

Cognitive Defaults in Indigineering: Baseline Orientations toward Indigenous Knowledge, Engineering, and Entrepreneurship among First-Year Engineering Students

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Abstract

Engineering education increasingly calls for pedagogies that engage local and Indigenous knowledge systems, yet few instruments exist to examine how students initially orient themselves at the intersection of Indigenous knowledge, engineering, and entrepreneurship. This study introduces the Indigineering Cognitive Defaults Instrument and reports a pre-intervention baseline from a first-year engineering course at the university of ANONYMOUS. Two hundred students completed 13 scenario-based items together with motivation and entrepreneurial competency measures. We examined item-level patterns against chance expectations, explored student profiles using k-means clustering, and assessed relationships among composite Indigenous knowledge (IK), engineering (ENG), and entrepreneurial (ENT) indices across the full sample and two authorization subsamples. Students demonstrated strong Indigenous knowledge legitimacy defaults (66-80%), modest entrepreneurial orientation, and comparatively weak analytical engineering (14%), tool-adaptability (19%), and co-creation ethics (13%) defaults. IK and ENG indices independently predicted entrepreneurial orientation in OLS models, whereas the hypothesized sequential mediation pathway was not supported. A gender difference emerged for the analytical engineering default, while IK legitimacy did not vary by childhood setting. The study provides initial psychometric and construct validity evidence for the instrument and suggests that culturally responsive engineering curricula may need to strengthen analytical and ethical capacities while building on students' existing recognition of Indigenous knowledge as a legitimate source of engineering innovation.

Keywords: cognitive defaults, indigenous knowledge systems, engineering education, culturally responsive pedagogy, entrepreneurship

1. Introduction

Engineering education is increasingly challenged to prepare graduates who can address complex societal problems while working across diverse knowledge systems. In postcolonial contexts, this challenge extends beyond expanding participation or incorporating local examples into existing curricula. It requires reconsidering what counts as legitimate engineering knowledge and how students learn to recognize, evaluate, and integrate different forms of knowledge when approaching engineering problems. Recent scholarship has therefore shifted from viewing Indigenous knowledge as a cultural supplement to recognizing it as a potential contributor to engineering design, sustainability, community innovation, and locally grounded technological development (Agrawal et al., 2022; Agrawal & Heydenrych, 2024; K'Akumu, 2024; Stephensen & Cunningham, 2024). Despite this growing interest, relatively little is known about how engineering students initially frame Indigenous knowledge when confronted with authentic engineering situations.

This question is fundamentally epistemological. Before students learn new engineering concepts or participate in community-engaged projects, they already possess assumptions about what constitutes legitimate engineering knowledge, which knowledge sources deserve attention, and what kinds of solutions appear reasonable. These initial assumptions shape problem definition, influence which stakeholders students consult, determine which evidence they regard as credible, and constrain the range of solutions they consider. Consequently, understanding students' initial epistemic framing is essential for designing engineering curricula that seek to integrate Indigenous knowledge, engineering reasoning, and entrepreneurship.

Existing engineering education research provides valuable insight into many aspects of student learning but offers limited tools for examining these initial epistemic orientations. Widely used instruments measure constructs such as engineering self-efficacy (Mamaril et al., 2016), academic motivation (Jones, 2009), entrepreneurial intentions (Liñán & Chen, 2009), engineering identity, or attitudes toward engineering. These measures explain how confident students feel, what motivates them, or what careers they intend to pursue. They do not examine the more fundamental question of how students initially determine what counts as relevant engineering knowledge when Indigenous knowledge, engineering analysis, and entrepreneurial opportunity intersect. As a result, engineering educators have limited empirical evidence about the epistemic starting points students bring into culturally responsive engineering classrooms.

To address this gap, the paper introduces the concept of cognitive defaults. Cognitive defaults refer to the immediate epistemic framing tendencies that students employ when they encounter engineering situations before extended analysis or classroom instruction. Drawing on dual-process theories of cognition (Kahneman, 2011; Evans, 2008), cognitive defaults are not interpreted as fixed beliefs or stable personality traits. Rather, they represent students' initial orientations regarding which knowledge sources appear legitimate, which problems deserve attention, and which solution pathways seem most appropriate. In engineering education, these defaults are important because early problem framing often shapes subsequent design reasoning, stakeholder engagement, and innovation trajectories.

Within the Indigineering framework, cognitive defaults operate across three interconnected dimensions: Indigenous knowledge, engineering reasoning, and entrepreneurship. Indigenous knowledge provides locally embedded ways of understanding problems and opportunities. Engineering contributes analytical reasoning, design processes, and technological transformation. Entrepreneurship contributes opportunity recognition, resource mobilization, and pathways for translating engineering solutions into community impact. Effective engineering education increasingly requires students to integrate these dimensions rather than treating them as separate domains. Yet whether students naturally approach engineering problems in this integrated manner remains largely unknown.

Understanding these initial orientations has practical importance for curriculum design. If students already recognize Indigenous knowledge as legitimate, educational interventions may need to focus less on changing attitudes and more on developing analytical reasoning, ethical collaboration, and entrepreneurial capability. Conversely, if students initially privilege formal engineering knowledge while dismissing community expertise, different pedagogical strategies would be required. Measuring students' cognitive defaults therefore provides an empirical foundation for designing, evaluating, and improving Indigineering pedagogies.

This study introduces the Indigineering Cognitive Defaults Questionnaire (ICDQ), a scenario-based questionnaire designed to measure students' initial epistemic framing at the intersection of Indigenous knowledge, engineering, and entrepreneurship. Using baseline data collected from 200 first-year engineering students from the University of ANONYNOUS prior to instruction, we examine the distribution of cognitive defaults, explore whether distinct cognitive profiles emerge, investigate demographic and experiential correlates, and evaluate competing models describing relationships among Indigenous knowledge, engineering, and entrepreneurial orientations.

This paper makes four contributions to engineering education research. First, it conceptualizes cognitive defaults as an epistemic construct describing students' initial engineering problem framing rather than their attitudes, intentions, or perceived abilities. Second, it introduces the ICDQ as a scenario-based questionnaire designed to measure these defaults. Third, it provides initial evidence regarding the psychometric properties and construct validity of the questionnaire. Finally, it offers one of the first empirical descriptions of baseline epistemic orientations among first-year engineering students, providing evidence that can inform culturally responsive engineering education and future Indigineering interventions.

Finally, the study addresses the following research questions:

RQ1. What cognitive default orientations do first-year engineering students bring toward Indigenous knowledge, engineering reasoning, and entrepreneurship, and do these orientations form interpretable profiles?

RQ2. How do demographic and experiential factors, including childhood setting, gender, and prior entrepreneurship exposure, relate to cognitive default orientations?

RQ3. Are relationships among Indigenous knowledge, engineering, and entrepreneurial defaults better explained by sequential mediation or by additive contributions?

2. Theoretical Framework

2.1 Cognitive Defaults as Initial Epistemic Framing

Engineering design begins long before students perform calculations, select materials, or generate solutions. The first step in any engineering activity is defining the problem, determining which knowledge sources are relevant, identifying legitimate stakeholders, and deciding which forms of evidence deserve consideration. These early judgments shape every subsequent stage of engineering reasoning. Yet engineering education research has devoted far greater attention to students' knowledge, motivation, self-efficacy, and design performance than to the initial epistemic processes through which students determine what counts as engineering knowledge.

This study conceptualizes these early judgments as cognitive defaults. Cognitive defaults are the immediate epistemic framing tendencies that students employ when encountering an engineering situation before extended analysis or formal instruction. They represent students' initial assumptions regarding where useful knowledge resides, which actors should be consulted, what constitutes credible evidence, and which solution pathways appear plausible.

This conceptualization draws inspiration from dual-process theories of cognition (Evans, 2008; Kahneman, 2011), which distinguish rapid intuitive processing from slower deliberative reasoning. However, cognitive defaults are not simply fast decisions. Rather, they are epistemic orientations that influence how engineering problems are framed before analytical reasoning begins. Two students may possess identical technical knowledge yet approach the same community engineering challenge differently because they begin with different assumptions about whose knowledge matters and how engineering problems should be understood.

Accordingly, cognitive defaults differ from several constructs commonly measured in engineering education. Self-efficacy concerns perceived capability to perform engineering tasks (Mamaril et al., 2016). Motivation reflects willingness to engage in learning (Jones, 2009). Entrepreneurial intentions concern future behavioral aspirations (Liñán & Chen, 2009). Cognitive defaults instead capture students' immediate epistemic framing of engineering situations. They therefore provide insight into the cognitive starting points from which engineering reasoning develops.

