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Enhancing Engineering Curricula with Entrepreneurship for Adaptation to Rapid Technological and Societal Changes

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Abstract

Rapid technological and societal change requires engineering graduates to combine technical competence with entrepreneurial and adaptive capabilities. This study compared learning outcomes in entrepreneurship-integrated and traditional engineering programmes and examined institutional barriers to curriculum integration. A convergent parallel mixed-methods design combined survey responses from 320 final-year students and recent graduates with interviews involving 18 faculty members and curriculum coordinators. Integrated programmes recorded significantly higher innovation capability ($d = 0.74$), entrepreneurial intent ($d = 0.67$), and adaptive thinking ($d = 0.51$), while technical problem-solving and employability readiness did not differ significantly. Thematic analysis identified five barrier clusters, with curriculum overload, accreditation rigidity, and institutional inertia rated most severe. The findings indicate that entrepreneurship integration strengthens adaptive competencies without weakening technical capability and support an empirically grounded model for curriculum reform in resource-constrained higher education institutions.

Keywords: *Engineering Education, Entrepreneurship Education, Curriculum integration; Adaptive Competencies, Technological change*

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Background to the Study

Engineering competence is no longer defined solely by mastery of established technical procedures. Automation, artificial intelligence, the green transition, and the wider disruptions associated with the Fourth Industrial Revolution are reshaping engineering work and increasing demand for graduates who can recognise opportunities, respond to uncertainty, mobilise resources, and develop solutions that remain viable across changing economic and social conditions (Schwab, 2021; World Economic Forum, 2023). These shifts require engineering education to develop adaptive and entrepreneurial capabilities alongside disciplinary knowledge.

Traditional engineering curricula are often organised around disciplinary specialisation and linear technical progression. Although this structure can produce strong technical competence, it may provide limited preparation for non-linear career pathways, innovation-led problem-solving, social entrepreneurship, and decision-making under market or societal uncertainty. The limited integration of entrepreneurial thinking therefore represents a substantive curriculum problem rather than an optional omission, because graduates may be technically capable yet insufficiently prepared to translate engineering knowledge into responsive and sustainable solutions (Nabi et al., 2021; Ratten, 2020).

Pressure for reform is increasingly reflected in international engineering and education frameworks. ABET, EUR-ACE, and UNESCO emphasise systems reasoning, societal awareness, professional responsibility, and the ability to design solutions that account for cultural, environmental, economic, health, and safety considerations (Marope et al., 2022; UNESCO, 2022). The challenge is particularly pronounced in developing-economy higher education institutions, where weak industry linkages, limited innovation infrastructure, rigid accreditation requirements, and slow curriculum review cycles can restrict the adoption of entrepreneurship-oriented learning (Bello & Aliyu, 2021; Ibidapo-Obe & Ajisola, 2020).

The study is anchored in experiential learning theory and the EntreComp framework. Experiential learning theory explains how transferable competencies develop through direct experience, reflection, conceptualisation, and active experimentation (Kolb & Kolb, 2022). EntreComp provides the operational competency structure used to assess entrepreneurial development through the domains of Ideas and Opportunities, Resources, and Into Action (European Commission, 2022). Together, these frameworks provide a basis for expecting curriculum integration to influence innovation capability, entrepreneurial intent, adaptive thinking, societal impact orientation, employability readiness, and technical problem-solving.

Existing comparative research has largely examined entrepreneurship as a standalone elective and has been concentrated in Western higher education settings. Although previous studies report gains in entrepreneurial intention and related skills, limited evidence explains whether curriculum-wide integration produces comparable outcomes in resource-constrained engineering institutions or how institutional barriers shape implementation (Hahn et al., 2020; Lackéus, 2020; Sirelkhatim & Gangi, 2021). The research problem is therefore the absence of an integrated empirical assessment that simultaneously compares student learning outcomes and identifies the institutional conditions that enable or obstruct engineering-entrepreneurship integration in a developing-economy context.

The remainder of the paper reviews the theoretical and empirical literature, explains the convergent parallel mixed-methods design, presents and integrates the quantitative and qualitative findings, and concludes with an evidence-based adaptation model and differentiated recommendations. Against this background, the study has two objectives: (1) to examine the effect of entrepreneurship integration on six EntreComp-derived learning outcomes relative to traditional engineering programmes; and (2) to identify institutional barriers to effective integration and propose adaptation strategies responsive to rapid technological and societal change.

Literature Review

Engineering Education under Technological and Societal Pressure

The pace of technological change has exceeded the adaptive capacity of many engineering curricula. Automation and artificial intelligence are reducing routine analytical roles once filled by engineering graduates, while the green transition is increasing demand for systems thinking and stakeholder engagement, competencies that disciplinary specialisation does not always develop. The World Economic Forum (2023) projects that 44% of workers' core skills will be disrupted within five years of the reporting period. Against this background, engineering education bodies have formalised expectations that were previously implicit. ABET's engineering criteria require graduates to apply engineering design in producing solutions that consider public health, safety, welfare, and global, cultural, social, environmental, and economic factors, requirements that directly involve entrepreneurial and societal competencies (Carayannis et al., 2021). EUR-ACE similarly emphasises professional responsibility and the societal impact of engineering. Curricula that do not develop these attributes risk preparing graduates for professional conditions that are changing around them (Ibidapo-Obe & Ajisola, 2020; Marope et al., 2022).

