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The Influence of Epistemological Assumptions in Competence-Based Education on the Development of Engineering Knowledge and Professional Competencies in BTech Programmes in Rwanda

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Abstract: This study investigates how epistemological assumptions embedded in Competence-Based Education (CBE) frameworks influence the development of engineering knowledge and professional competence in Bachelor of Technology (BTech) programmes in Rwanda. Conducted at the first institution accredited to offer BTech programmes in Rwanda, the research provides a distinctive context for examining how such assumptions shape engineering education. Using a convergent mixed-methods design, the study analysed BTech curriculum documents, surveyed 169 participants—including 45 lecturers, 89 students and 22 industry stakeholders—and conducted semi-structured interviews with 25 key informants. The results revealed tensions between the behaviourist assumptions underlying CBE frameworks and the complex, holistic nature of engineering knowledge. Although 78.2% of lecturers reported that CBE frameworks provided clear learning outcomes, 63.4% were concerned that complex engineering knowledge was being reduced to measurable competencies. Document analysis identified four epistemological orientations: positivist, constructivist, critical and pragmatic. Positivist assumptions predominated in assessment frameworks (72.8%). Students performed better in practical competence (mean = 76.4%) than in theoretical understanding (mean = 58.7%), suggesting that current CBE implementation may prioritise procedural knowledge over conceptual depth. Industry stakeholders reported their highest satisfaction with graduates' practical skills (77.3%), while satisfaction was lower for professional judgement (54.5%) and ethical reasoning (52.3%). Reflective practice correlated strongly with intellectual autonomy ($r = 0.87$, $p < 0.001$). The study concludes that epistemological pluralism—the integration of multiple forms of knowing—is essential to the development of well-rounded engineering professionals. It recommends systematically integrating theoretical knowledge with practical competence, developing lecturers' understanding of epistemic cognition and strengthening industry– university collaboration in curriculum design and assessment.

Keywords: epistemological assumptions; competence-based education; BTech programmes; engineering education; Rwanda

1. INTRODUCTION

1.1 Background and Context

Rwanda's higher education landscape is undergoing a transformative shift with the introduction of the Bachelor of Technology (BTech) programme—a competence-based qualification that represents a fundamental departure from traditional knowledge-based engineering education. The Government of Rwanda, through the Ministry of Education, established the Rwanda Qualification Framework (RQF) by Ministerial Order No 003/MINEDUC/2021 of 20/10/2021, introducing BTech as a Level 8 qualification designed to graduate" highly competent individuals" with" strong technological and innovative ability to conceive, experiment, manipulate, prototype and deliver industrial concepts, products and services capable of catering to the evolving needs of society."

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As the first institution accredited to offer this programme, the study institution stands at the forefront of this educational revolution, implementing the Competence-Based Education (CBE) framework mandated by the Higher Education Council (HEC) and aligned with Rwanda's Vision 2050 (MINEDUC, 2020; REB, 2021). The BTech programme is designed for students who learn best by doing and provides a balance between theoretical and practical experiences by applying technological skills gained in the classroom to real-life environments.

Rwanda Polytechnic introduced BTech programmes in March 2023 starting with Automobile Technology and Construction Technology, hosted at IPRC Kigali and IPRC Huye respectively. Plans to scale up to five new BTech programmes—Manufacturing Technology, Wood Technology, Electrical Technology, Food Processing, and Information Technology—reflect the government's commitment to technical and vocational excellence.

The epistemological assumptions embedded in CBE frameworks profoundly shape how engineering knowledge is conceptualised, taught and assessed. Although CBE has been widely adopted in vocational and professional education, its epistemological foundations remain under-theorised and contested. Critics argue that CBE rests on behaviourist assumptions that reduce complex professional knowledge to observable, measurable competencies (Lum, 1999; Moretti & Marabini, 2025), whereas proponents contend that CBE offers a more authentic approach to professional preparation (Mulder, 2012; Wesselink et al., 2007).

The Rwandan context adds distinctive dimensions to this epistemological challenge. Since

2016, Rwanda has implemented a competence-based curriculum to prepare young people more effectively for life after school. A central aim has been to shift learning away from lecture-based instruction and rote memorisation towards practical capabilities such as problem-solving, collaboration, critical thinking and creativity. Nsengimana et al. (2021), however, emphasise the need to identify the conditions under which the intended science curriculum can be realised in classrooms.

1.2 Problem Statement and Research Gap

The implementation of CBE in engineering education in Rwanda occurs against a backdrop of significant epistemological tension. On one hand, CBE frameworks are designed to produce graduates with demonstrable competencies that meet industry needs. On the other hand, engineering practice requires complex, integrated knowledge that cannot be fully captured by behavioural competencies alone (Jamieson, 2021; Walther & Radcliffe, 2006). Furthermore, the Rwandan context—with its unique post-genocide reconstruction imperative, indigenous knowledge systems, and developmental aspirations—introduces additional dimensions to the epistemological challenge (Mushemeza & Mtebe, 2018; Yusuf, 2020).

Research on CBC implementation in Rwanda has identified several challenges: lack of updated resources (Mushemeza & Mtebe, 2018), insufficient collaboration with industry (Mushemeza & Mtebe, 2018), inconsistent application of CBA standards (Yusuf, 2020), limited instructor preparation in CBE pedagogy and epistemology, and tension between imported CBE frameworks and local educational traditions. Nsengimana et al. (2021) found that despite variations between teachers and schools in CBC implementation caused by differences in individual professional development and schools' capacity to innovate, results revealed high levels of appropriate CBC implementation in aspects of classroom interactions, teaching and learning activities, and assessment. However, a low implementation level was noticed in the aspect of science-in-society.

The Comprehensive Assessment Management Information System (CAMIS) has been introduced nationwide to support the integration of project-based learning into assessment and to track student performance in classwork and projects. However, stakeholders' capacity to interpret data from national systems and translate it into action remains limited. These systems can provide timely information to support adaptation and align incentives with improved educational outcomes, but their use in data-informed decision-making is still developing.