2.2 Engineering as an Epistemic Practice

Understanding cognitive defaults requires recognizing that engineering is fundamentally an epistemic activity rather than merely a technical one. Engineers continuously decide what information is relevant, which forms of evidence are trustworthy, how uncertainty should be managed, and whose expertise should inform design decisions. Engineering knowledge therefore emerges through the interaction of analytical reasoning, professional judgment, stakeholder engagement, and contextual understanding rather than through the application of universal technical rules alone.

Engineering education scholars have long emphasized that engineering design is an iterative process of constructing, evaluating, and refining knowledge under conditions of uncertainty (Atman et al., 2007; Bucciarelli, 1994; Dym et al., 2005). Design thinking similarly requires integrating technical analysis with social, economic, environmental, and contextual considerations (Cross, 2006).

Consequently, engineering education is not simply concerned with teaching technical procedures but with developing students' capacity to recognize and integrate multiple forms of legitimate knowledge during problem solving.

This perspective is particularly relevant within community-based and culturally responsive engineering education. Engineering problems situated within communities frequently require students to reason across formal engineering knowledge, local experience, practical expertise, and stakeholder priorities. The challenge is therefore not whether Indigenous knowledge exists but whether students recognize it as potentially legitimate engineering knowledge worthy of systematic analysis.

2.3 Indigineering as an Epistemic Integration Framework

The Indigineering framework provides a conceptual model for understanding how multiple knowledge systems contribute to engineering innovation. Rather than positioning Indigenous knowledge and engineering as competing epistemologies, Indigineering views them as complementary sources of knowledge that can be integrated through engineering analysis and entrepreneurial action.

Within this framework, Indigenous knowledge contributes situated understanding of communities, environments, materials, and long-standing productive practices (Agrawal, 1995; Dei, 2000). Engineering contributes analytical reasoning, experimentation, modeling, design, and technological transformation. Entrepreneurship contributes opportunity recognition, resource mobilization, value creation, and pathways for translating engineering solutions into sustainable community impact (Baron, 2006; Mitchell et al., 2002).

Importantly, these three dimensions should not be viewed as sequential stages of innovation. Effective engineering innovation often requires students to move iteratively among community knowledge, engineering analysis, and entrepreneurial reasoning throughout the design process. Consequently, the framework predicts that students may possess strengths in one dimension while exhibiting weaker orientations in others, making it important to examine how these orientations coexist rather than assuming they naturally develop together.

2.4 Operationalizing Cognitive Defaults

The theoretical framework implies that students' initial responses to authentic engineering scenarios provide observable evidence of underlying epistemic orientations. Scenario-based assessment is particularly appropriate because it presents realistic situations requiring respondents to select an immediate course of action rather than report abstract attitudes or socially desirable beliefs.

Accordingly, the Indigineering Cognitive Defaults Questionnaire (ICDQ) is proposed to empirically measure cognitive defaults across four theoretically derived domains: (1) Indigenous knowledge legitimacy, (2) engineering transformation, (3) entrepreneurial orientation, and (4) integration and co-creation. Each item presents an authentic engineering situation with multiple plausible responses. Rather than identifying universally correct answers, the instrument identifies responses aligned with the theoretical assumptions of the Indigineering framework regarding knowledge legitimacy, analytical reasoning, entrepreneurial opportunity, and ethical collaboration.

The ICDQ therefore should not be interpreted as a measure of engineering competence or technical ability. Instead, it measures students' initial epistemic framing, the cognitive orientations they bring to engineering problems before formal instruction, deliberate reflection, or extended design activity. These initial orientations provide a baseline for understanding how engineering education may subsequently influence students' ways of knowing, reasoning, and innovating.

3. Research Hypotheses

The theoretical framework conceptualizes cognitive defaults as students' initial epistemic framing when approaching engineering problems situated at the intersection of Indigenous knowledge, engineering reasoning, and entrepreneurship. Because these orientations represent different dimensions of engineering reasoning rather than a single continuum, they are expected to vary independently across students and produce distinct patterns of problem framing. The following hypotheses examine these expectations.

Cognitive Default Profiles

If students enter engineering programs with different epistemic orientations toward knowledge legitimacy, engineering analysis, and entrepreneurial opportunity, their responses should form coherent cognitive profiles rather than random combinations of item selections. These profiles would reflect different ways of initially framing engineering problems.

H1. Students' cognitive defaults will form interpretable cognitive profiles characterized by distinct combinations of Indigenous knowledge, engineering, and entrepreneurial orientations.

Indigenous Knowledge Legitimacy

Indigineering proposes that Indigenous knowledge constitutes a legitimate source of engineering knowledge rather than simply cultural background. In Ghana, Indigenous knowledge is embedded within community practices, everyday technologies, family traditions, and informal production systems. Consequently, recognition of Indigenous knowledge may function as a broad cultural orientation rather than being determined solely by rural upbringing or direct exposure.

H2. Indigenous knowledge legitimacy will be widely shared across students and will not differ substantially by childhood setting.

Analytical Engineering Defaults

Recognizing Indigenous knowledge as legitimate does not necessarily imply that students naturally approach community practices analytically. Engineering analysis requires abstraction, modeling, measurement, experimentation, and systematic reasoning that students may not yet have developed before formal engineering instruction.

Accordingly, students are expected to display stronger defaults toward recognizing Indigenous knowledge than toward analytically transforming that knowledge through engineering reasoning.

H3. Students will demonstrate stronger Indigenous knowledge legitimacy defaults than analytical engineering defaults.

Entrepreneurship and Opportunity Framing

Entrepreneurship within the Indigineering framework extends beyond venture creation to include recognizing opportunities for community improvement through engineering innovation. Students with stronger Indigenous knowledge and engineering orientations should therefore be more likely to recognize entrepreneurial possibilities embedded within local contexts.

H4. Students with stronger Indigenous knowledge and engineering defaults will exhibit stronger entrepreneurial orientations.

Gender and Cognitive Defaults

Prior research has generally found that gender differences in engineering education are more consistently associated with technical confidence, participation, and engineering identity than with broad cultural orientations. Consequently, any gender differences are expected to emerge primarily within engineering reasoning rather than Indigenous knowledge legitimacy.

H5a. Gender will not significantly predict Indigenous knowledge legitimacy defaults.

H5b. Gender differences, if present, will be more likely to occur within analytical engineering defaults than Indigenous knowledge legitimacy.

Relationships Among the Three Pillars

The Indigineering framework conceptualizes Indigenous knowledge, engineering reasoning, and entrepreneurship as complementary dimensions of engineering innovation rather than a fixed developmental sequence. Students may therefore exhibit strengths in one dimension without necessarily exhibiting comparable strengths in another. This perspective predicts that Indigenous knowledge and engineering reasoning contribute independently to entrepreneurial orientation rather than operating through a strictly sequential pathway.

H6. Indigenous knowledge and engineering orientations will independently predict entrepreneurial orientation, whereas the relationship between Indigenous knowledge and entrepreneurship will not be fully mediated through engineering orientation.

Research Questions

The study addresses the following research questions.

RQ1. What cognitive default orientations do first-year engineering students bring toward Indigenous knowledge, engineering reasoning, and entrepreneurship, and do these orientations form interpretable cognitive profiles?

RQ2. How are cognitive defaults associated with demographic and experiential characteristics, including childhood setting, gender, and prior entrepreneurship exposure?

RQ3. Are relationships among Indigenous knowledge, engineering, and entrepreneurial defaults better explained by additive or sequential models?

4. Method

4.1 Research Design

This study employed a cross-sectional baseline survey design to examine first-year engineering students' cognitive defaults prior to any formal instruction in Indigineering. The study represents the first phase of a broader research program investigating how engineering education influences students' epistemic orientations toward Indigenous knowledge, engineering reasoning, and entrepreneurship. The baseline administration provides an opportunity to examine students' initial epistemic framing before classroom experiences, instructional interventions, or structured reflection may influence their responses.

4.2 Context and Participants

Participants were 200 first-year engineering students enrolled in an introductory engineering course at a large public university of ANONYMOUS. Students completed the survey before receiving any instruction related to Indigenous knowledge, engineering design, entrepreneurship, or the Indigineering framework, thereby ensuring that responses reflected baseline orientations rather than instructional effects.