Entrepreneurship Education in Higher Education: Conceptual Foundations

Entrepreneurship education in higher education extends beyond business start-up instruction. Fayolle and Liñán (2023) define it as the deliberate development of opportunity recognition, resourcefulness, risk tolerance, and adaptive problem-solving. These competencies are distinct from technical skill but interact productively with it when developed in parallel. A critical distinction therefore exists between teaching entrepreneurship to engineers as a supplementary business module and embedding entrepreneurship as a mode of engineering practice that is iterative, user-centred, failure-tolerant, and impact-oriented (Neck et al., 2021). The latter approach draws on problem-based learning, design thinking, and experiential learning. Lackéus (2020) found that experiential entrepreneurship education produced larger gains in opportunity recognition and initiative than lecture-based approaches, a finding also reported by Karimi et al. (2021) in a non-Western context. The European Commission (2022) introduced EntreComp as a standardised competency architecture for assessing these outcomes. Its dimensions, particularly innovation, resource mobilisation, and coping with uncertainty, correspond directly with the adaptability demands identified in engineering education reform.

The Engineering-Entrepreneurship Integration Link

Figure 1 presents the conceptual framework developed for this study, synthesizing the three converging domains whose intersection defines the adaptive engineering graduate profile that anchors both objectives.

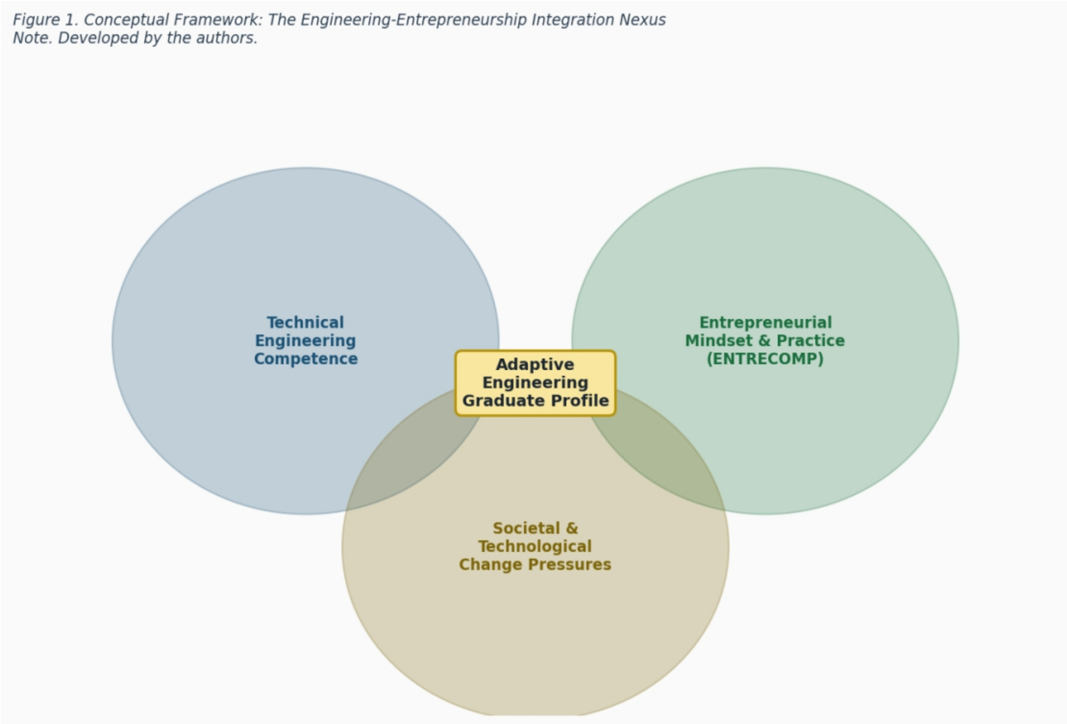


Figure 1.
Note: Developed by the authors.

Internationally, integration has been implemented through embedded studio courses, capstone entrepreneurship projects, and interdisciplinary innovation laboratories. Evidence from MIT, Stanford's d. school, and Olin College indicates improvements in innovation orientation and entrepreneurial intent among students who complete integration-intensive programmes (Martin et al., 2022; Souitaris et al., 2021). However, the transferability of these models to resource-constrained, developing-economy higher education institutions remains insufficiently established because accreditation structures, faculty capacity, and industry linkages differ substantially. MIT and Olin operate with dedicated faculty, industry endowments, and accreditation environments that recognise entrepreneurship as a legitimate technical competency. These conditions do not characterise most engineering institutions in sub-Saharan Africa or South Asia (Bello & Aliyu, 2021; Dzisi & Obeng, 2023).