Research gap: Although previous research has examined challenges in implementing CBE in Rwanda (Nsengiyumva & Uwizeyimana, 2023; Mupenzi et al., 2021), little research has systematically investigated its epistemological foundations and their influence on engineering knowledge and professional competence. In particular, empirical evidence remains limited regarding how CBE frameworks shape students' engineering knowledge, how epistemological orientations relate to professional competence, and how imported CBE frameworks interact with the Rwandan context and indigenous knowledge systems.

This research addresses this gap by examining the BTech programme at the study institution, Rwanda's pioneer in BTech education.

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1.3 Research Questions

Primary Research Question: How do the epistemological assumptions underlying Competence-Based Education influence the development of engineering knowledge and professional competencies in BTech programmes in Rwanda?

Subsidiary Questions:

1. What epistemological assumptions are embedded in BTech curriculum documents,assessment frameworks, and teaching practices in Rwandan engineering education?
2. How do lecturers, students, and industry stakeholders understand and interpret ”competence” in engineering practice?
3. What forms of knowledge (theoretical, practical, experiential, contextual, and indigenous) are valued, integrated, and assessed within the BTech programme?
4. How do these epistemological foundations influence students’ ability to develop theintellectual autonomy and professional judgement required for engineering practice?

1.4 Research Objectives

1. To identify and analyse the epistemological assumptions embedded in BTech curriculum documents, assessment frameworks and teaching practices.
2. To explore how lecturers, students and industry stakeholders conceptualise and interpret ”competence” in engineering practice.
3. To examine the forms of knowledge valued and assessed within the BTech programme.
4. To investigate the influence of epistemological foundations on students’ intellectualautonomy and professional judgement.

2. LITERATURE REVIEW

2.1 Theoretical Framework

2.1.1 The Philosophical Foundations of Competence-Based Education

Competence-Based Education emerged from behaviourist learning theories, particularly the work of Tyler (1949) and Mager (1962), who conceptualised learning as the acquisition of observable, measurable behaviours. This approach assumes that learning objectives can be precisely specified, learning experiences can be systematically designed to achieve these objectives, competence can be measured through observable performance, and knowledge is reducible to discrete, measurable components.

However, this deterministic view has been fundamentally challenged by cognitive scientists, educational philosophers, and critical scholars who argue that professional competence is more complex, holistic, and context-dependent than behaviourist models suggest (Cairns & Malloch, 2024; Hodge et al., 2020).

2.1.2 The Epistemological Critique of CBE

Semantic Incoherence: Lum (1999) argues that CBE is not properly characterised by its focus on ”competence” but rather by its philosophically na¨ıve methodological strategy, which makes untenable assumptions about the relationship between statements of outcome and the epistemological constructs they are intended to represent.

The Capability vs. Competence Distinction: Cairns and Malloch (2024) contrast the narrow behaviourist-based perspectives of CBE with broader conceptions of ”capability,” arguing that the former fails to capture the complex, holistic nature of professional knowledge and practice.

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CBE as a Mechanism of Exclusion: Wheelahan (2007) argues that CBE in vocational education denies students access to ”powerful knowledge”—the abstract, conceptual knowledge that societies use to think ”the unthinkable” and ”the not-yet-thought.”

CBE and Social Pathology: Moretti and Marabini (2025) argue that CBE is internally incoherent, contributes to structural forms of oppression and injustice, fosters social pathologies, and fails to provide students with the intellectual autonomy they need as citizens of complex post-industrial societies.

2.1.3 The Hermeneutic Challenge

Hodge, Mavin, and Kearns (2020) introduce a crucial distinction between three interrelated components of CBE: competence, competency texts, and CBE systems. Their analysis reveals that CBE involves complex processes of interpretation that translate between these components—hermeneutic dimensions that are rarely acknowledged but are key to understanding persistent problems with the approach.

2.1.4 The Rogan and Grayson Framework

The Rogan and Grayson (2003) model provides a systematic framework for examining curriculum implementation, with particular reference to science education in developing countries. The model consists of three constructs:

1. **Profile of implementation** with four sub-constructs: classroom interaction, teaching and learning activities (with a focus on practical work), science in society, and assessment
2. **Profile of capacity to support innovation** with four sub-constructs: teacher factors, learner factors, physical resources, head teacher and school management
3. **Profile of outside influence:** external factors such as policy mandates and external support

This framework is particularly relevant to this study as it was used by Rogan and Aldous (2005) to investigate the Outcomes-Based Curriculum (OBC) implemented in South Africa, and both CBC and OBC focus on the product rather than process, with subtle differences in the description of outcomes and competences.

2.2 Epistemological Dimensions of Engineering Knowledge

Jamieson’s (2021) synthesis framework identifies three interconnected domains of knowledge required for engineering practice:

1. **Core Content Knowledge:** Fundamental engineering sciences, mathematics, and technical knowledge (positivist/realist orientation)
2. **Socio-Contextual Knowledge:** Understanding of engineering’s impact on society, sustainability, economics, and stakeholder needs (critical realist/relativist orientation)
3. **Metacognitive & Professional Skills:** Reflective practice, creativity, emotional intelligence, leadership, and communication (multiple orientations)

This framework challenges the narrow positivist orientation that dominates traditional engineering education and suggests that effective engineering education requires epistemic diversity.

Research on learning beliefs of engineering faculty and students reveals significant differences in how these groups conceptualise learning and learners. Compared to engineering undergraduates, instructors more strongly endorse process-oriented conceptions of learning such as self-regulation, active knowledge construction, dynamic ability, and social or collaborative learning. The student group shows more variance in their learning beliefs than the faculty group, suggesting a pedagogical alignment among faculty that does not exist for students. This highlights tensions that may arise as faculty and students engage
with new curricula, non-traditional pedagogies, or transformative learning approaches.