Of the 308 survey openings recorded on Qualtrics, and 200 responses were completed. The sample consisted of 135 male students (67.5%) and 65 female students (32.5%). Students represented diverse childhood settings, including rural communities, small towns, medium-sized cities, and large metropolitan areas. Additional demographic characteristics, previous engineering exposure, Indigenous knowledge familiarity, entrepreneurial experience, financial constraints, and career aspirations are presented in Table 2.

All participants provided informed consent. Individual identifiers were collected solely to permit future longitudinal matching and were removed prior to analysis. All analyses reported in this study used de-identified data.

4.3 Instrumentation

Indigineering Cognitive Defaults Questionnaire (ICDQ)

The ICDQ was developed specifically for this study to measure students' initial epistemic framing when confronted with engineering situations involving Indigenous knowledge, engineering reasoning, and entrepreneurship. Rather than measuring attitudes, perceived competence, or behavioral intentions, the instrument captures students' immediate problem-framing orientations before extended deliberation.

The instrument contains 13 scenario-based items organized into four domains:

- Indigenous knowledge legitimacy (Q1–Q4)
- Engineering transformation (Q5–Q7)
- Entrepreneurial orientation (Q8–Q10)
- Integration and co-creation (Q11–Q13)

Items are presented in the Appendix. Prior to deployment, the authors conveyed a panel of expert to review the items, and corrections were made based on the feedback received.

Participants were instructed to respond rapidly by selecting the option that felt most natural rather than the answer they believed instructors would prefer. This instruction was intended to elicit initial epistemic framing rather than reflective reasoning.

Responses aligned with the Indigineering framework were coded as one, with alternative responses coded as zero. Composite Indigenous Knowledge (IK), Engineering (ENG), and Entrepreneurial (ENT) indices were created by summing aligned responses within each domain. Because the ICDQ measures distinct epistemic orientations rather than a single latent construct, interpretation focuses primarily on item-level and domain-level patterns rather than overall scale scores.

Motivation

Academic motivation was measured using the MUSIC Model of Academic Motivation (Jones, 2009). The instrument measures empowerment, usefulness, success, interest, and caring using six-point Likert scales. The MUSIC instrument was included to provide convergent validity evidence by examining relationships between cognitive defaults and students' broader motivational orientations.

Entrepreneurial Competencies

Entrepreneurial competencies were assessed using an adapted version of Morris et al.'s (2013) competency framework. Because survey-length considerations required item reduction, two representative items were retained for each competency. Preliminary analyses indicated inconsistent reliability for individual competency subscales; therefore, only the overall competency composite was used for subsequent analyses.

Demographic Variables

Demographic measures included gender, age, childhood setting, region of origin, prior engineering exposure, Indigenous knowledge familiarity, local practice exposure, entrepreneurship experience, financial constraint, migration history, and career aspirations. These variables were examined as potential correlates of cognitive default orientations.

4.4 Data Collection

Data were collected electronically using Qualtrics during regularly scheduled class sessions before instruction began. Participation was voluntary and had no influence on course grades. Students completed the survey in approximately 20–25 minutes.

To minimize social desirability and reflective reasoning, the cognitive-default scenarios appeared before all motivational and demographic measures.

4.5 Data Analysis

Data analysis was conducted in multiple steps. First, descriptive statistics and one-sample binomial tests examined whether theory-aligned responses occurred more or less frequently than expected by chance. Second, k-means cluster analysis explored whether students formed distinct cognitive profiles

based on their default orientations. Third, demographic and experiential differences were examined using chi-square tests, Kruskal–Wallis tests, logistic regression, and ordinary least squares regression where appropriate. Fourth, convergent validity evidence was examined through correlations with academic motivation and entrepreneurial competency measures. Finally, competing theoretical models describing relationships among Indigenous knowledge, engineering, and entrepreneurial orientations were evaluated using correlation analysis, multiple regression, and bootstrapped mediation analysis. To assess robustness, all analyses were repeated for the full sample and for the two authorization subgroups. Because results were substantively consistent across samples, findings are reported primarily for the full sample ($N = 200$).

Results

Preliminary Psychometric Evidence

Table 3 reports reliability estimates for the MUSIC subscales and the entrepreneurial competencies composite. Four of the five MUSIC subscales showed acceptable to excellent internal consistency: usefulness ($\alpha = .91$), caring ($\alpha = .88$), success ($\alpha = .85$), and interest ($\alpha = .80$). Empowerment was weaker ($\alpha = .62$), suggesting that this dimension may not function identically in this context. The overall MUSIC composite remained acceptable ($\alpha = .74$). The entrepreneurial competencies overall composite was strong ($\alpha = .92$), even though the individual two-item subscales varied widely, which supports using the overall score only.

Table 3 *Scale Reliability and Descriptive Statistics ($N = 200$)*

Scale	Items	α	M	SD	r with overall
MUSIC Empowerment	5	.62	4.43	0.72	.58
MUSIC Usefulness	5	.91	5.33	0.66	.76
MUSIC Success	4	.85	5.15	0.68	.75
MUSIC Interest	6	.80	4.82	0.70	.77
MUSIC Caring	6	.88	5.34	0.61	.65
MUSIC Overall	26	.74 ^a	5.02	0.46	
ENT Competencies Overall	28	.92	4.61	0.60	

Note. ^a Alpha computed treating five subscale means as items in a general motivation scale. MUSIC subscale descriptives based on $n = 176$ with complete MUSIC data; ENT competencies based on $n = 176$.

RQ1: Distribution and Profiles of Cognitive Defaults

Table 4 reports the proportion of students selecting the theory-aligned response for each cognitive default item, with one-sample binomial tests against chance responding (.25). Ten of the 13 defaults differed significantly from chance. IK defaults were consistently above chance: 80% of students prioritized people with local experience as a first knowledge reference (Q2, $p < .001$), 76% ranked improving an existing local practice among their top two starting points for a business idea (Q3, $p < .001$), and 66% chose community consultation as their first response to a local problem (Q1, $p < .001$). The undervalued-domain default (Q4, 45%) and the engineering exploration default (Q5, 68%) were also above chance. Entrepreneurial defaults were more mixed: 63% chose venture noticing based on regular dependence (Q9, $p < .001$), 59% chose local retention (Q10, $p < .001$), and 39% prioritized decent-work stability (Q8, $p < .001$).

Three defaults were at or below chance. The fusion default (Q11, 29%) did not differ significantly from chance ($p = .253$). The analytical engineering default (Q6, 14%) and the co-creation ethics default (Q13, 13%) were both well below chance (both $p < .001$), indicating that these orientations were not simply uncommon but actively disfavored in first-response terms. The engineering tool-adaptability default (Q7, 19%) was marginally below chance ($p = .050$).