Learning Outcomes in Integrated vs. Traditional Engineering Curricula

Previous comparative studies have examined learning outcomes across several dimensions. Drawing on EntreComp and validated instruments from engineering education research, this study measures innovation capability, entrepreneurial intent, adaptive thinking, societal impact orientation, employability readiness, and technical problem-solving. Existing evidence generally indicates that integrated programmes improve innovation and entrepreneurial intent, but findings on technical competence and societal impact orientation remain mixed (Hahn et al., 2020; Pittaway & Cope, 2021; Rideout & Gray, 2021). Evidence concerning societal impact is particularly inconsistent, and the variation may depend on whether the integration model includes explicit community-engagement activities. No previous study has combined a six-domain, EntreComp-anchored outcome comparison with a concurrent analysis of institutional barriers through a convergent parallel mixed-methods design in a developing-economy engineering education context.

Documented Barriers: A Sensitising Framework from Prior Literature

Previous scholarship identifies five broad barriers to entrepreneurship integration: accreditation-driven curriculum overload, faculty resistance to non-technical content, funding and infrastructure deficits, weak industry-academia linkages, and policy or institutional inertia (Ismail et al., 2021; Mwasalwiba, 2021; Okafor & Bello, 2023). These categories provide a sensitising framework against which the study's empirically derived themes are compared, extended, or challenged. Table 4 therefore maps each empirical finding to the corresponding categories in the prior literature.

Methodology

Research Design

This study adopts a convergent parallel mixed-methods design in which quantitative survey data and qualitative interview data are collected concurrently, analysed independently, and integrated through a joint display at the interpretation stage (Creswell & Creswell, 2023; Tashakkori & Teddlie, 2021). Meta-inferences from the joint display inform the integrated findings and adaptation model. The design was selected because Objective 1 requires group-level measurement across six competency domains, whereas Objective 2 requires in-depth accounts from faculty members and curriculum stakeholders. Interpreting both strands together strengthens their explanatory value (Rossman & Wilson, 2022). Figure 2 summarises the research process.

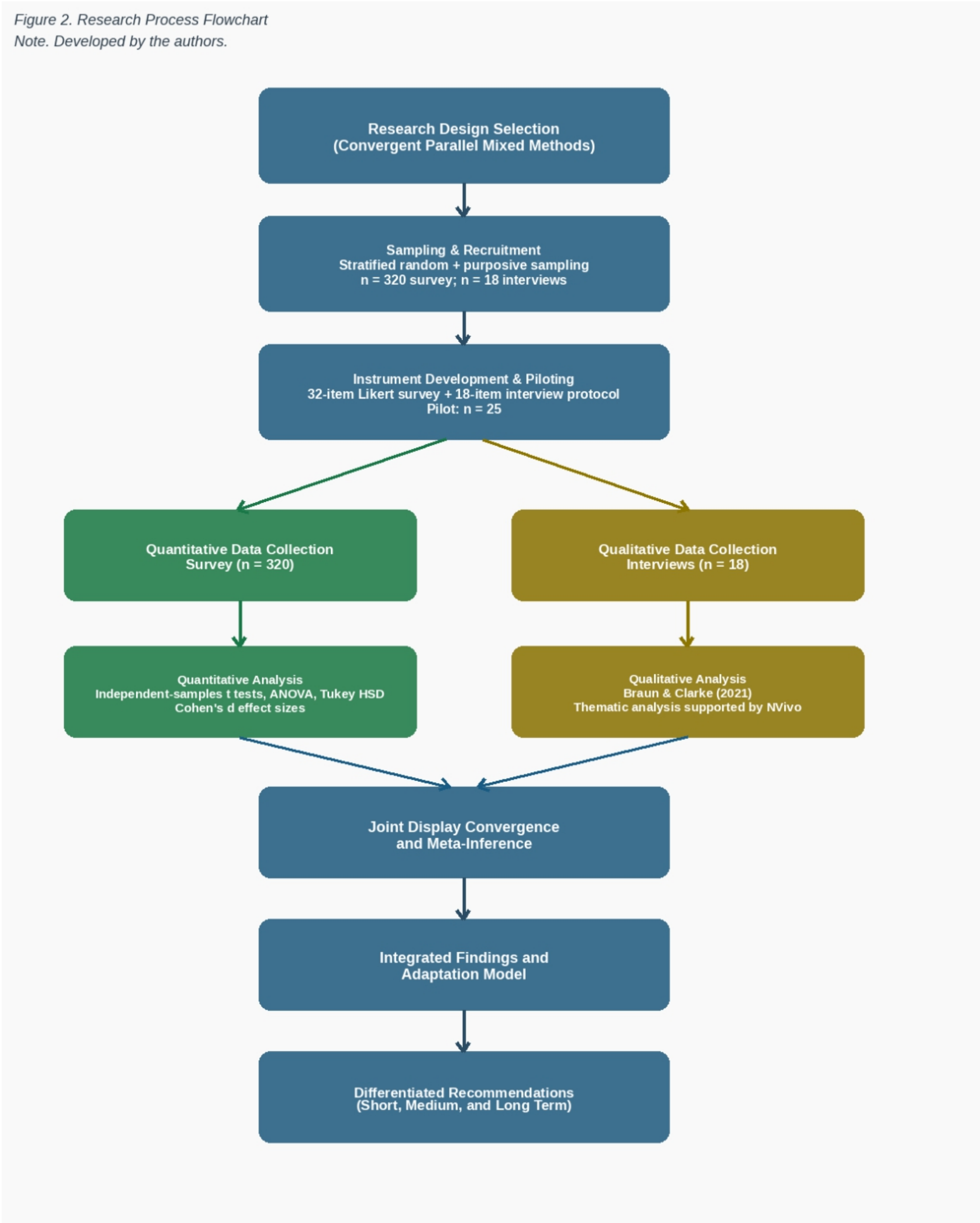


Figure 2.
Note: Developed by the authors.