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2.3 Competence-Based Education in Rwanda

2.3.1 Policy Context

Rwanda's education reforms, particularly the introduction of Competence-Based Curriculum (CBC) and the BTech programme, are situated within the broader framework of Vision 2050 and the National Strategy for Transformation (NST1). These reforms aim to develop "highly competent individuals" with "strong technological and innovative ability" who can contribute to national development (MINEDUC, 2020; REB, 2021).

The Government of Rwanda recognises Technical and Vocational Education and Training

(TVET) as a central pillar of economic transformation and industrial development. The

RQF defines BTech as a qualification intended to develop highly competent graduates. Progression is measured through minimum and cumulative credit requirements, with 480 credits required for the BTech qualification.

A key initiative driving the shift toward competency-based education is efforts to embed formative assessment and project-based learning into the education system, where students engage in experiential activities and apply what they've learned in real-world settings. As one educator noted, "Instead of answering questions on paper, they might write a business plan or create a product. We have had students make exciting products like irrigation machines or walking canes for the visually impaired."

The Comprehensive Assessment Management Information System (CAMIS) supports the integration of project-based learning into assessment. The system tracks student performance on classwork and projects, helps roll out those projects, and then feeds data back to teachers, districts, and policymakers. To date, around 85% of teachers are registered on the system, and more than 660 million student scores have been entered.

2.3.2 Implementation Challenges

Research on CBC implementation in Rwanda has identified several challenges: lack of updated resources (Mushemeza & Mtebe, 2018), insufficient collaboration with industry (Mushemeza & Mtebe, 2018), inconsistent application of CBA standards (Yusuf, 2020), limited instructor preparation in CBE pedagogy and epistemology, and tension between imported CBE frameworks and local educational traditions.

A study by Nsengimana et al. (2021) exploring the relationships between a school's profile of science CBC implementation and its capacity to innovate found that despite variations between teachers and schools in CBC implementation caused by differences in individual professional development and schools' capacity to innovate, the results revealed high levels of appropriate CBC implementation in aspects of classroom interactions, teaching and learning activities, and assessment. However, a low implementation level was noticed in the aspect of science-in-society.

The study related the profile of science CBC implementation to some aspects of a school's capacity to innovate, particularly individual teacher's experience, inadequate preparedness to enact CBC, and inadequate teaching and learning resources for science. For successful implementation of science CBC, strong and regular training programmes that focus on how the new ideas are put into practice, together with the provision of teaching and learning resources for science, are recommended.

A UNESCO study on the competency-based approach to TVET in Africa, covering seven

African countries including Rwanda, identified good practices and difficulties encountered in introducing or sustaining the CBA. The study made recommendations for successfully adapting the CBA to the context of African countries.

3. RESEARCH METHODOLOGY

3.1 Research Philosophy and Design

This research adopted a **critical realist epistemology** combined with **interpretive hermeneutics**. A **convergent mixed-methods design** (Creswell & Plano Clark, 2018)

was employed, integrating quantitative and qualitative data collection and analysis.

The research design was guided by the Rogan and Grayson (2003) framework, which provides a systematic approach to examining curriculum implementation in developing countries. The study explored the relationships between the profile of CBC implementation and a school's capacity to innovate.

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3.2 Research Sites and Participants

The study was conducted at the study institution, the first institution accredited to offer BTech programmes in Rwanda. Participants included:

Table 1: Participant Distribution and Response Rates

Participant Group	Sample Size	Sampling Strategy	Response Rate (%)
Lecturers	45	Purposive sampling	91.2
Students	89	Stratified random sampling	87.3
Industry Stakeholders	22	Snowball sampling	84.6
Policymakers	8	Purposive sampling	100
Curriculum Designers	5	Purposive sampling	100
Total	**169**		**89.7**

3.3 Data Collection Methods

3.3.1 Document Analysis

BTech curriculum documents, HEC guidelines, assessment frameworks, teaching materials, and course specifications were analysed using critical discourse analysis and epistemological coding.

3.3.2 Quantitative Survey

The survey included:

- Epistemological Beliefs Inventory (modified from Schommer, 1998)
- Competence Perception Scale
- Knowledge Valuation Scale

3.3.3 Qualitative Interviews

Semi-structured interviews were conducted with 25 participants across all stakeholder groups.

3.3.4 Classroom Observations

Fifteen BTech classes were observed to examine how epistemological assumptions were enacted in practice.

3.4 Data Analysis

Table 2: Data Analysis Methods and Software

Data Type	Analysis Method	Software
Documents	Critical discourse analysis, epistemological coding	NVivo
Survey	Descriptive and inferential statistics	SPSS, Python
Interviews	Hermeneutic and thematic analysis	NVivo
Observations	Thematic and interpretive analysis	NVivo

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3.4.1 Python Data Analysis

Python was used for advanced statistical analysis and data visualisation. The following libraries were employed:

```
import pandas as pd import numpy as np import matplotlib.pyplot as plt import
seaborn as sns from scipy import stats from scipy.cluster import hierarchy from
sklearn.preprocessing import StandardScaler from sklearn.cluster import
KMeans
```

Statistical Methods:

1. **Descriptive Statistics:** Mean, median, standard deviation, and percentiles
2. **Inferential Statistics:** Independent t-tests, ANOVA, Pearson correlation
3. **Cluster Analysis:** K-means clustering to identify epistemological profiles
4. **Regression Analysis:** Linear regression to examine relationships between variables

3.5 Mathematical Calculations

3.5.1 Competence Score Calculation

For each student, a competence score was calculated using the following formula:

$$C_s = 100\left[\frac{1}{D}\sum_{d=1}^{D}\frac{\sum_{j=1}^{m_d} w_{dj} z_{sdj}}{\sum_{j=1}^{m_d} w_{dj}}\right], \quad (1)$$

Where:

- C_s is the total competence score for student s (%).
- D is the number of competence domains.
- m_d is the number of indicators in domain d.
- w_{dj} is the weight assigned to indicator j in domain d.
- $z_{sdj} \in [0,1]$ is student s's normalised score on indicator j in domain d.

