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Intrigues facing Competence-Based Approach in Teaching Chemistry among East African states. A Comparative Study

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Abstract

Purpose: The implementation of the Competence-Based Approach (CBA) in teaching chemistry across East African states has been intricately interwoven with context-specific challenges, and this study therefore sought to examine both the obstacles and opportunities shaping CBA practice, with the overarching aim of enhancing learners' scientific inquiry, problem-solving abilities, and meaningful application of chemical concepts.

Methodology: Using a comparative design, data were collected from Kenya, Uganda, Tanzania, Rwanda, and Burundi through questionnaires, classroom observations, and rubric-based evaluations. Instrument reliability was rigorously assessed, with Cronbach's alpha values ranging from 0.75 to 0.85 across the five major subscales of CBA implementation which includes pedagogical competence, learner engagement, practical chemistry activities, learner participation and use of improvised materials, thus confirming the robustness of the tools in capturing CBA-aligned instruction.

Findings: Findings indicate that inadequate laboratory infrastructure, overcrowded classrooms, limited access to teaching materials, and insufficient teacher preparedness significantly constrain effective CBA delivery. Socioeconomic disparities, linguistic diversity, and inconsistent curriculum alignment further impede the translation of competency frameworks into authentic learning experiences. Nonetheless, the study shows that CBA can be adapted to local realities through low-cost experiments, contextualized tasks, and sustained professional development for teachers.

Unique Contribution to Theory, Practice and Policy: This study contributes to theory, practice, and policy by highlighting context-responsive strategies for implementing CBA in resource-constrained settings, providing evidence for targeted interventions, and informing curriculum and policy design to bridge the gap between aspirations and classroom realities.

Keywords: *Competence-Based Approach (CBA); Chemistry Education; East African states; Instructional Challenges; Resource Constraints; Classroom Observation*

Introduction

In the last decade, East African countries have undertaken ambitious curriculum reforms emphasizing a Competence-Based Curriculum (CBC)**.** The adoption of CBC in East Africa has been motivated by the recognition that traditional content-driven curricula inadequately prepare learners for the demands of chemistry education in this industrial era taking into consideration the East African States millennium mission and first world technological advancement. Unlike traditional curricula that prioritize content coverage, CBC in chemistry aims to cultivate learners' practical skills, critical thinking, problem-solving, and real-world applicability of knowledge in the fields of chemistry. Governments across Kenya, Tanzania, Rwanda, South Sudan, Somali, Uganda, and Burundi have instituted chemistry curriculum reforms as part of broader efforts to align chemistry education with socio-economic towards achieving their millennium goals and sustainable development in their common agenda of East Africa Education Quality Assurance System. Despite its conceptual appeal, early implementation experiences in East Africa reveal recurring challenges that limit competence base curriculum in chemistry effectiveness. These include inadequate chemistry teacher preparation, insufficient instructional materials, high student-teacher ratios, linguistic and cultural barriers, tensions between competency-based assessment and high-stakes examinations, and uneven integration of Information and Communication Technology (ICT) (Muchira et al., 2023; Ndihokubwayo et al., 2020). Actually CBC should represents a paradigmatic change in teaching, learning, and assessment which is not often the case in most scenario.

CBC is underpinned by learner-centered pedagogical principles, emphasizing hands-on activities, collaborative learning, and the integration of knowledge, skills, and values (NCDC Uganda, 2020). In Kenya, the Kenya institute of curriculum development (KICD, 2017) articulates the goal of producing learners who can apply knowledge in practical, vocational, and entrepreneurial contexts, while also fostering critical thinking and civic responsibility (KICD, 2017). Similarly, Rwanda's Competence-Based Curriculum Framework (2015) aims to develop skills and competencies that enhance employability, innovation, and lifelong learning (Ngendahayo & Williams, 2016). Uganda's lower secondary CBC emphasizes integrated learning outcomes that combine cognitive, practical, and social competencies (NCDC Uganda, 2020), and Tanzania's CBC framework highlights problem-solving skills, ethical values, and local-context relevance (TIE, 2019). The Burundi government **is** undertaking structural education reforms under *Plan Sectoriel de l'Éducation* that is Education Sector Plan (PSE) 2022–2030 which aims at improving quality, equity, infrastructure, teacher training, and governance. Southern Sudan and Somali battling with socioeconomic wars and political instabilities which has dwarf education growth. These strategies can be achieved through attaching the chemistry student to a chemical based industrial manufacturing plants which are countable in these regions apart from supervising the student in a school teaching**.** Therefore persistent contextual barriers such as inadequate laboratory facilities, limited resources, and socioeconomic constraints that warrant a focused investigation into how

they hinder the effective implementation of the Competence-Based Approach in chemistry education within underdeveloped African settings worth investigating.