Table 4 *Cognitive Default Proportions With Binomial Tests ($N = 200$)*

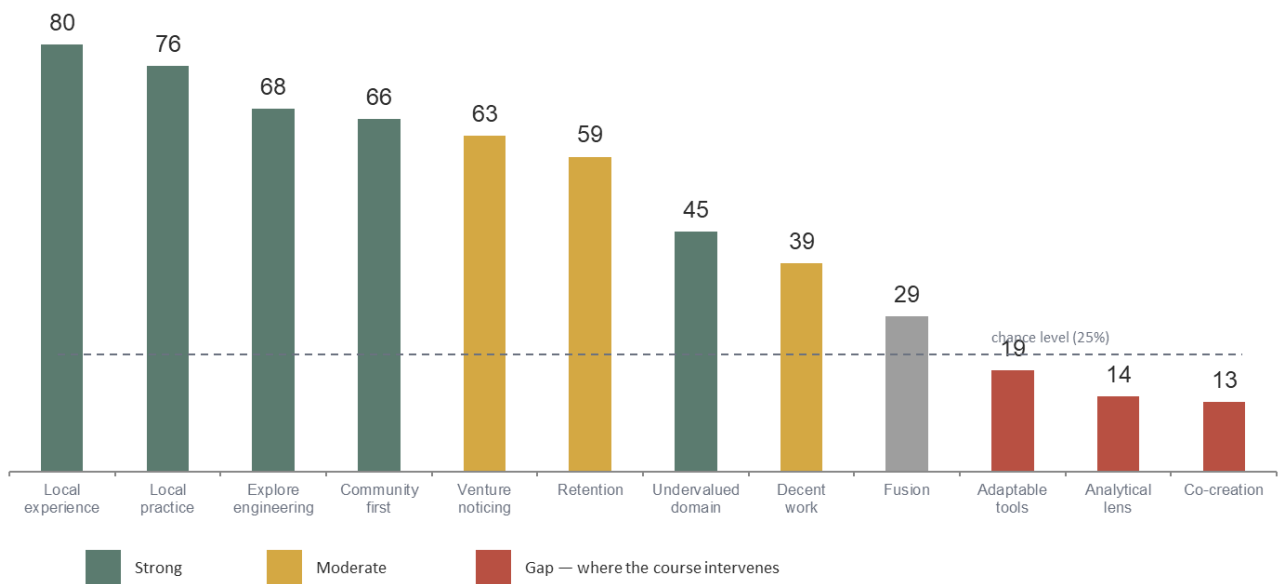
Item	Pillar	n	% Aligned	p	Direction
Q2: Local experience first	IK	200	80%	<.001	Above chance
Q3: Local practice top 2	IK	200	76%	<.001	Above chance
Q5: Explore engineering ideas	ENG	200	68%	<.001	Above chance
Q1: Community first	IK	200	66%	<.001	Above chance
Q9: Venture noticing	ENT	200	63%	<.001	Above chance
Q10: Local retention	ENT	200	59%	<.001	Above chance
Q4: Undervalued domain	IK	200	45%	<.001	Above chance
Q8: Decent work	ENT	200	39%	<.001	Above chance
Q11: Fusion (all pillars)	Cross	200	29%	.253	At chance

Q10: Migration default	ENT	200	23%	.463	At chance
Q7: Adaptable tools	ENG	200	19%	.050	Below chance
Q6: Analytical lens	ENG	200	14%	<.001	Below chance
Q13: Co-creation early	Ethics	200	13%	<.001	Below chance

All analyses were conducted in Stata 16.0. The present paper reports initial instrument evidence rather than final validation. That positioning follows the Standards for Educational and Psychological Testing, which treat validation as an accumulation of evidence for score interpretation and use rather than as a one-time property of an instrument (AERA, APA, & NCME, 2014), and it responds to broader concerns that STEM education studies often report psychometric evidence too narrowly (Maric et al., 2023). To assess robustness, each analysis was run on the individual-publication-authorization sample ($n = 130$), the aggregate-authorization sample ($n = 70$), and the full population ($N = 200$). Results are reported for the full population unless otherwise noted. For RQ1, we used one-sample binomial tests against a chance probability of .25, non-parametric tests for ranking items, and k-means clustering on the 11 binary default indicators used for profiling. For RQ2, we used chi-square tests, Kruskal-Wallis tests, and logistic or OLS models with demographic controls as appropriate. For RQ3, we estimated bivariate correlations, OLS path models, and a bootstrapped indirect-effect test. Convergent validity was examined through correlations with the MUSIC overall composite and the entrepreneurial competency composite.

Ranking data reinforced these patterns. When asked to rank starting points for a business idea (Q3), “improving an existing local practice” received a mean rank of 1.85 (where 1 = first choice), significantly lower than all alternatives (Kruskal-Wallis $\chi^2 = 109.5$, $p < .001$). When ordering problem-solving steps (Q12), “observe/ask what people currently do” received a mean rank of 1.46, again strongly preferred as the first step ($\chi^2 = 241.5$, $p < .001$).

Figure 1 Cognitive default alignment proportions. The dashed line indicates chance-level responding (25%). Error bars represent 95% confidence intervals.

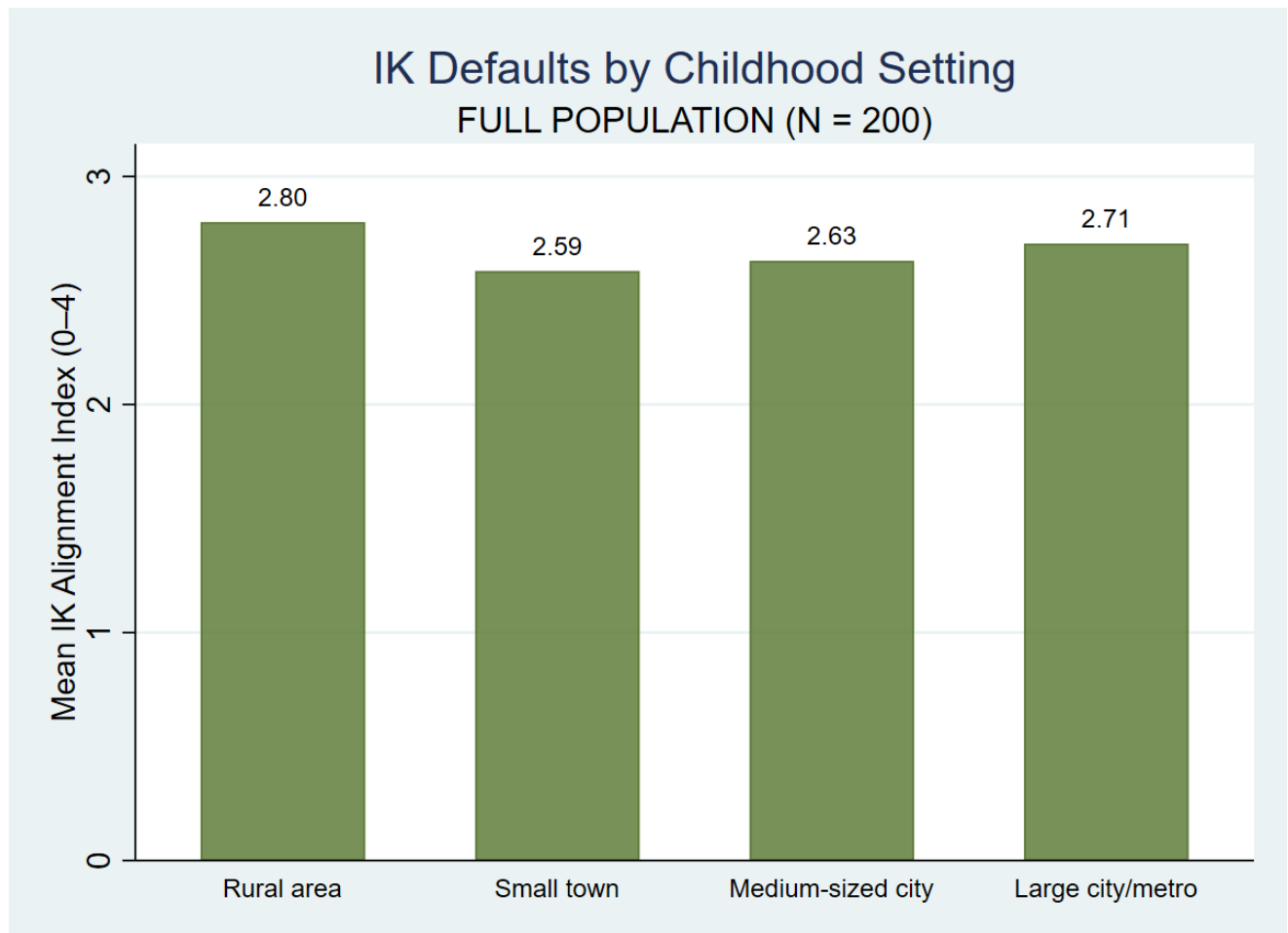


RQ2: Demographic and Experiential Correlates

Childhood Setting and IK Defaults

Contrary to H3, IK default alignment did not vary by childhood setting. Mean IK index scores were very similar across upbringing categories: rural ($M = 2.80$, $SD = 1.01$), small town ($M = 2.59$, $SD = 1.00$), medium-sized city ($M = 2.63$, $SD = 1.10$), and large city ($M = 2.71$, $SD = 1.05$). The Kruskal-Wallis test was nonsignificant ($\chi^2 = 0.85$, $p = .837$). Neither local practice exposure nor self-reported indigenous-practice familiarity predicted IK defaults in models with controls. The same null pattern appeared across all three analytical samples, which is more consistent with IK legitimacy operating as a broad cultural orientation than as a simple consequence of rural lived experience.

Figure 2 Mean IK index by childhood setting. Error bars represent 95% confidence intervals. No significant differences were observed across upbringing categories ($p = .837$).