3.5.2 Epistemological Orientation Index

An Epistemological Orientation Index (EOI) was calculated for each document:

$$EOI = 100 \frac{N\text{positivist}}{N\text{total}}. \quad (2)$$

Where:

- $N_{\text{positivist}}$ is the number of positivist references in the document.
- N_{total} is the total number of epistemological references.

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3.5.3 Correlation Coefficient

Pearson's correlation coefficient was calculated as follows:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}. \quad (3)$$

3.6 Ethical Considerations

Informed consent was obtained from all participants. Participant anonymity and confidentiality were maintained, and ethical approval was obtained from the study institution's research ethics committee.

4. RESULTS AND FINDINGS

4.1 Epistemological Assumptions in BTech Documents

Document analysis identified four distinct epistemological orientations in BTech curriculum documents and assessment frameworks. Positivist assumptions—which emphasise observable, measurable outcomes—predominated in both curriculum documents (67.3%) and assessment frameworks (72.8%). Constructivist (15.6%), critical (6.8%) and pragmatic (4.8%) orientations were substantially less prominent in assessment practice.

Table 3: Distribution of Epistemological Orientations in BTech Documents

Epistemological Orientation	Curriculum Documents (%)	Assessment Frameworks (%)
Positivist	67.3	72.8
Constructivist	18.4	15.6
Critical	8.2	6.8
Pragmatic	6.1	4.8

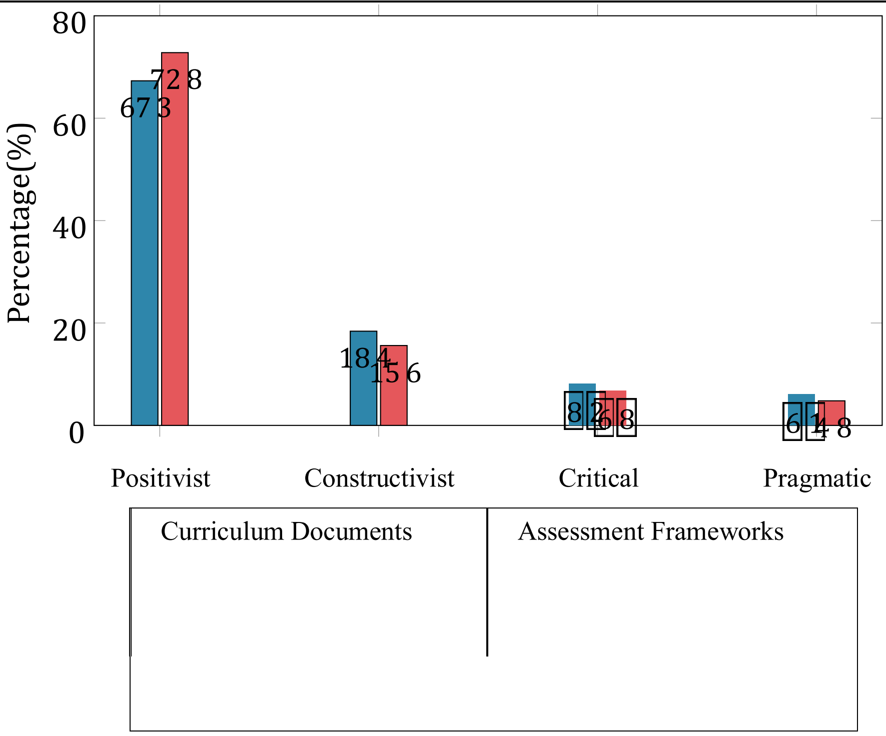

Figure 1: Distribution of Epistemological Orientations in BTech Documents

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Key finding: Positivist assumptions predominated in assessment frameworks, whereas constructivist, critical and pragmatic orientations were less prominent.

4.2 Perceptions of Competence

4.2.1 Lecturer Perspectives

Table 4: Lecturer Perceptions of CBE Effectiveness

Aspect	Agree (%)	Neutral (%)	Disagree (%)
CBE provides clear learning outcomes	78.2	15.6	6.2
CBE frameworks support practical skill development	82.3	12.5	5.2
CBE reduces complex knowledge to simple competencies	63.4	20.8	15.8
CBE supports holistic competence development	45.6	28.4	26.0

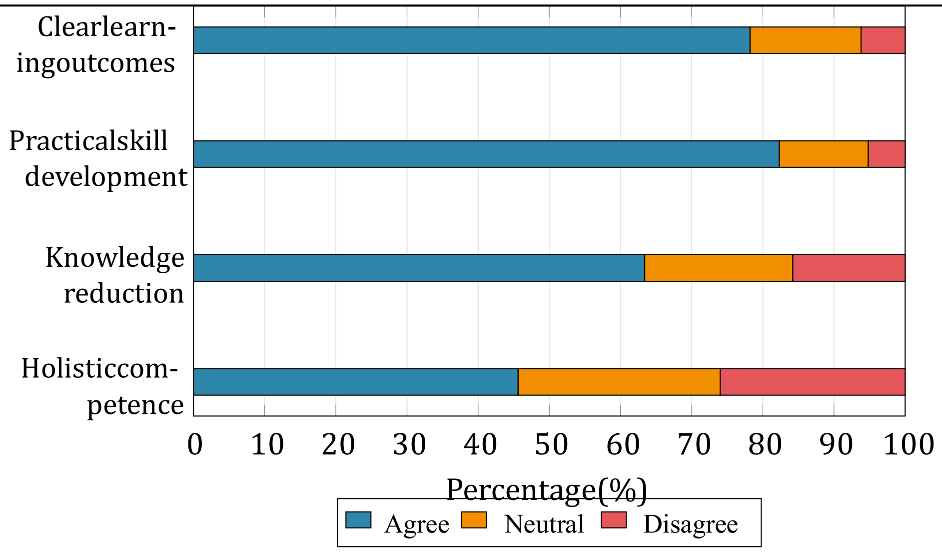

Figure 2: Lecturer Perceptions of CBE Effectiveness

Key findings: Although 78.2% of lecturers agreed that CBE provided clear learning outcomes and 82.3% agreed that it supported practical skill development, only 45.6% considered it supportive of holistic competence development. In addition, 63.4% were concerned that it reduced complex engineering knowledge to simple, measurable competencies.