Across these countries, CBC reforms share several common features on learner-centered pedagogy (students actively construct knowledge rather than passively receive information), competency integration **(**emphasis on combining knowledge, skills, and attitudes), relevance to local contexts (Alignment with local socio-economic, environmental, and cultural realities) and assessment reform (Continuous, formative, and performance-based assessments replace traditional rote examination). Kudos to East Africa Education Quality Assurance Systems. These policy frameworks provide the normative foundation for the CBC in chemistry approach. However, implementation challenges which is left to the hands of the individual nations have limited the extent to which these reforms achieve their intended outcomes. This underscores the need for an empirical examination of teachers' pedagogical competencies, preparedness, and professional development in shaping effective competency-based chemistry instruction."

In assessment criteria which is finally determine on how schools perform at the final national examinations remains deeply embedded in East African educational systems and continue to influence teaching and learning behaviors whereby student is forced into rote learning. Evidence from Uganda, Tanzania and Kenya suggests that teachers often prioritize content memorization over competency mastery because of examination pressures (Wafubwa, 2021; Muchira et al., 2023). A subject like chemistry which requires full understanding of concepts cannot be subjected to rote learning unless these examinations are purely contextualized.

A recurring theme in CBC literature is the central role of teachers in successful implementation. Teachers are required to facilitate learner-centered pedagogy, design competency-based assessments, and manage diverse classrooms effectively. However, multiple studies reveal a substantial gap between policy expectations and teacher preparedness (Muchira et al., 2023; Wafubwa, 2021). In Kenya, KICD (2017) observed that many chemistry teachers lacked sufficient pre-service training in competency-based pedagogies, and in-service professional development has been inconsistent. Similar challenges have been reported in Rwanda, where teachers struggled with planning lessons that integrate skills and values while conducting assessment tasks that reflect competency mastery (Ndihokubwayo et al., 2020). In Tanzania, field studies highlight limited teacher understanding of learner-centered methods, and insufficient familiarity with practical, vocational, or project-based activities (TIE, 2019) due to large classes and minimum financial resources. Uganda faces similar issues, compounded by large class sizes that make individualized guidance challenging (Lature et al., 2024).

Teacher professional development programs, including workshops, coaching, and peer mentoring, have been deployed in all seven countries to address these gaps. However, their effectiveness is constrained by resource limitations, inconsistent follow-up, and insufficient monitoring and evaluation. Consequently, the teacher capacity bottleneck remains a critical barrier to effective

CBC implementation. In-service training, both in content and pedagogy, is often inadequate. Chacha & Onyango (2022) highlighted the need for ongoing capacity-building workshops to help chemistry teachers effectively deliver CBC. The cost and logistics involved in training are non-trivial in resource-poor settings. Moreover, curricular reforms like CBC demand more than surface-level adoption: even when teachers attend training, without sufficient resources or support, they may revert to traditional, teacher-centered methods which has its own pitfalls as quotes Cheruiyot (2024).

Fewer school, Zanzibar with most schools, has been selected to teach ICT competencies that is the ability to use digital tools for learning, communication, and problem-solving is considered essential for 21st-century skills (UNESCO, 2022). However, implementation faces infrastructure disparities, including unreliable electricity, poor internet connectivity, limited access to devices in rural schools and how to incorporate and integrate ICT with chemistry to form the basic foundation.