Gender and Cognitive Defaults

H4a was not supported: 49% of male students and 37% of female students chose everyday household domains on the undervalued-domain item (chi-square = 2.54, $p = .111$). No gender differences were observed on the IK default items, which is consistent with H4b. However, an exploratory gender pattern emerged on the analytical engineering default (Q6). Male students were more likely than female students to adopt the analytical lens (19% vs. 3%, chi-square = 9.54, $p = .002$), and female gender remained a negative predictor in the controlled logistic model (OR = 0.13, $p = .006$). The gender difference in this dataset therefore appears to be located in analytical framing rather than in IK legitimacy.

Entrepreneurship Exposure and Venture Cognition

Prior entrepreneurship exposure was associated with venture cognition, but not in the predicted direction. Students without meaningful entrepreneurship exposure were more likely to notice venture potential in local practices (79% vs. 60%, chi-square = 4.71, $p = .030$) and more likely to consider migration (41% vs. 19%, chi-square = 8.14, $p = .004$). These patterns remained after controlling for financial constraint. Rather than indicating lower entrepreneurial capacity among the exposed group, the pattern may suggest that exposure calibrates first-response optimism by making barriers and risks more salient.

Student Profiles

K-means clustering of the 11 binary cognitive defaults produced two- and three-cluster solutions that were interpretable across all three samples. The two-cluster solution split the cohort roughly in half, with the retention default (Q10) functioning as the strongest discriminator. Cluster 1 ('Retention-Ready') combined strong IK defaults, high engineering exploration, and near-universal local retention. Cluster 2 ('Mobile/Uncertain') showed similar IK legitimacy but much weaker retention and somewhat weaker engineering exploration. The three-cluster solution added a smaller 'Disengaged' group characterized by lower IK defaults, low engineering exploration, and somewhat higher co-creation responses. These patterns suggest that the cohort was not homogeneous even where aggregate IK legitimacy was strong.

Table 5 *Cluster Centroids for Two- and Three-Cluster K-Means Solutions (N = 200)*

Panel A: Two-Cluster Solution

Default Item	Cluster 1	Cluster 2	Overall	Interpretation
<i>Cluster size (n)</i>	122 (61%)	78 (39%)	200	
Q1: Community first (IK)	.86	.35	.66	Strong diff
Q2: Local experience (IK)	.96	.55	.80	Strong diff
Q4: Undervalued domain (IK)	.61	.19	.45	Strong diff
Q5: Explore engineering (ENG)	.84	.41	.68	Strong diff
Q6: Analytical lens (ENG)	.13	.15	.14	No diff
Q7: Adaptable tools (ENG)	.16	.24	.19	No diff
Q8: Decent work (ENT)	.43	.32	.39	Modest diff
Q9: Venture noticing (ENT)	.75	.44	.63	Strong diff
Q10: Retention (ENT)	.75	.33	.59	Key discriminator
Q11: Fusion (Cross)	.33	.22	.28	Modest diff

Q13: Co-creation (Ethics)	.10	.18	.13	Reversed
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Note. Cluster 1 = “Retention-Ready”: high IK, high engineering exploration, strong retention. Cluster 2 = “Mobile/Uncertain”: lower IK, lower engineering exploration, lower retention but similar analytical lens and co-creation. The retention default (Q10) is the primary discriminator between clusters. Cluster solution quality was assessed via the Calinski-Harabasz pseudo-F criterion: k = 2, pseudo-F = 27.78; k = 3, pseudo-F = 22.88; k = 4, pseudo-F = 18.45. The two-cluster solution (k = 2) returned the highest pseudo-F, indicating the best-fitting partition.

Panel B: Three-Cluster Solution

Default Item	Cl. 1	Cl. 2	Cl. 3	Overall	Pattern
<i>Cluster size (n)</i>	92 (46%)	61 (31%)	47 (24%)	200	
Q1: Community first	.84	.21	.89	.66	Cl.2 low
Q2: Local experience	.96	.51	.87	.80	Cl.2 low
Q4: Undervalued domain	.57	.10	.68	.45	Cl.2 very low
Q5: Explore eng.	.85	.43	.66	.68	Cl.2 low
Q6: Analytical lens	.13	.20	.09	.14	Flat
Q7: Adaptable tools	.15	.26	.17	.19	Cl.2 slightly high
Q8: Decent work	.42	.33	.38	.39	Flat
Q9: Venture notice	.76	.48	.57	.63	Cl.1 high
Q10: Retention	1.00	.43	.00	.59	Key discriminator
Q11: Fusion	.32	.25	.28	.28	Flat
Q13: Co-creation	.11	.16	.13	.13	Flat

Note. Cluster 1 = “Retention-Ready” (100% retention): strong across IK, ENG exploration, and ENT. Cluster 2 = “Disengaged”: low IK defaults (21 – 51%), low engineering exploration (43%), moderate retention (43%). Cluster 3 = “Mobile Aligned”: strong IK (87 – 89%) but 0% retention; moderate

ENT. The three-cluster solution splits the two-cluster “Mobile/Uncertain” group into those who value IK but not retention (Cl. 3) and those who are disengaged across all pillars (Cl. 2).

RQ3: Additive Rather Than Sequential Structure

Table 6 reports the bivariate correlations among the three default indices and the OLS models predicting entrepreneurial orientation. IK alignment was positively associated with ENT alignment ($r = .156$, $p = .028$), and ENG alignment was also positively associated with ENT alignment ($r = .137$, $p = .054$, reaching significance in the multivariable model). By contrast, IK did not predict ENG ($r = -.026$, $p = .716$). This pattern was consistent across the three analytical samples. The absence of an IK-ENG association does not prove that no small sequential relationship exists, but it does weigh against a strong sequential pathway in this dataset. A formal bootstrapped mediation test supported that reading: the indirect effect was $b = -.003$, 95% CI $[-.024, .015]$, which spans zero.

In the full OLS model, the ENT index was predicted independently by both IK ($\beta = .126$, $p = .035$) and ENG ($\beta = .193$, $p = .031$), with engineering exposure also contributing positively ($\beta = .205$, $p = .011$). The model explained 11.5% of the variance ($R\text{-squared} = .115$). Given the discrete nature of the indices, this is a modest explanatory model, but the pattern is nevertheless more consistent with additive contributions than with a staged mediation sequence.

Table 6 OLS Regression Analysis: Additive Effects of IK and ENG Orientation on Entrepreneurial Defaults ($N = 200$)

Panel A: Bivariate Correlations Among Default Indices

	IK Index	ENG Index	ENT Index
IK Index (0 – 4)	–		
ENG Index (0 – 3)	– .026	–	
ENT Index (0 – 3)	.156*	.137†	–

Note. * $p < .05$. † $p = .054$. $N = 200$ for all correlations.

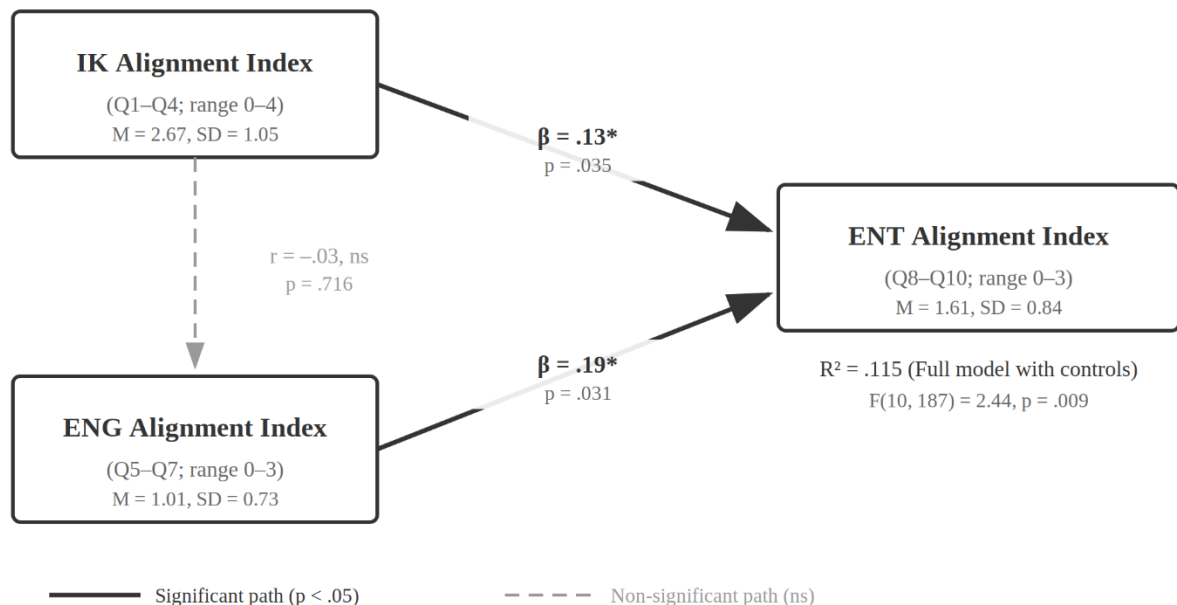
Panel B: OLS Regression of ENT Index on IK and ENG Indices With Controls