Population and Sample

The target population comprised final-year engineering students, engineering graduates within five years of graduation, and faculty members responsible for curriculum design in universities offering either entrepreneurship-integrated or traditional engineering programmes within a developing-economy context. Purposive and stratified random sampling were used to ensure representation across programme types, disciplines, and gender. The survey included 320 respondents, with 160 participants from each programme type. Equivalence between the groups in age, gender, and disciplinary distribution was verified before comparative analysis. The qualitative strand involved 18 faculty members and curriculum coordinators. Recruitment continued until successive interviews generated no new themes, indicating thematic saturation in accordance with Braun and Clarke (2021). Table 1 presents the sample distribution.

Table 1: Sample Distribution by Participant Category, Programme Type, and Data Strand

Participant Category	Entrepreneurship-Integrated	Traditional	Total	Data Strand
Final-Year Undergraduate Students	80	80	160	Survey
Recent Engineering Graduates (< 5 yrs)	80	80	160	Survey
Faculty / Curriculum Coordinators	9	9	18	Interview
Total	169	169	338	Both

Note: Developed by the authors.

Instrumentation and Pilot Testing

The survey instrument comprised 32 items measured on a five-point Likert scale and assessed self-reported competency across six EntreComp-derived outcome domains. Before full deployment, the instrument was piloted with 25 respondents who were not included in either study group. Items that generated ambiguous responses or weak inter-item consistency were revised. Cronbach's alpha for the full dataset was .84, indicating acceptable internal consistency. The semi-structured interview schedule contained 18 open-ended questions designed to elicit participants' experiences of integration attempts, implementation obstacles, and contextual enabling or inhibiting factors.

Analytical Methods

Quantitative analysis included descriptive statistics, independent-samples t tests for between-group comparisons across the six outcome domains, and one-way analysis of variance for subgroup comparisons by discipline, gender, and year of study. When analysis of variance produced a statistically significant result, Tukey's honestly significant difference post hoc test was used to identify the specific group differences. Cohen's d was calculated and interpreted using the conventional thresholds of 0.20 for a small effect, 0.50 for a medium effect, and 0.80

for a large effect. Qualitative analysis followed Braun and Clarke's (2021) six-phase thematic analysis framework and was supported by NVivo coding. A joint display placed the quantitative outcome patterns alongside the qualitative barrier themes, enabling meta-inferences that informed the integrated adaptation model.

Validity, Reliability, and Trustworthiness

Content validity was established through review by three engineering education scholars before piloting. In the qualitative strand, credibility was supported through member checking, whereby selected interview participants reviewed the preliminary thematic interpretations and confirmed their accuracy. Transferability was supported through detailed contextual description, dependability through a documented audit trail of coding decisions, and confirmability through reflexive bracketing of researcher assumptions in a pre-analysis memo, following Lincoln and Guba (2023).

Ethical Considerations

Institutional ethical approval was obtained prior to data collection. All participants provided written informed consent. Data were anonymised at source, and no institutional names appear in any reported finding.

Results and Analysis

Respondent Profile

Table 2 presents the demographic characteristics of the 320 survey respondents. Male participants constituted 61.9% of the sample, while electrical and computer engineering represented the largest disciplinary subgroup (30.6%). Equal representation across programme types was maintained by design.

Table 2: Demographic Profile of Survey Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	198	61.9
	Female	118	36.9
	Other / Prefer not to say	4	1.3
Age Bracket	18-24 years	172	53.8
	25-30 years	118	36.9
	31 years and above	30	9.4
Engineering Discipline	Electrical / Computer Engineering	98	30.6
	Civil / Structural Engineering	84	26.3
	Mechanical Engineering	78	24.4
	Chemical / Environmental Engineering	60	18.8
Programme Type	Entrepreneurship-Integrated	160	50.0
	Traditional	160	50.0

Note: Developed by the authors.

Objective 1: Effect of Entrepreneurship Integration on Learning Outcomes

Results

Competency self-assessment scores were calculated for the six EntreComp-derived outcome domains in both programme groups. Independent-samples t tests were then conducted for each domain. Table 3 presents the results.

Table 3: Comparative Learning Outcomes: Entrepreneurship-Integrated vs. Traditional Engineering Programmes

Outcome Domain	Integrated M (SD)	Traditional M (SD)	t-value	df	p-value	Cohen's d
Innovation Capability	4.12 (0.51)	3.41 (0.60)	9.18	318	< .001	0.74
Entrepreneurial Intent	4.08 (0.48)	3.35 (0.57)	9.84	318	< .001	0.67
Adaptive Thinking	3.95 (0.55)	3.28 (0.62)	8.21	318	< .001	0.51
Societal Impact Orientation	3.61 (0.58)	3.44 (0.61)	2.01	318	.045	0.28
Employability Readiness	3.72 (0.52)	3.67 (0.54)	0.67	318	.503	0.09
Technical Problem-Solving	3.88 (0.49)	3.82 (0.51)	0.85	318	.396	0.12

Note: M = mean; SD = standard deviation. Cohen's d was interpreted using the following thresholds: small = 0.20, medium = 0.50, and large = 0.80. Developed by the authors.

