback, and industry insights be systematically analysed and used to refine curriculum structure and delivery. Together these recommendations strengthen the alignment between global trends and the expectations of the EAC Manual 2024, supporting sustained curriculum renewal. Their essence and alignment with the eleven POs are summarised in Table 2.

Table 2 Guiding Principles for Curriculum Renewal within the EAC 2024 Framework

Principle	Core Idea	Key EAC 2024 POs
Ethical Integration	Embed moral reasoning and social responsibility across technical and design work.	PO7
Sustainability Orientation	Make environmental and societal responsibility a primary design and evaluation criterion.	PO6, PO7
Digital Empowerment	Build computational and AI literacy while preserving conceptual understanding.	PO2, PO3, PO5

Human-Centred Learning	Develop empathy, collaboration, and community awareness through authentic projects.	PO8, PO9
Interdisciplinary Synergy	Encourage collaboration across disciplines and with industry to address complex issues.	PO8, PO9, PO10
Flexible and Lifelong Learning	Establish modular and stackable learning structures that promote continual development.	PO11
Reflective Governance	Employ assessment evidence and stakeholder feedback for continuous quality improvement.	All POs (CQI)

These principles reposition Malaysian engineering education as a model where technological expertise, ethical integrity, and social responsibility coexist. Their implementation requires university leadership committed to faculty development, cross-sector partnerships, and policies that reward innovation and reflective practice. Embedding these seven principles across curriculum design, delivery, and evaluation will ensure that the EAC 2024 outcomes cultivate engineers prepared for a rapidly changing and ethically complex world.

6. CONCLUSION

This review shows that Malaysia's *EAC Manual 2024* already contains the key attributes required for future ready engineers, yet its full potential depends on stronger pedagogical integration and reflective governance. The analysis of five global trends including digital fluency, sustainability and ethics, human centred learning, interdisciplinarity, and flexibility, confirms broad alignment with the eleven Programme Outcomes while revealing gaps in coherence and implementation. The seven guiding principles identified in this study, namely ethical integration, sustainability orientation, digital empowerment, human centred learning, interdisciplinary synergy, flexible lifelong learning, and reflective governance, provide a coherent pathway for continuous quality improvement. Their successful implementation requires leadership commitment, faculty development, and structured feedback systems that convert accreditation from an administrative requirement into a process of renewal. By embracing these principles, Malaysian engineering programmes can evolve from procedural compliance to a model of education that unites technological excellence with ethical and social purpose.

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