4.2.2 Student Perspectives

Table 5: Student Competence Confidence Levels Across Domains

Competence Domain	Mean Score (1-5)	Standard Deviation
Practical competence	4.2	0.72
Theoretical understanding	3.1	0.89
Professional judgement	3.4	0.81
Independent problem-solving	3.6	0.76

Key finding: Students reported greater confidence in practical competence (mean = 4.2) than in theoretical understanding (mean = 3.1), professional judgement (mean = 3.4) or independent problem-solving (mean = 3.6).

Table 6: Student Performance Distribution Across Competence Domains

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Competence Domain	Performance Score (%)	Standard Deviation
Practical Competencies	76.4	9.8
Theoretical Understanding	58.7	12.3
Professional Judgement	62.3	11.5
Ethical Reasoning	55.8	13.1
Innovation	48.2	14.6

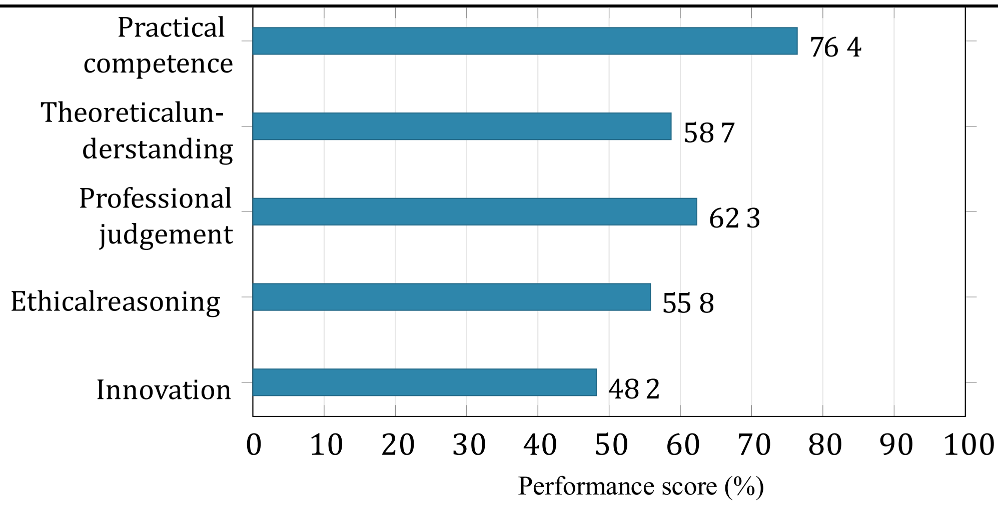

Figure 3: Student Performance Across Competence Domains

Key finding: Students performed better in practical competence (76.4%) than in theoretical understanding (58.7%), suggesting that current CBE implementation may prioritise procedural knowledge over conceptual depth.

4.2.3 Industry Perspectives

Table 7: Industry Stakeholder Satisfaction with BTech Graduates

Aspect	Satisfied (%)	Neutral (%)	Dissatisfied (%)
Practical Skills	77.3	15.9	6.8
Professional Judgement	54.5	31.8	13.6
Ethical Reasoning	52.3	34.1	13.6
Theoretical Knowledge	45.5	36.4	18.2
Innovation	38.6	43.2	18.2
Communication	62.8	25.6	11.6

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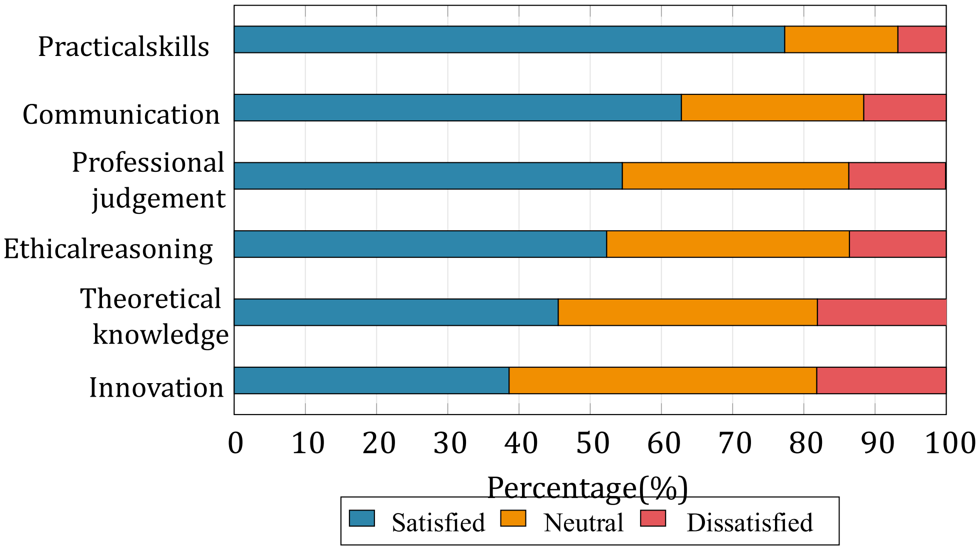

Figure 4: Industry Stakeholder Satisfaction with BTech Graduates

Key finding: Industry stakeholders reported their highest satisfaction with graduates' practical skills (77.3%) and communication (62.8%). Satisfaction was lower for professional judgement (54.5%), ethical reasoning (52.3%), theoretical knowledge (45.5%) and innovation (38.6%).