Students in entrepreneurship-integrated programmes recorded significantly higher scores for innovation capability, entrepreneurial intent, and adaptive thinking. Societal impact orientation showed a statistically significant but practically small difference (d = 0.28). Technical problem-solving and employability readiness did not differ significantly between the groups. Effect sizes for the three primary domains ranged from medium to moderately large (d = 0.51 to 0.74), indicating practical as well as statistical importance. Figure 3 presents the mean scores across the six domains by programme type.

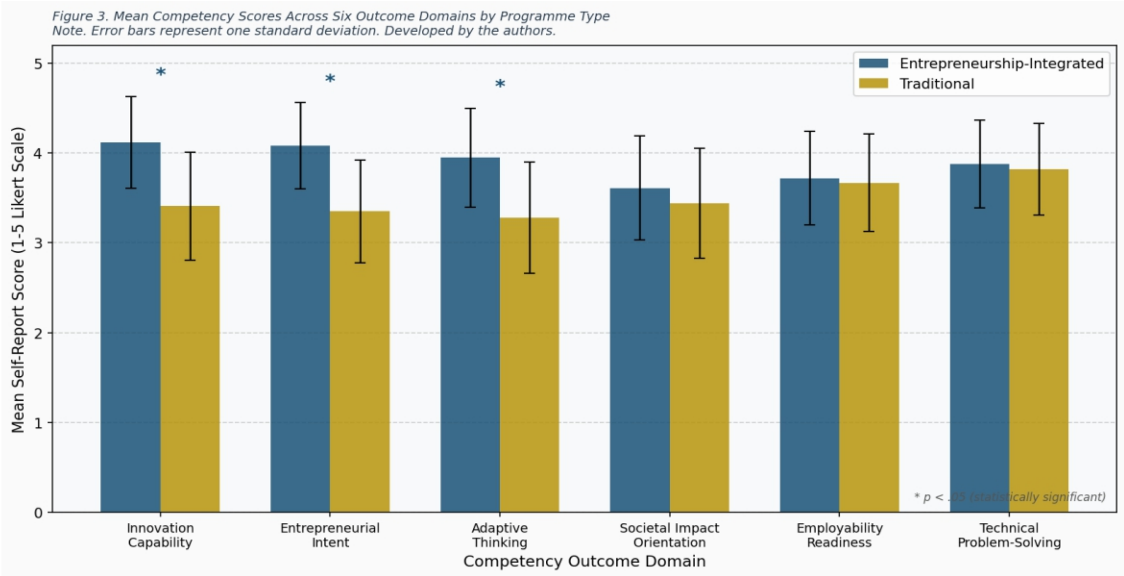


Figure 3.
Note: Error bars represent one standard deviation. Asterisks (*) denote p < .05. Developed by the authors.

Figure 4 presents the full competency profile for both groups on a radar chart, allowing simultaneous visual inspection of convergence and divergence zones across the six domains.

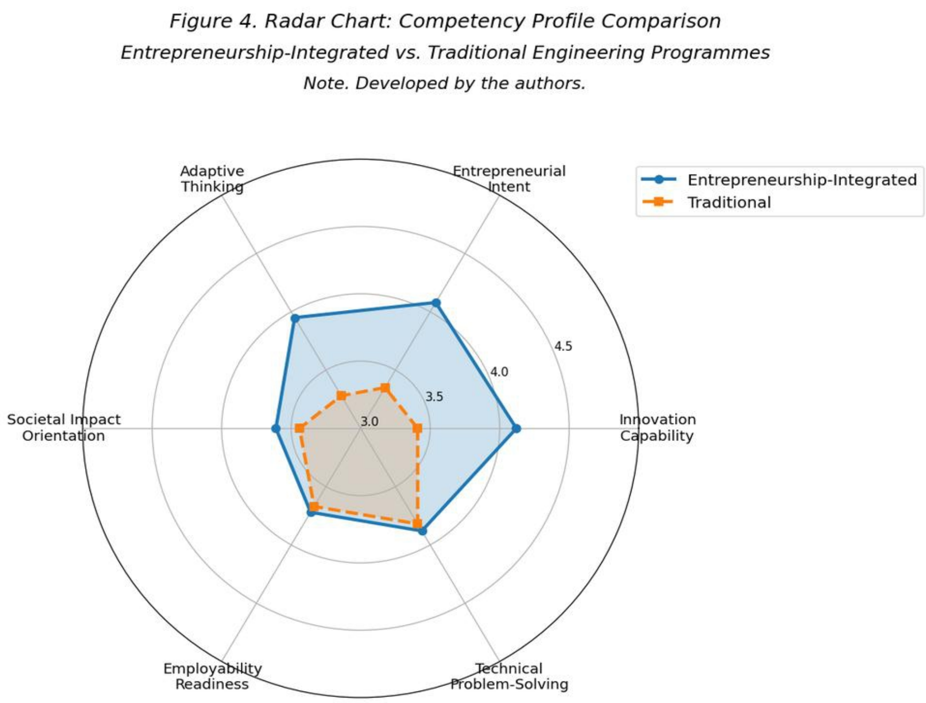


Figure 4.
Note: Developed by the authors.