Predictor	β	SE	t	p	95% CI LL	95% CI UL
IK Index	.126	.059	2.12	.035	.009	.243
ENG Index	.193	.089	2.17	.031	.018	.368
Female	.076	.138	0.55	.581	– .196	.348

Age	– .022	.032	– 0.69	.491	– .085	.041
Upbringing: Small town	– .014	.241	– 0.06	.954	– .490	.462
Upbringing: Medium city	– .393	.240	– 1.64	.103	– .867	.080
Upbringing: Large city	– .323	.229	– 1.41	.160	– .776	.129
Local practice exposure	– .095	.080	– 1.20	.234	– .253	.062
Engineering exposure	.205	.080	2.56	.011	.047	.362
ENT exposure (any)	– .261	.165	– 1.58	.116	– .587	.065

Note. Outcome: ENT Index (0 – 3). N = 198 (2 cases with missing age). $R^2 = .115$, Adj. $R^2 = .068$, $F(10, 187) = 2.44$, $p = .009$. Reference category for upbringing = rural area. *Both IK and ENG indices are significant independent predictors, confirming the additive model.* The ENT index showed near-symmetric distribution (skewness = -0.097 , kurtosis = 2.325), supporting OLS over count or ordinal alternatives.

Figure 3 Path diagram illustrating the additive model. IK alignment and ENG alignment contribute independently to ENT orientation (solid arrows, $p < .05$). The dashed arrow from IK to ENG is nonsignificant ($p = .716$), ruling out sequential mediation.



Note. N = 200. Coefficients from OLS regression with demographic controls. * $p < .05$.

Convergent Validity Evidence

Course Motivation and Cognitive Defaults

The MUSIC overall composite was positively associated with the ENT index ($r = .25$, $p = .001$) but not with the IK index ($r = .05$, $p = .473$) or the ENG index ($r = -.05$, $p = .544$). In OLS regression, a one-unit increase in overall motivation predicted .48 additional ENT-aligned defaults ($t = 3.42$, $p = .001$, $R\text{-squared} = .063$). The association was directionally consistent across all three samples. This pattern is useful substantively as well as psychometrically: it suggests that entrepreneurial defaults are linked to students' broader motivational orientation in the course, whereas IK legitimacy is not simply a by-product of classroom motivation. This interpretation is consistent with broader work showing that motivation matters for participation and persistence in foundational engineering settings (Nelson et al., 2015).

Entrepreneurial Competencies and Convergent Validity

The entrepreneurial competency composite showed modest convergent validity with the ENT default index ($r = .24$, $p = .001$). Students who chose local retention also reported higher entrepreneurial competency scores on average ($M = 4.74$ vs. 4.45 , $t = 3.25$, $p = .001$). The IK index correlated weakly but significantly with the competency composite ($r = .19$, $p = .010$), whereas the ENG index did not. This suggests related but non-identical constructs: defaults capture first-response orientation, whereas competency scores capture self-reported capability.

Authorization-Group Sensitivity Check

To assess possible selection effects, we compared the 130 individual-publication-authorization respondents with the 70 aggregate-authorization respondents on the main variables. Only one of the 13 cognitive default items differed significantly across groups (Q6 analytical lens: 10% vs. 21%, $p = .026$), and none of the composite indices differed. The aggregate-authorization group reported lower overall motivation and lower entrepreneurial competency, which suggests a modest engagement difference, but the cognitive defaults themselves were strikingly similar. This supports the decision to treat the full population as the primary analytical sample while retaining the authorization split as a sensitivity check.

Table 7 *Master Correlation Matrix: Cognitive Default Indices, Motivation, Competencies, and Demographics*

Variable	1	2	3	4	5	6	7	8	9	10
1. IK Index	-									
2. ENG Index	-.03									
3. ENT Index	.16*	.14†								
4. MUSIC Overall	.05	-.05	.25**							

5. ENT Comp.	.19*	.06	.24**	.59**						
6. Female	- .11	- .14*	- .02	.09	.02					
7. Age	.12	.05	.03	.09	.12	- .20**				
8. Local Practice	.11	.06	.01	.03	.14†	- .03	.37**			
9. Indig. Familiarity	.13†	- .05	.02	.04	.13†	- .17*	.23**	.38**		
10. Eng. Exposure	.20**	.05	.17*	.32**	.27**	- .22**	.24**	.43**	.28**	
11. Fin. Constraint	.14*	.10	- .03	- .02	.07	- .11	.22**	.08	.12	.12

Note. N = 200 for default indices and demographics; N = 176 for MUSIC and ENT Competencies (complete cases). * $p < .05$. ** $p < .01$. † $p < .10$. IK Index = sum of Q1, Q2, Q3 (top 2), Q4 defaults (range 0 – 4). ENG Index = sum of Q5, Q6, Q7 defaults (range 0 – 3). ENT Index = sum of Q8, Q9, Q10 defaults (range 0 – 3). MUSIC Overall = mean of five MUSIC subscale means. ENT Comp. = overall mean of 28 Morris et al. competency items. Female coded 1 = female, 0 = male

Discussion

This study introduced an instrument intended to capture how first-year engineering students in Ghana initially orient themselves toward indigenous knowledge, engineering transformation, and entrepreneurship. Three findings are especially important for current debates on culturally responsive engineering education: the strong baseline legitimacy of IK, the weakness of analytical and ethical engineering defaults, and the more additive than sequential relationship among the three pillars.

What Students Bring Versus What the Course Must Build: The clearest contrast in the data is between strong IK legitimacy and weak analytical and ethical engineering defaults. Most students began from community knowledge, local experience, or the improvement of an existing practice. Far fewer instinctively adopted an analytical lens, treated tools as adaptable to uncertain local settings, or foregrounded co-creation ethics. This pattern matters pedagogically because it suggests that the major developmental work is not persuading students that local knowledge matters; it is helping them transform that recognition into analytical, design, and ethical practice. The finding also helps explain why decolonising or community-engaged engineering activities can remain demanding for students even when local relevance is high: legitimacy alone does not automatically produce analytical readiness or co-creative practice (Agrawal & Heydenrych, 2024; Harsh et al., 2017).

Indigenous Knowledge Legitimacy as a Cultural Orientation: The null relationship between childhood setting and IK defaults is one of the most consequential findings in the paper. In this cohort, valuing indigenous knowledge did not depend on growing up in a rural area or reporting stronger direct exposure to local productive practice. That finding cautions against equating IK with

rurality. It also supports a more nuanced view of culture in engineering education: knowledge legitimacy may circulate through national, familial, and community narratives in ways that are not captured by simple rural-urban distinctions (Handford et al., 2019; Secules et al., 2018). This reading is also consistent with work on epistemic politics showing that knowledge legitimacy is institutionally mediated, not merely geographically inherited (K'Akumu, 2024).

The MUSIC overall composite was positively associated with the ENT index ($r = .25$, $p = .001$) but not with the IK index ($r = .05$, $p = .473$) or the ENG index ($r = -.05$, $p = .544$). In OLS regression, a one-unit increase in overall motivation predicted .48 additional ENT-aligned defaults ($t = 3.42$, $p = .001$, $R\text{-squared} = .063$). The association was directionally consistent across all three samples. This pattern is useful substantively as well as psychometrically: it suggests that entrepreneurial defaults are linked to students' broader motivational orientation in the course, whereas IK legitimacy is not simply a by-product of classroom motivation. This interpretation is consistent with broader work showing that motivation matters for participation and persistence in foundational engineering settings and that motivational patterns can vary with pedagogy and gender in STEM classrooms (Nelson et al., 2015; Stolk et al., 2021).