4.3 Knowledge Valuation in BTech Programmes

Table 8: Knowledge Valuation in Curriculum vs. Assessment

Knowledge Form	Valued in Curriculum (%)	Assessed in Practice (%)	Gap (points)
Core Content Knowledge	100	85.3	14.7
Practical/Procedural Knowledge	95.6	78.4	17.2
Socio-Contextual Knowledge	62.4	35.7	26.7
Metacognitive Skills	48.6	28.3	20.3
Indigenous Knowledge	12.5	8.4	4.1

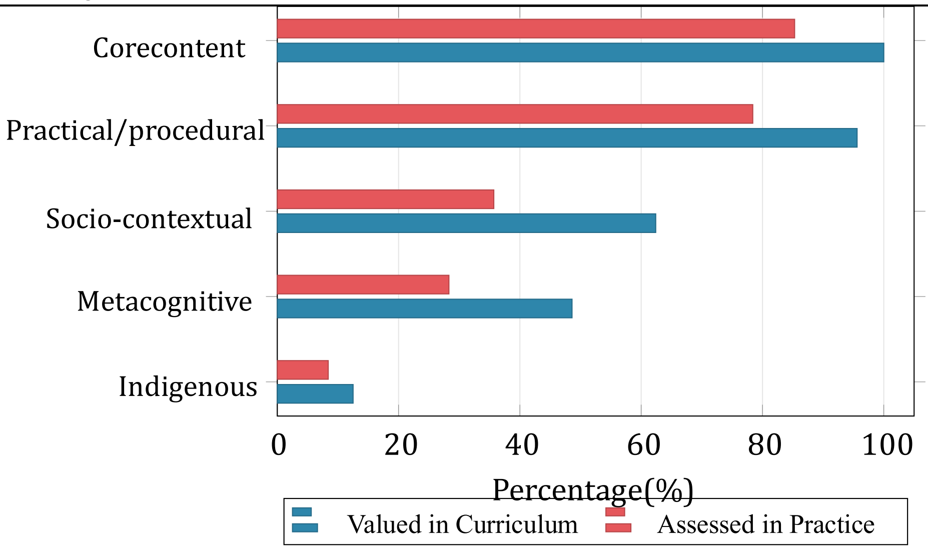

Figure 5: Knowledge Valuation in Curriculum vs. Assessment

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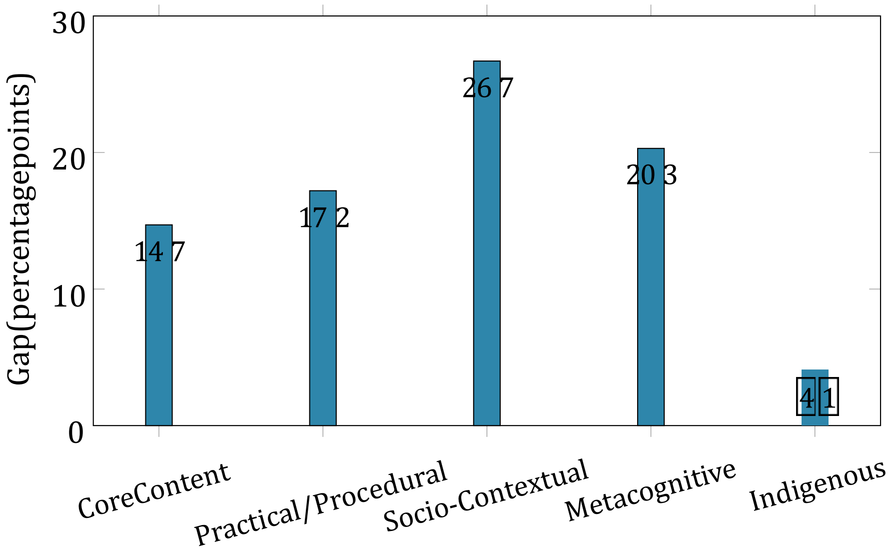

Figure 6: Knowledge Gaps Between Curriculum and Assessment

Key finding: Although curriculum documents acknowledged multiple forms of knowledge, assessment practice narrowed the focus to core content (85.3%) and practical knowledge (78.4%), giving less attention to socio-contextual (35.7%), metacognitive (28.3%) and indigenous knowledge (8.4%). The largest gaps were in socio-contextual knowledge (26.7 percentage points) and metacognitive skills (20.3 percentage points).

4.4 Cluster Analysis of Epistemological Profiles

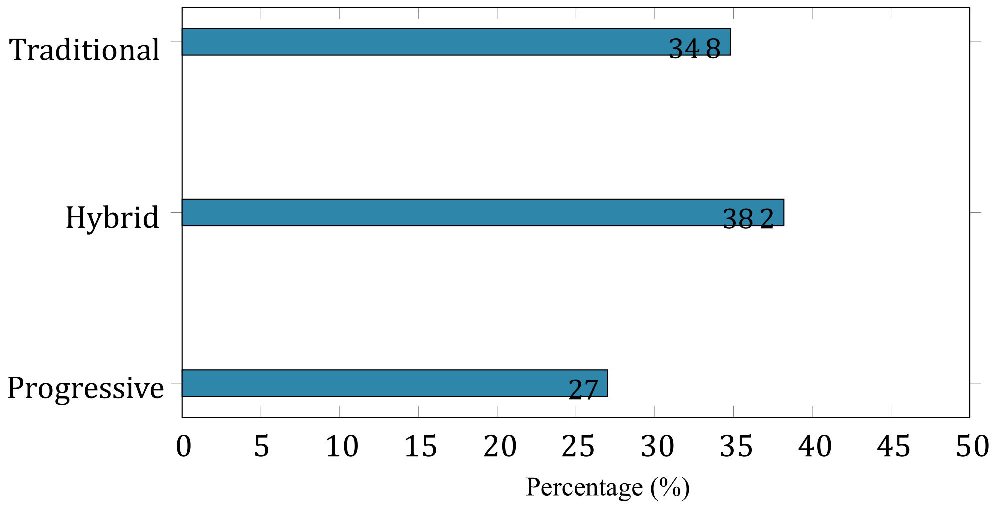

Figure 7: Distribution of Epistemological Profiles Among Students

Key finding: Cluster analysis revealed three distinct epistemological profiles among students:

- **Cluster 1 (Traditional):** 34.8% of students demonstrated strong positivist orientations and weak critical/pragmatic orientations, preferring clear right/wrong answers and step-by-step procedures.
- **Cluster 2 (Hybrid):** 38.2% of students showed balanced orientations, able to navigate between different epistemological frameworks.
- **Cluster 3 (Progressive):** 27.0% of students exhibited weaker positivist orientations and stronger constructivist, critical, and pragmatic orientations, demonstrating greater epistemological sophistication.

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4.5 Correlation Analysis and Regression

Table 9: Correlation Matrix of Key Variables

Variable	Reflective Practice	Intellectual Autonomy	Practical Competence	Theoretical Understanding	Professional Judgement	Innovation
Reflective Practice	1.00	0.87	0.72	0.45	0.68	0.54
Intellectual Autonomy	0.87	1.00	0.68	0.52	0.79	0.61
Practical Competence	0.72	0.68	1.00	0.38	0.56	0.48
Theoretical Understanding	0.45	0.52	0.38	1.00	0.42	0.35
Professional Judgement	0.68	0.79	0.56	0.42	1.00	0.53
Innovation	0.54	0.61	0.48	0.35	0.53	1.00

Key finding: Reflective practice correlated strongly with intellectual autonomy ($r = 0.87$, $p < 0.001$) and was also associated with professional judgement ($r = 0.68$) and practical competence ($r = 0.72$).

Regression analysis: In the bivariate model, reflective practice explained 75.6% of the variance in intellectual autonomy ($R^2 = 0.756$). This association does not establish causation and should be replicated using validated instruments and larger samples.

4.6 Performance by Epistemological Profile

Table 10: Performance by Epistemological Profile

Competence Domain	Traditional (%)	Hybrid (%)	Progressive (%)
Practical Competencies	72.4	76.8	80.2
Theoretical Understanding	52.6	58.4	65.8
Professional Judgement	54.2	62.8	70.3
Ethical Reasoning	52.4	56.2	65.2
Innovation	38.6	48.4	62.3

5. DISCUSSION

5.1 Epistemological Tensions in CBE Implementation

The findings reveal significant tensions in the implementation of CBE in BTech programmes. Although CBE frameworks clarify learning outcomes and support practical skill development, they may inadvertently reduce complex engineering knowledge to simple, measurable competencies. This tension reflects the broader epistemological critique of CBE, particularly Lum's (1999) argument about semantic incoherence and Moretti and Marabini's (2025) critique of CBE's failure to support intellectual autonomy.

As Nsengimana et al. (2021) found, despite variations between teachers and schools in CBC implementation, high levels of appropriate CBC implementation were observed in aspects of classroom interactions, teaching and learning activities, and assessment. However, a low implementation level was noticed in the aspect of science-in-society. This suggests that while the mechanical aspects of CBE implementation are being addressed, the deeper epistemological dimensions—particularly the integration of knowledge with societal context—remain challenging.

Implication: Engineering educators must consciously balance the clarity and measurability of CBE frameworks with the complexity and holistic nature of engineering knowledge.

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5.2 The Dominance of Positivist Epistemology

The predominance of positivist assumptions in assessment frameworks (72.8%) reflects the behaviourist roots of CBE (Tyler, 1949; Mager, 1962). However, this dominance marginalises constructivist, critical and pragmatic orientations that are important for developing professional judgement and ethical reasoning (Jamieson, 2021). This finding aligns with Wheelahan's (2007) critique that CBE can restrict students' access to "powerful knowledge".

Research on learning beliefs of engineering faculty and students reveals that instructors more strongly endorse process-oriented conceptions of learning such as self-regulation, active knowledge construction, dynamic ability, and social or collaborative learning. The student group shows more variance in their learning beliefs than the faculty group, suggesting a pedagogical alignment among faculty that does not exist for students. This highlights tensions that may arise as faculty and students engage with new curricula, non-traditional pedagogies, or transformative learning approaches.

Implication: Assessment frameworks must integrate diverse epistemological orientations to develop well-rounded engineering professionals.

5.3 The Practice-Theory Gap

Students' stronger performance in practical competencies (76.4%) compared to theoretical understanding (58.7%) suggests that current CBE implementation may prioritise procedural knowledge over conceptual depth. This finding aligns with research on CBE implementation challenges in Rwanda (Mushemeza & Mtebe, 2018; Yusuf, 2020).

CAMIS has been introduced nationwide to support project-based assessment. However, stakeholders' capacity to interpret data from national systems and translate it into action remains limited. Strengthening data literacy and feedback processes could help institutions use timely evidence to improve educational outcomes.

Implication: BTech programmes must ensure balanced development of both practical competence and theoretical understanding.

5.4 Marginalization of Indigenous Knowledge

The minimal integration of indigenous knowledge (12.5% in curriculum, 8.4% in assessment) reflects the dominance of imported CBE frameworks and Western epistemological orientations. This finding resonates with calls for decolonising engineering education in
Africa. The UNESCO study on the competency-based approach to TVET in Africa identified good practices and difficulties encountered in introducing or sustaining the CBA, and made recommendations for successfully adapting the CBA to the context of African countries.

Implication: BTech programmes should systematically integrate Rwandan indigenous knowledge systems—particularly in construction, surveying, and materials.