Sub-group ANOVA results indicated statistically significant discipline-based differences in entrepreneurial intent scores, $F(3, 316) = 6.42$, $p = .003$. Tukey HSD post-hoc tests revealed that electrical and computer engineering students in integrated programmes scored significantly higher than civil and mechanical engineering counterparts on this domain (mean difference = 0.38, $p < .05$). No statistically significant gender-based differences were found across any of the six domains.

Discussion of Objective 1 Findings

The results do not support a simple claim that integrated programmes are superior across all competencies. Their strongest advantages occurred in innovation capability, entrepreneurial intent, and adaptive thinking, the dimensions most directly associated with adaptation to technological and societal change. Technical problem-solving scores, however, were statistically comparable across the two groups. This finding is important because a persistent faculty concern is that entrepreneurship content may displace technical formation. The present results do not support that concern.

The absence of a significant difference in employability readiness requires careful interpretation. It contrasts with findings from Western higher education contexts, where employability gains are frequently associated with entrepreneurship education (Nabi et al., 2021; Piperopoulos & Dimov, 2021). One explanation is that self-reported employability reflects labour-market signals beyond curriculum type. Students in traditional programmes may therefore remain confident in their technical credentials even when employers place increasing value on adaptive competencies. A second explanation concerns measurement sensitivity, because self-report scales may not adequately distinguish technical employability from adaptive employability. Societal impact orientation showed a statistically significant but small effect ($d = 0.28$). This limited effect may reflect the restricted sensitivity of a cross-sectional assessment to changes that develop through sustained exposure. Longitudinal studies of design-thinking graduates suggest that societal awareness may emerge over a longer period than that covered by a single undergraduate integration programme (Lans et al., 2021; Warhuus et al., 2021).

Objective 2: Institutional Barriers to Entrepreneurship Integration

Results

Thematic analysis of the interview transcripts, conducted using Braun and Clarke's (2021) six-phase framework and supported by NVivo, yielded five empirically derived barrier themes. Each theme is presented in relation to the sensitising framework established in the literature review and is classified as confirming, extending, or diverging from previous scholarship. Table 4 presents the barrier analysis, while Figure 5 shows the frequency and severity ratings.

Table 4: Institutionally Identified Barriers to Entrepreneurship Integration in Engineering Curricula

Barrier Theme	**Frequency (n=18)**	**Severity M (1-5)**	**Relationship to Prior Literature**
Curriculum Overload & Accreditation Rigidity	16	4.61	Confirms prior literature; extends by identifying institutional insecurity dimension in developing economy HEIs
Faculty Capacity & Attitudinal Resistance	14	3.92	Partially confirms prior literature; extends by distinguishing capacity-based from ideology-based resistance
Industry-Academia Linkage Deficit	12	3.74	Confirms prior literature; context-specific severity higher than Western HEI benchmarks
Inadequate Funding & Infrastructure	11	3.55	Confirms prior literature; linked to absence of maker spaces and innovation hub infrastructure
Policy & Institutional Inertia	13	4.21	Confirms prior literature; manifests through long review cycles and absence of faculty incentive structures

Note: Frequency counts are based on 18 interview participants. Severity was rated on a five-point Likert scale. Developed by the authors.

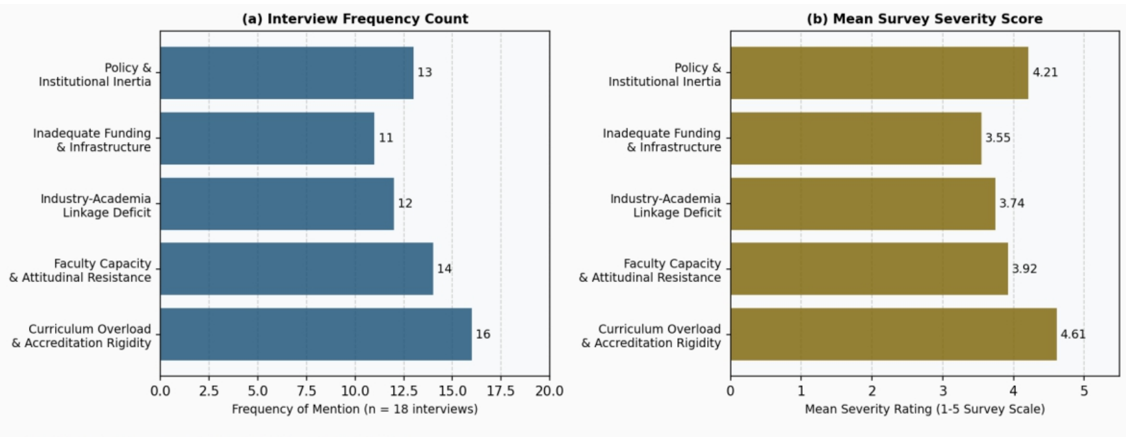


Figure 5. Barrier Frequency and Severity Ratings Across Five Themes
Note. Developed by the authors.