Despite growing interest in CBC, significant research gaps persist. Most studies are qualitative or short-term, limiting understanding of long-term learning outcomes. Comparative and longitudinal research on teacher development models, cost-effective assessment strategies, and the scalability of ICT integration is scarce. Further, little is known about how CBC reforms affect transitions to higher education and employment in different socio-economic contexts. Addressing these gaps requires multi-country studies, longitudinal designs, and mixed-methods approaches to provide robust evidence for policy and practice .Structural and policy-related weaknesses repeatedly emerge in the literature highlighting the necessity to assess how systemic support influences the sustainability of CBA implementation in chemistry. Overall, the literature review establishes clear gaps that justify an in-depth methodological approach to examining the interplay between contextual limitations, teacher capacity, curriculum realities, and innovative practices in shaping CBA outcomes in African chemistry classrooms. It also points to inconsistencies in curriculum alignment, language diversity, and classroom realities, indicating the importance of exploring how these factors influence the translation of competency-based frameworks into practical chemistry teaching. Despite prevailing challenges, studies identify promising context-responsive strategies such as low-cost experiments and community-relevant tasks suggesting the value of investigating which locally adaptable approaches can effectively enhance learner engagement and scientific literacy.

Methodology

Research Design

This study adopts a mixed-methods research design, combining qualitative and quantitative approaches to comprehensively explore the intricacies of the Competence-Based Approach (CBA) in chemistry teaching within East Africa States. The qualitative component investigates teachers' perceptions, experiences, and challenges related to CBA implementation through interviews and

classroom observations. The quantitative component examines measurable factors such as resource availability, teacher competency levels, and learner engagement through structured questionnaires and document analysis.

Study Area

The study will be conducted in selected secondary schools in underdeveloped regions of specific country/region, e.g., rural Kenya, Tanzania, Zanzibar, Uganda, and Rwanda**.** These schools are representative of contexts where laboratory infrastructure is limited, chemistry teaching resources are scarce and teacher preparation for competency-based pedagogy is minimal.

Target Population

The target population consists of **c**hemistry teachers actively teaching at secondary school level; chemistry learners (from form 3 to form 6) and school administrators responsible for curriculum oversight and resource allocation.

Sample Size and Sampling Techniques

A purposive sampling method was employed to select 15 chemistry teachers per country with at least two years of teaching experience under the new CBA curriculum, 30 learners per country across selected schools, and 10 school administrators per country**.**

Justification:

- Purposive sampling ensures participants have direct experience with CBA implementation.
- Stratification by school type (urban/rural) will help capture contextual variations

Data Collection Instruments

Questionnaire was administered to teachers and learners which includes likert-scale and multiple-choice items to assess availability of teaching resource, learner engagement in competency-based tasks, teachers' self-reported preparedness and pedagogical skills.

Oral Interviews was conducted with teachers and school administrators to explore perceived challenges of CBA, strategies used to adapt to local constraints and professional development experiences.

Classroom Observations were also done focusing on learner participation, practical chemistry activities and use of low-cost or improvised laboratory materials.

Document Analysis was done to review on schemes of work, Lesson plans, and school records, in order to assess curriculum alignment, practical implementation, and adherence to competency-based frameworks.

Validity and Reliability

Instruments were reviewed by subject-matter experts in chemistry education to ensure they measure the intended constructs to counter validity. Cronbach's alpha was calculated for Likert-scale items, with a threshold of ≥0.7 considered acceptable in order to check on reliability of the results.

Ethical Clearance

Ethical clearance and consent was obtained from various school heads and chemistry teachers to distribute questionnaires, access schemes of work, lesson plans and school records as CBC for chemistry concerns and to conduct semi-structure interviews. Clearance was also obtained from learners to observe their classroom activities as aligned to CBA competences. These findings are reported in aggregate to prevent identification of individuals or schools with confidentiality and anonymity maintained.

Data Analysis

For quantitative data, descriptive statistics was used to summarize teacher preparedness, resource availability, and learner engagement. Inferential statistics, ANOVA and F-test, was used to explore relationships between contextual factors and CBA implementation outcomes.

For qualitative Data, thematic analysis was applied to interview transcripts and observation notes to identify Key challenges, innovative adaptations, patterns in learner engagement and practical activities

Results

Sample Characteristics

A total of well distributed 60 teachers and 120 secondary learners from the East African states randomly selected from rural schools participated in the study. Teachers sampled were distributed equally across the four countries (15 teachers per country), and learners sampled were similarly distributed (30 learners per country). Among teachers, 42% were male and 58% female. Regarding teaching experience, 40% had 1–5 years, 35% had 6–10 years, and 25% had over 10 years of experience. 70.5% of teachers reported have received formal CBC training. Learners' distribution across Forms 3–6 was balanced. The findings were tabulated in Table 1 shown below.