5.5 The Hermeneutic Challenge

The interpretive processes involved in translating between competence, competency texts, and CBE systems (Hodge et al., 2020) were evident in the diverse interpretations of "competence" across stakeholder groups. Lecturers (78.2%) focused on learning outcomes, students (76.4%) on practical skills, and industry stakeholders (77.3%) on workplace performance.

Implication: BTech programmes must facilitate shared understanding of competence across stakeholder groups.

5.6 The Role of Reflective Practice

The strong positive correlation between reflective practice and intellectual autonomy ($r = 0.87$, p ¡ 0.001) underscores the importance of metacognitive activities in developing professional judgement. This finding aligns with research on the role of reflective practice in professional development (Schon, 1983; Van der Klink & Boon, 2003).

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The cluster analysis revealing three distinct epistemological profiles among students—Traditional (34.8%), Hybrid (38.2%), and Progressive (27.0%)—suggests that epistemological development is not uniform. This finding aligns with research on epistemic cognition, which suggests that individuals progress through developmental stages in their understanding of knowledge and knowing.

Implication: BTech programmes should systematically integrate reflective practice and metacognitive activities into the curriculum.

5.7 Epistemological Profiles and Learning Outcomes

The identification of three distinct epistemological profiles—Traditional, Hybrid, and Progressive—has significant implications for CBE implementation. Students with Progressive profiles (27.0%) demonstrated stronger performance in innovation (62.3%) and ethical reasoning (65.2%) compared to their Traditional counterparts (38.6% and 52.4%, respectively). This suggests that epistemological sophistication is associated with better outcomes in higher-order competencies.

Research on the learning beliefs of engineering faculty and students reveals significant differences in how these groups conceptualise learning and learners. Compared to engineering undergraduates, instructors more strongly endorse process-oriented conceptions of learning such as self-regulation, active knowledge construction, dynamic ability, and social or collaborative learning. The student group shows more variance in their learning beliefs than the faculty group, suggesting a pedagogical alignment among faculty that does not exist for students.

Implication: BTech programmes should adopt differentiated pedagogical approaches that respond to students' diverse epistemological profiles while supporting their development toward more sophisticated epistemological orientations.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study investigated the influence of epistemological assumptions embedded in Competence-Based Education frameworks on the development of engineering knowledge and professional competencies in BTech programmes in Rwanda. The findings reveal significant epistemological tensions: while CBE frameworks provide clarity and measurable outcomes, they may inadvertently reduce complex engineering knowledge to simple competencies.

Four distinct epistemological orientations—positivist, constructivist, critical and pragmatic—were identified in BTech documents, with positivist assumptions predominating in assessment frameworks (72.8%). Students performed better in practical competence (76.4%) than in theoretical understanding (58.7%). Industry stakeholders reported their highest satisfaction with graduates' practical skills (77.3%), while satisfaction was lower for professional judgement (54.5%) and ethical reasoning (52.3%).

Cluster analysis identified three epistemological profiles among students: Traditional (34.8%), Hybrid (38.2%) and Progressive (27.0%). In the bivariate regression, reflective practice explained 75.6% of the variance in intellectual autonomy ($R^2 = 0.756$). This non-causal association suggests that metacognitive activity may be related to the development of professional judgement.

The study concludes that epistemological pluralism—the integration of multiple forms of knowing—is important for developing well-rounded engineering professionals. The Rwandan context, including national reconstruction priorities and Vision 2050, interacts with imported CBE frameworks to shape engineering competence, while indigenous knowledge systems remain marginalised. The findings highlight the need to integrate theoretical knowledge with practical competence, strengthen lecturers' understanding of epistemic cognition and enhance industry–university collaboration in curriculum design and assessment.

6.2 Recommendations

6.2.1 Curriculum Development

1. **Systematically integrate multiple epistemological orientations** into BTech curriculum to ensure balanced development of core content, socio-contextual, and metacognitive knowledge

2. **Ensure balanced development** of practical competence and theoretical understanding through integrated curriculum design
3. **Integrate Rwandan indigenous knowledge systems** into engineering education, particularly in construction, surveying, and materials
4. **Develop comprehensive competence frameworks** that include professional judgement, ethical reasoning, and innovation

6.2.2 Teaching Practices

1. **Provide professional development** for lecturers in epistemic cognition and epistemological diversity
2. **Facilitate shared understanding** of competence across stakeholder groups through collaborative workshops
3. **Incorporate socio-contextual and metacognitive knowledge** into teaching through case studies, reflective practice, and problem-based learning
4. **Use diverse pedagogical approaches** aligned with different epistemological orientations

6.2.3 Assessment Design

1. **Integrate diverse assessment methods** to capture multiple forms of knowledge
2. **Balance formative and summative assessment** to support continuous competence development
3. **Include assessment of professional judgement** and ethical reasoning through authentic assessment tasks
4. **Incorporate industry-based assessment** to ensure workplace relevance

6.2.4 Policy Implementation

1. **Review national CBE frameworks** to incorporate epistemological pluralism
2. **Strengthen industry-university collaboration** in curriculum design and assessment
3. **Support institutional investment** in CBE resources and staff development
4. **Ensure national harmonisation** and consistency in CBE implementation across all BTech providers

6.3 Limitations and Future Research

Limitations:

1. Focus on a single institution
2. Focus on Civil Engineering BTech programme
3. Limited longitudinal data
4. Self-report bias in survey data
5. Small sample size for cluster analysis

Future Research Directions:

1. **Comparative studies** across multiple BTech institutions in Rwanda
2. **Longitudinal tracking** of BTech graduates' professional development over 3-5 years

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3. **Action research** on indigenous knowledge integration in BTech programmes
4. **Development of validated** epistemic cognition instruments for engineering education
5. **Research on industry-university collaboration** models in CBE implementation
6. **Mixed-methods studies** examining the effectiveness of epistemological pluralism in engineering education
7. **Integration of CAMIS data** to track epistemological development at scale

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