Figure 5.
Note: Panel (a) shows interview frequency counts; panel (b) shows mean survey severity scores. Developed by the authors.

Curriculum overload and accreditation rigidity were the most frequently reported (n = 16) and most severe (M = 4.61) barriers. Participants indicated that accreditation-mandated technical credit loads left little structural space for entrepreneurship content without displacing existing modules. One curriculum coordinator illustrated this constraint by describing the curriculum as "a fully loaded container ship with no room for new cargo." Faculty capacity and attitudinal resistance ranked second in frequency (n = 14, M = 3.92), although the basis of resistance varied more than previous literature commonly suggests. Weak industry-academia linkages (n = 12, M = 3.74) restricted the practical and experiential dimensions of integration, while inadequate funding and infrastructure (n = 11, M = 3.55) constrained the establishment of maker spaces and innovation facilities. Policy and institutional inertia (n = 13, M = 4.21) operated at the governance level through lengthy curriculum review cycles, limited incentives for curriculum development, and insufficient senior leadership prioritisation. Figure 6 links each barrier to its causal mechanism, proposed adaptation strategy, expected outcome, and implementation level.

Figure 6. Barrier-to-Strategy Resolution Flowchart
Note. Developed by the authors.

Figure 6.
Note: Developed by the authors.

Discussion of Objective 2 Findings

The dominance of curriculum overload is consistent with previous scholarship, but its institutional basis differs in the developing-economy context examined here. In well-established Western engineering programmes, accreditation rigidity may reflect confidence in existing standards and concern that reform will dilute technical content. In the present context, rigidity also appears to arise from uncertainty while accreditation systems are being consolidated. Although both conditions produce resistance to changes in credit structures, they require different policy framing. Reform is more likely to gain institutional acceptance when entrepreneurship is presented as an additional graduate competency within a restructured credit framework rather than as a replacement for technical content (Okafor & Bello, 2023; Ughulu, 2022).

Faculty resistance appears to be the most tractable of the five barriers. Although 14 of the 18 interview participants reported resistance, further probing showed that it was more often linked to capacity limitations than to principled rejection of entrepreneurship as non-engineering content. Many participants lacked training in problem-based learning or design-thinking facilitation, had no established model for embedding entrepreneurship within existing modules, and received no institutional incentive to experiment. Capacity-based resistance therefore requires a different response from ideological opposition. Targeted professional development linked to performance incentives offers the most direct intervention (Ismail et al., 2021). The industry-academia linkage deficit is not unique to this context, but it is particularly restrictive because the experiential component of entrepreneurship integration depends on sustained industry engagement. Lackéus (2020) indicates that experiential approaches generate the strongest competency gains. Without partners who can host project-based learning, co-design modules, or provide authentic engineering problems, entrepreneurship education is likely to default to lecture-based delivery, which is associated with smaller competency gains.

Cross-Objective Synthesis

The convergence of the findings for Objectives 1 and 2 reveals a coherent structural pattern. Innovation capability, entrepreneurial intent, and adaptive thinking, the outcomes most improved by integration, are also the outcomes most directly constrained by the identified barriers. Curriculum overload limits sustained exposure to iterative, project-based learning; policy inertia restricts the conditions required for entrepreneurial identity development; and faculty capacity deficits weaken the experiential pedagogies that support adaptive thinking. The correspondence between outcomes and barriers demonstrates a systemic relationship between the benefits that integration can produce and the institutional conditions that prevent their development. Table 5 presents the cross-objective alignment matrix that provides the empirical foundation for Figure 7.

Table 5: Cross-Objective Alignment Matrix: Outcome Domains and Suppressing Barriers

Outcome Domain	Primary Suppressing Barrier	Mechanism of Suppression	Adaptation Strategy
Innovation Capability	Curriculum Overload	No space in credit structure for iterative, project-based innovation work	Credit framework restructuring; embed innovation modules as core
Entrepreneurial Intent	Policy & Institutional Inertia	Long review cycles prevent curriculum reform that builds entrepreneurial identity	Accreditation standard revision; formal recognition of entrepreneurial intent as graduate outcome
Adaptive Thinking	Faculty Capacity Deficit	Experiential pedagogy required for adaptive skill transfer is absent from faculty practice	Targeted professional development; PBL and design thinking training grants
Societal Impact Orientation	Industry-Academia Linkage Deficit	Real-world problem exposure, necessary for societal awareness, is unavailable without industry partners	Mandatory industry co-design agreements for curriculum development
Employability Readiness	Inadequate Infrastructure	Prototype and maker facilities necessary for work-ready skill demonstration are absent	Government-funded HEI innovation hubs linked to graduate employment outcomes

Note: Developed by the authors.

This study contributes a convergent parallel mixed-methods framework that simultaneously measures learning-outcome effects and institutional barrier profiles in engineering-entrepreneurship integration. This approach has not previously been applied in developing-economy higher education contexts. Integrating the two objectives produces an adaptation model that is empirically grounded rather than based solely on prescriptive assumptions.