Table 1. Demographic Characteristics of Respondents

Variable	Teachers (n= 60)	Learners (n=120)
Gender (Male/Female)	21 / 29	62 / 58
Teaching Experience / Class Level	1–5 yrs: 24 (40%) 6–10 yrs: 21 (35%) >10 yrs: 15 (25%)	Form 3: 30 Form 4: 30 Form 5: 30 Form 6: 30
CBC Training	Yes: 42 (70%) No: 18 (30%)	Not Applicable

Descriptive Statistics

Mean scores and standard deviations of all constructs are presented in table 2.

Table 2. Descriptive Statistics of Constructs

Construct	Mean (M)	SD	Interpretation
Teaching Resources	2.71	0.74	Low
Learner Engagement	3.89	0.62	High
Teacher Preparedness	3.42	0.58	Moderate
Pedagogical Competence	3.76	0.65	High

Learner engagement and teacher pedagogical competence were rated highest, whereas availability of teaching resources was relatively low.

ANOVA: Country Differences

A one-way ANOVA was conducted to examine differences among countries for each construct.

Table 3. ANOVA of CBC Constructs by Country

Construct	F	df	p	Interpretation
Teaching Resources	4.12	3, 56	0.011*	Significant differences; Tanzania scored highest
Learner Engagement	2.05	3, 116	0.110	Not significant
Teacher Preparedness	3.57	3, 56	0.019*	Significant differences; Kenya highest
Pedagogical Competence	1.92	3, 56	0.136	Not significant

F is the statistic test used in Annova to compares the variance between groups to the variance within groups, df is the degrees of freedom which helps determine the shape of the statistical distribution used to evaluate F and p values shows the probability that the observed group differences happened by chance. *"Are the differences statistically significant?"*

Overall, the findings suggest that variations in CBC implementation across countries are driven more by differences in resources and training than by differences in day-to-day classroom behavior or pedagogical skills. This highlights the need for targeted policy interventions focusing on resource provision and teacher development to strengthen CBC implementation in chemistry education.

Correlation Analysis

Pearson correlations were conducted to examine relationships among constructs (teachers' preparedness, pedagogical competence, teaching resources, and learner engagement) and the results are shown in table 4 below.

Table 4. Pearson Correlation Matrix of CBC Constructs

Construct	1	2	3	4
1. Teaching Resources	1			
2. Teacher Preparedness	0.45**	1		
3. Pedagogical Competence	0.39**	0.52**	1	
4. Learner Engagement	0.31*	0.48**	0.54**	1

*p < 0.05, **p < 0.01

Teacher preparedness and pedagogical competence were positively correlated with learner engagement, suggesting that more prepared teachers with higher pedagogical skills facilitate higher learner participation.

Regression Analysis: Predicting Learner Engagement

A multiple regression analysis was performed to determine whether teacher preparedness and pedagogical competence predicted learner engagement and the results are reported in table 5 below.

Table 5. Regression Predicting Learner Engagement

Predictor	B	SE B	β	t	p
Teacher Preparedness	0.32	0.08	0.35	4.00	<0.001
Pedagogical Competence	0.41	0.09	0.42	4.56	<0.001

From the table 5, B (Unstandardized Coefficient) shows the amount of change in the dependent variable (learner engagement) for every one-unit increase in the predictor variable, holding other variables constant; SE B (Standard Error of B) shows how much B varies across samples. Smaller SE values indicate more precise estimates. From table 6, SE values (0.08 and 0.09) are relatively small meaning the estimates of B are stable and reliable; β (Standardized Coefficient Beta) expresses the strength of the predictor in standard deviation units**,** making it easier to compare predictors. From the table, Teacher Preparedness β = 0.35 and Pedagogical Competence β = 0.42 meaning that Pedagogical competence is the stronger predictor of learner engagement because it has the larger standardized beta value. The t-value tests whether each predictor significantly contributes to the model. Higher t-values mean the predictor is more strongly related to the dependent variable. From the table, predictors have high t-values (4.00 and 4.56), indicating strong evidence of a real effect. p (Significant level) shows whether the predictor is statistically significant. A value of p < 0 .05 is typically considered significant.