Gender, Engineering, and the Feminine Economy: The gender findings also warrant a careful reading. Women in this cohort did not differ from men on IK legitimacy or on the undervalued-domain item, but they were substantially less likely to adopt the analytical engineering default. In practical terms, that suggests the immediate equity challenge is not cultural recognition but access to and confidence in analytical framing. A gender-responsive Indigineering pedagogy would therefore need to strengthen analytical participation without assuming that women require prior persuasion about the value of community knowledge. More broadly, the result is compatible with evidence that gendered differences in STEM classrooms are often mediated by pedagogy and participation structures rather than by stable deficits in interest or cultural orientation (Stolk et al., 2021).

The Entrepreneurship Exposure Paradox: The entrepreneurship-exposure pattern is best interpreted as a complication rather than a contradiction. Students with prior exposure may be responding less optimistically because they have seen more of the constraints surrounding venture creation. That possibility is consistent with entrepreneurship research showing that opportunity recognition depends not only on enthusiasm but also on the interpretive scripts through which uncertainty is read (Baron, 2006; Mitchell et al., 2002). It is also compatible with engineering entrepreneurship work suggesting that entrepreneurial learning difficulties can emerge from clashes among institutional, cultural, and opportunity-framing logics rather than from lack of creativity alone (Hagvall Svensson, 2023). Future work should test whether the effect persists once family business background, financial constraint, and career expectations are modeled together. That question matters because different explanations imply different pedagogical responses: a barrier-reading would call for stronger structural and mentoring support, whereas a familiarity-reading would call for more deliberate opportunity-framing work.

Implications for Engineering Education in Africa: The implications for engineering education in Africa are therefore specific rather than generic. If students already grant legitimacy to indigenous knowledge, curriculum work should focus less on symbolic recognition and more on the analytical,

participatory, and ethical capacities needed to work responsibly with that knowledge. This implication resonates with engineering and technology education scholarship arguing that indigenous perspectives should be embedded through concrete pedagogical design rather than appended rhetorically (Goldfinch et al., 2017; Blose & Gumbo, 2024; Ndlovu & Gumbo, 2024; Stephensen & Cunningham, 2024). Furthermore, successful integration depends on explicit epistemological framing, pedagogical models that let students reason across knowledge systems, and practical support for teachers navigating implementation constraints (Zinyeka et al., 2016; Onwu & Mufundirwa, 2020; Ogegbo & Ramnarain, 2024; Mlotshwa & Tsakeni, 2024). The present instrument may be useful in that broader agenda because it offers one way of measuring whether such pedagogical efforts are changing initial orientations rather than only self-reported attitudes.

Limitations: Several limitations should shape how the findings are interpreted. First, the study is cross-sectional and cannot support causal claims about how orientations develop. Second, the sample comes from one institution in Ghana, so broader generalization requires replication. Third, all measures rely on self-report, including scenario responses intended to capture first instincts. Fourth, the weaker performance of the MUSIC empowerment subscale suggests that some imported measures may require contextual adaptation. Finally, the platform count used to estimate survey non-completion may include duplicate openings, so attrition estimates should be treated as approximate.

Future Research: The next step is longitudinal rather than rhetorical. A post-course administration of the same instrument would allow the strongest test of whether the intervention shifts the low-baseline defaults identified here, especially analytical framing, tool adaptability, and co-creation ethics. Replication across institutions and countries would also help determine whether the present pattern is specific to this Ghanaian cohort or reflects a broader regional baseline. Future work could also pair the instrument with community-driven or decolonising engineering interventions so that shifts in defaults can be traced alongside changes in classroom design and student experience (Agrawal et al., 2022; Agrawal & Heydenrych, 2024). More generally, future work should treat the present paper as an opening measurement study and extend it through test-retest evidence, external validation, and richer mixed-method inquiry into how students explain their choices.

Conclusion

This paper offers a baseline portrait of how first-year engineering students in one Ghanaian context initially orient themselves toward indigenous knowledge, engineering, and entrepreneurship. The findings suggest that IK legitimacy is already strong, whereas analytical engineering and co-creation ethics are comparatively weak. They also suggest that entrepreneurial orientation is shaped by additive contributions from IK and engineering rather than by a clearly sequential pathway. These results provide initial support for the Indigineering Cognitive Defaults Instrument and identify a focused pedagogical challenge for culturally responsive engineering education: not whether students can recognize the value of local knowledge, but whether curricula can help them work with that knowledge analytically, ethically, and entrepreneurially.

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Appendix A Cognitive Default Instrument

This appendix presents the 13 cognitive default items administered in Part 1 of the survey instrument. Table A1 lists items in compact form with scenario text, response options, and theory-aligned coding (bold indicates the aligned response). Table A2 maps constructs to items, propositions, analyses, and validation evidence.

Instructions to participants: *"The following questions are designed to capture your first instinctive response. Answer quickly. Choose the option that feels most natural. Do not try to choose the 'best' or 'correct' answer. Do not overthink."*

Table A1 *Cognitive Default Items: Scenarios, Response Options, and Theory-Aligned Coding*

Item	Scenario / Prompt	Response Options (theory-aligned in bold)	Coding
Section A: Indigenous Knowledge (IK) – Legitimacy and Anchoring			
Q1	You must propose a solution idea in 2 minutes for a problem in your home	A. Search online for proven solutions B. Ask people from that community what they	1 if B

	region. Where do you start first?	already do and why C. Start from a standard engineering design/template D. Not sure	
Q2	The first place you'd look for ideas to improve productivity in a rural livelihood is:	A. Online videos or articles B. People with hands-on local experience in that livelihood C. Lecture notes or textbooks D. A peer who has seen "what works" in other regions	$1 \text{ if } B$
Q3	Rank your likely starting points for a business or solution idea (1 = first instinct):	• Improving an existing local practice you've observed • Adapting a solution from another country • Adapting a solution from a major city • Starting from a standard engineering design	$rank(local); top-2 = 1 \text{ if } rank \leq 2$
Q4	You need a locally grounded product idea with real users. Where do you instinctively look first?	A. Sectors with most investment/attention B. Everyday household/community activities few redesign C. Product category with strong demand signals D. A technical bottleneck you can improve	$1 \text{ if } B$
Section B: Engineering (ENG) – Transformation Self-Efficacy			
Q5	You observe a local practice used successfully for a long time. What is your first instinct?	A. Leave it as it is B. Explore how engineering could benefit from, build on, or improve it C. Identify where a modern alternative could outperform it D. Not sure	$1 \text{ if } B$
Q6	You are introduced to a traditional local system for the first time. Most natural way to make sense of it?	A. Understand its purpose and meaning in the community B. Watch real use and represent parts/relationships analytically C. Compare to similar systems you know D. Not sure	$1 \text{ if } B$
Q7	You are unsure whether standard engineering tools apply to a local practice. Your instinctive response?	A. Map constraints first before deciding if tools fit B. Engineering tools can be adapted with careful analysis C. Focus on user behavior/incentives first D. Not sure	$1 \text{ if } B$
Section C: Entrepreneurship (ENT) – Venture Confidence and Retention			

Q8	Two ideas could generate similar income. What's the first factor you instinctively check?	A. How fast it can start earning B. How stable or predictable the work and income would be C. Whether it creates strong differentiation D. Whether it has a proven replicable model	1 if B
Q9	You see a local solution that technically works. What do you first look for as a venture?	A. Whether it could work better technically B. Whether people depend on it regularly C. Whether a workable business model exists D. Not sure	1 if B
Q10	It's six months after graduation. The job market feels uncertain. Your first instinctive plan?	A. Apply broadly wherever opportunities are strongest B. Develop a solution/business from problems I understand from lived experience C. Prioritize a stable formal job search D. Build credentials first	RET=1 if B; MIG=1 if A
Section D: Fusion and Mechanism (Theory Tests)			
Q11	You have 90 seconds to sketch a solution approach. Which feels most natural?	A. Engineering design, then find a place to apply it B. Local practice, then engineer improvements C. Adoption/maintenance first, then design backward D. Context + engineering + adoption together	Strong=1 if D; Partial=1 if B
Q12	Drag into the order you'd instinctively do first (1st → 4th):	• Observe/ask what people currently do and why • Build a quick prototype or test improvement • Map how it could be adopted or sustained • Research how it's done in other countries	Align=1 if Obs=1st Proto=2nd
Q13	Your project uses know-how from a community practice. What do you instinctively do first?	A. Clarify idea internally first, then discuss credit later B. Discuss expectations for credit or benefits early C. Use existing guideline/template first, then talk with community D. Not sure	1 if B

Note. Theory-aligned responses shown in bold. All items use forced-choice format except Q3 and Q12 (ranking). Coding column shows binary scoring rule; all items coded 1 = theory-aligned, 0 = otherwise.