Conclusion and Recommendations

Summary of Findings

Objective 1 established that entrepreneurship-integrated engineering programmes produce stronger outcomes in the competency dimensions most directly associated with technological and societal adaptability. Innovation capability ($d = 0.74$), entrepreneurial intent ($d = 0.67$), and adaptive thinking ($d = 0.51$) showed medium-to-moderately-large effects in favour of integrated programmes. Technical problem-solving scores were statistically comparable across the two programme types, which does not support the concern that entrepreneurship integration displaces technical competence. Objective 2 identified five institutional barrier clusters. Curriculum overload and policy inertia were rated most severe, while the distinction between capacity-based and ideology-based faculty resistance has direct implications for intervention design.

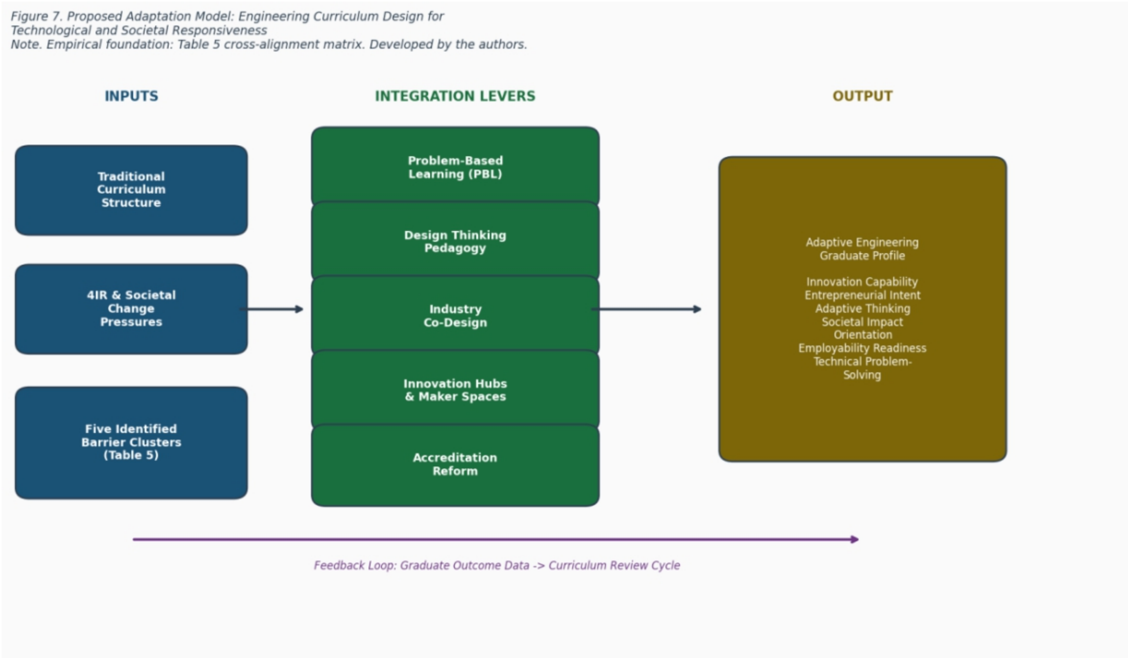
Differentiated Recommendations

Short-term interventions that can be implemented within one academic cycle should address faculty capacity, the most tractable barrier identified. Institutions should fund professional development in problem-based learning and design-thinking facilitation and link participation to incentives that reward curriculum development. At the same time, piloting entrepreneurship components within existing engineering modules, without increasing credit hours, would test whether modest restructuring can begin to develop the competency profile shown in Figure 4. Medium-term action is required at the accreditation level. ABET, EUR-ACE, COREN, and their regional equivalents should formally recognise innovation capability, adaptive thinking, and entrepreneurial intent as graduate outcomes with standing comparable to technical competencies. This intervention directly addresses curriculum overload driven by accreditation rigidity by changing the competencies that accreditation requires. Without such reform, institutional initiatives will continue to operate against existing structural constraints.

In the long term, governments and policy actors should fund dedicated engineering-entrepreneurship innovation hubs within higher education institutions and connect them to mandatory industry co-design agreements for curriculum development. Weak industry-academia linkage, the third most severe barrier, directly limits the practical and experiential dimensions of integration. Resolving it requires sustained external funding and a policy framework that recognises curriculum co-design as a legitimate form of industrial engagement. Future research should prioritise longitudinal assessment of actual graduate career outcomes beyond self-reported competency, replication across multiple national and regional developing-economy contexts, and development of more sensitive measures of societal impact orientation. The small cross-sectional effect observed for this dimension may reflect measurement limitations rather than limited theoretical importance.

Proposed Adaptation Model

Figure 7 presents the study's synthesising contribution: an adaptation model for engineering curriculum design that connects the five barrier clusters, five integration levers, and six EntreComp outcome domains within a single framework. The model includes a feedback loop linking graduate outcome data to institutional curriculum review cycles and is empirically grounded in the cross-objective alignment matrix presented in Table 5.



Note: Empirical foundation: Table 5 cross-alignment matrix. Developed by the authors.

Embedding entrepreneurship within engineering education does not weaken technical formation. Instead, it extends the graduate competency profile beyond technical certainty to include adaptive thinking, opportunity recognition, and awareness of societal impact. Under conditions of rapid technological and societal change, this extension represents a necessary development in the purpose and practice of engineering education.

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