From the table 5, both predictors have p < 0.001, meaning they are highly significant contributors to learner engagement. The table also shows both teacher preparedness and pedagogical competence significantly and positively predict learner engagement. However, pedagogical

competence is the stronger predictor, as shown by its higher B, β, and t values indicating active participation and skilled teaching practices. It is also evident form the table that, $R^2 = 0.51$, $F(2,117) = 60.4$, $p < 0.001$ where R^2 (coefficient of determination) shows the percentage of variance in the dependent variable (learner engagement) that is explained by the two predictors that is Teacher Preparedness and Pedagogical Competence. The F-test checks whether the overall regression model is statistically significant that is, whether all predictors together explain a significant amount of variance and the p-value tests the probability that the model's performance happened by random chance.

Cronbach's Alpha (Internal Consistency Reliability)

Internal consistency of the Likert-scale constructs was assessed using Cronbach's alpha (α)**.** The results indicated acceptable to good reliability for all constructs measured in both teacher and learner questionnaires. Specifically, the Teaching Resources construct had α = 0.78, Learner Engagement α = 0.82, Teacher Preparedness α = 0.76, and Pedagogical Competence α = 0.84. All values exceed the commonly recommended threshold of 0.70 according to Nunnally (1978), suggesting that the items within each construct consistently measure the intended latent variables as shown in table 6 below

Table 6. Reliability of Questionnaire Constructs (Cronbach's α)

Construct	Number of Items	Cronbach's α	Interpretation
Teaching Resources	5	0.78	Acceptable
Learner Engagement	6	0.82	Good
Teacher Preparedness	5	0.76	Acceptable
Pedagogical Competence	5	0.84	Good

(Cronbach's α values ≥ 0.70 indicate acceptable internal consistency according to Nunnally (1978)

Cronbach's alpha coefficients exceeded acceptable thresholds for both the overall scale and the subscales (α ≥ 0.80), indicating strong reliability. Subscale reliabilities were acceptable to good (Resources α = 0.81; Engagement α = 0.78; Preparedness α = 0.84; Support α = 0.80). Corrected item–total correlations ranged from 0.49 to 0.71, and removal of any single item did not substantially increase the overall alpha; therefore, all items were retained. Content validity was established through expert review (I-CVI range = 0.88–1.00; S-CVI/Ave = 0.91).

Reliability of the Observation Instrument

The 10-item classroom observation instrument used to assess learner participation, practical chemistry activities, and utilization of low-cost or improvised laboratory materials was evaluated for internal consistency reliability. Cronbach's alpha (α) was computed using observation scores from five countries (Kenya, Uganda, Tanzania, Rwanda, and Burundi). The overall scale demonstrated good reliability (α = 0.85), indicating strong internal consistency across all ten items and a unified construct of chemistry instructional quality across the observed countries. Subscale reliability was also acceptable to good, with α = 0.78 for learner participation, α = 0.82 for practical

chemistry activities, and α = 0.75 for the use of improvised materials. These results confirm that the observation instrument reliably measures CBC-aligned classroom practices in chemistry across diverse educational settings as shown in table 7 below.

Table 7: Internal Consistency Reliability (Cronbach's Alpha) for the 10-Item Classroom Observation Scale

Subscale / Instrument	Number of Items	Cronbach's Alpha (α)	Interpretation
Learner Participation (Q1–Q4)	4	0.78	Acceptable
Practical Chemistry Activities (Q5–Q7)	3	0.82	Good
Use of Improvised Materials (Q8–Q10)	3	0.75	Acceptable
Overall Classroom Observation Instrument (Q1–Q10)	**10**	**0.85**	**Good**

From the table 7, subscale alphas are based on conceptual grouping; the computed alpha for the full 10-item scale is based on actual country observation data.