Table A2 Construct-to-Item Mapping With Baseline Results and Validation Evidence (N = 200)

Construct	Items	Pillar	Prop.	Analysis	Baseline Finding	Validation Evidence
IK legitimacy	Q1 – Q4	IK	P1	Binomial; KW	66 – 80% aligned; no urban/rural diff.	IK index: 3-sample null replication (KW $p = .84 - .96$); $r = .19$ with ENT comp. ($p = .010$)
ENG transformation	Q5 – Q7	ENG	P1 mech.	Binomial; χ^2	68% explore; 14% analytical; 19% adaptable	ENG index: identical across consent groups ($p = .940$); gender gap replicates 3 samples
ENT opportunity	Q3,Q9,Q10	ENT	P1, P4	Binomial; logistic	59 – 63% aligned; exposure paradox	ENT index: $r = .24$ with ENT competencies ($p = .001$); no consent bias ($p = .819$)
Decent work	Q8	ENT	P2	Binomial	39% stability-first (sig. above chance)	Replicates across all 3 samples ($p < .001$, .015, $< .001$)
Undervalued domains	Q4	IK	P3	χ^2 gender $\times$	45% aligned; no gender difference	Gender null replicates across all 3 samples ($p = .19, .36, .11$)
Retention vs. migration	Q10	ENT	P4	χ^2 ; logistic	59% retention; ENT exp. $\rightarrow$ lower migration	Migration $\times$ ENT exp. strengthens across samples ($p = .039, .046, .004$)
Fusion orientation	Q11 – Q12	Cross	Core	Binomial; KW	29% fusion (at chance); observe-first ($M = 1.46$)	Consistent at/near chance across all 3 samples
Co-creation ethics	Q13	Ethics	Bound.	Binomial	13% early discussion (below chance)	Full replication: $p < .001$, .046, $< .001$ across 3 samples

Note. P1 = IK as legitimate starting point. P2 = decent work alongside income. P3 = undervalued domains as innovation sites. P4 = local entrepreneurship supports retention. KW = Kruskal-Wallis. Prop. = proposition. Bound. = boundary condition. Validation evidence draws on three-sample replication (consent $n = 130$, aggregate-authorization $n = 70$, full population $N = 200$; see Appendix B) and convergent validity with entrepreneurial competency scales (Morris et al., $\alpha = .92$). Traditional reliability coefficients (α) are not reported for cognitive default items because they are single-item binary scenario responses measuring distinct cognitive orientations, not reflective scale items.

Appendix B: Three-Sample Replication Summary

This table summarizes key findings across the consent (n = 130), aggregate-authorization (n = 70), and full population (N = 200) samples. The replication column indicates whether findings are consistent across samples. Of the 22 principal findings, 18 replicate fully, 3 strengthen with larger sample size (a power effect), and 1 differs across authorization groups (Q6 analytical lens).

Finding	Full-authorization	Non-Cons.	Full Pop.	p (Cons.)	p (NC)	p (Full)	Replication
<i>Panel A: Cognitive Default Proportions (% theory-aligned; binomial test vs. $H_0 = .25$)</i>							
Q1: Community first	68%	63%	66%	< .001	< .001	< .001	✓ Full replication
Q2: Local experience	83%	74%	80%	< .001	< .001	< .001	✓ Full replication
Q4: Undervalued domain	48%	39%	45%	< .001	.028	< .001	✓ Full replication
Q5: Explore engineering	71%	61%	68%	< .001	< .001	< .001	✓ Full replication
Q6: Analytical lens	10%	21%	14%	< .001	.537	< .001	⚠ NC higher (21% vs 10%)
Q7: Adaptable tools	20%	17%	19%	.171	.177	.050	✓ Consistent below/at chance
Q8: Decent work	38%	39%	39%	< .001	.015	< .001	✓ Full replication
Q9: Venture noticing	59%	70%	63%	< .001	< .001	< .001	✓ Full replication

[illegible]

Venture noticing × ENT exp.	79%v60%	dir. consist.	79%v60%	p = .040	p = .434	p = .030	⚠ NC underpowered; full confirms
Migration × ENT exposure	41%v19%	dir. consist.	41%v19%	p = .039	p = .046	p = .004	✓ Strengthens across samples
Retention × ENT exposure				p = .697	p = .550	p = .430	✓ Consistent null
Panel E: Additive Model — IK and ENG as Independent Predictors of ENT							
IK → ENG (path a)	$\beta = -.03$	$\beta = .00$	$\beta = -.02$	p = .611	p = 1.00	p = .716	✓ Null: rules out mediation
IK → ENT (bivariate)	$\beta = .10$	$\beta = .19$	$\beta = .13$	p = .176	p = .065	p = .028	⚠ Strengthens with N
ENG → ENT (bivariate)	$\beta = .13$	$\beta = .23$	$\beta = .18$	p = .274	p = .086	p = .045	⚠ Strengthens with N
Joint model R ²				.024	.089	.044	✓ Consistent direction
Full model R ²				.148	.133	.115	✓ Similar explanatory power
IK in full model	$\beta = .10$	$\beta = .19$	$\beta = .13$	p = .154	p = .104	p = .035	✓ Direction consistent; sig in full
ENG in full model	$\beta = .13$	$\beta = .24$	$\beta = .19$	p = .276	p = .103	p = .031	✓ Direction consistent; sig in full

Eng. exposure control	$\beta=.23$	$\beta=.17$	$\beta=.20$	$p = .020$	$p = .297$	$p = .011$	✓ Consistent positive predictor
Panel F: Course Motivation and Cognitive Default Indices							
MUSIC → ENT index	$\beta=.50$	$\beta=.45$	$\beta=.48$	$p = .005$	$p = .094$	$p = .001$	✓ Robust across samples
MUSIC → IK index	$\beta=.30$	$\beta= -.40$	$\beta=.12$	$p = .156$	$p = .204$	$p = .473$	✓ Null; direction unstable
MUSIC → ENG index	$\beta= -.07$	$\beta= -.08$	$\beta= -.07$	$p = .612$	$p = .735$	$p = .544$	✓ Perfect null replication
Panel G: Convergent Validity and Consent-Group Comparison							
ENT comp. × ENT index	$r = .26$	$r = .22$	$r = .24$	$p = .005$	$p = .069$	$p = .001$	✓ Consistent across samples
ENT comp. × IK index	$r = .10$	$r = .18$	$r = .19$	$p = .268$	$p = .134$	$p = .010$	⚠ Strengthens with N
MUSIC overall (C vs NC)	5.09	4.89				$p = .004$	Consenters more motivated
ENT comp. (C vs NC)	4.72	4.41				$p = .001$	Consenters rate higher
IK index (C vs NC)	2.69	2.51				$p = .118$	✓ No selection bias
ENG index (C vs NC)	1.01	1.00				$p = .940$	✓ No selection bias
ENT index (C vs NC)	1.62	1.60				$p = .819$	✓ No selection bias

Note. ✓ = replicates across samples. ⚠ = strengthens with larger N or differs in one sample (explained by power). KW = Kruskal-Wallis. C = full-authorization sample; NC = non-full-authorization sample. Binomial tests in Panel A against $H_0: p = .25$. All cognitive default indices (IK, ENG, ENT) are free of authorization-group selection bias (Panel G, bottom three rows).

Replication Summary: Of the 22 principal findings reported in the main text, 18 replicate fully across all three samples. Three findings (IK → ENT, ENG → ENT, and gender × analytical lens) are directionally consistent across all samples but reach statistical significance only in the full population, a pattern consistent with the power limitations of the smaller subsamples. One finding (Q6 analytical lens proportion) differs across authorization groups: 10% in the full-authorization sample versus 21% in the non-full-authorization sample ($\chi^2 = 4.96$, $p = .026$). This is the only cognitive default item showing a significant authorization-group difference and may reflect a selection dynamic in which students who already think analytically were less inclined to consent to research use. The full-population estimate (14%) is the most representative. No composite index (IK, ENG, or ENT) differs across authorization groups, confirming that the primary constructs of interest are unbiased by the selection mechanism.