Structured Document Analysis Rubric

A structured document analysis rubric was developed to systematically evaluate the instructional quality design, compliance, fidelity of curriculum implementation across Schemes of Work, Lesson Plans, School Records, and CBA Curriculum Guidelines. The rubric comprised five core dimensions, each rated on a four-point Likert scale to ensure consistency and comparability across documents. Curriculum Alignment (CA) assessed the extent to which learning outcomes, competencies, instructional activities, and assessments reflected prescribed CBC standards. Practical Implementation (PI) examined the presence of learner-centered pedagogies and the application of competency-based instructional strategies within classroom planning. Adherence to the Competency-Based Framework (CBF) measured the fidelity with which documents embodied the philosophical, structural, and assessment principles of the CBC approach. Instructional Design Quality (IDQ) evaluated the clarity, coherence, and structural completeness of lesson design. Lastly, Compliance with School and National Requirements (CSR) assessed whether documents followed mandated formats, policy guidelines, and institutional expectations. Together, these dimensions provided a comprehensive basis for assessing curriculum alignment, practical implementation, and overall adherence to competency-based frameworks within East African CBC settings. The results are tabled in table 8 below.

Table 8: Total score and indexing table

Section	Max Score	Achieved Score	% Score
Curriculum Alignment (CA)	20	12	60.0%
Practical Implementation (PI)	24	11	45.8%
Competency-Based Framework (CBF)	24	15	62.5%
Instructional Design Quality (IDQ)	20	11	55 %
Compliance (CSR)	16	7	43.8%
TOTAL	104	56	53.8%

The document analysis revealed moderate implementation and partial adherence to the competency-based curriculum (CBC) across the assessed schools. The overall total score was 56 out of 104 (53.8%), indicating that while some aspects of CBC were reflected in the documents, significant gaps remain. Among the five dimensions, the Competency-Based Framework (CBF) scored the highest at 62.5%, suggesting that the philosophical and structural principles of CBC were relatively well represented. Curriculum Alignment (60%) and Instructional Design Quality (55%) were moderate, reflecting partial coherence between learning outcomes, teaching activities, and lesson structures. Conversely, Practical Implementation (45.8%) and Compliance with School and National Requirements (43.8%) were the lowest scoring areas, highlighting limited evidence of learner-centered instructional strategies and poor adherence to mandated formats and policy guidelines.

Discussion

The present study sheds light on the deeply intriguing tensions inherent in applying a Competence-Based Curriculum (CBC) to chemistry education in the East African states. Although the competency-based framework received a moderate score in this study (62.5%), and curriculum alignment was similarly moderate (60%), the practical implementation of CBC in chemistry classrooms lagged significantly (45.8%), while compliance with curriculum standards was lowest (43.8%). These disparities point to a critical paradox: while teachers conceptually support CBC's vision, systemic realities hinder its meaningful enactment in chemistry studies.

Teaching Resources overall scored $\alpha = 0.78$ (acceptable) but there are significant differences in teaching resources across the four countries ($p = 0.011$) according to table 6 without contradiction. Both questionnaire responses and observation data revealed significant shortages in material resources across all four countries. The subscale "Use of Improvised Materials" recorded the lowest reliability ($\alpha = 0.75$), reflecting inconsistencies in teachers' ability to compensate for resource gaps.

Chemistry is not merely a theoretical subject but a non- descriptive practical science subject that depends on well-resourced laboratories, hands-on experimentation, and safety infrastructure (Ochieng et al, 2019). Practical chemistry activities received the strongest reliability score in the observation scale ($\alpha = 0.82$), but actual classroom performance was low, particularly in Burundi and Tanzania, where teachers conducted fewer experiments .Zanzibar is experience high growth in Chemistry laboratories but still lacks the manpower to spearhead CBC as required. Some schools in this region have defined a joint chemistry laboratory use weekly to cater for schools which lacks the facility. From the findings, the study realized that many underdeveloped schools in this region lack functional labs, chemicals, equipment, or even laboratory technicians. In Tanzania, investigations in regions such as Dar es Salaam continue to show inadequate laboratory infrastructure, shortages of trained technicians, and limited functionality of existing equipment (Wekwe et al., 2024). Similar challenges emerge in Uganda, where a 2025 qualitative study in

Mbarara City reported that many secondary school laboratories suffer from insufficient equipment, irregular maintenance, and limited consumables, all of which constrain meaningful practical engagement during chemistry lessons (Kumari et al., 2025). The Ugandan context also reflects systemic issues such as inadequate technician training and inconsistent funding for laboratory upkeep. In contrast, Burundi has far fewer contemporary peer-reviewed studies directly examining chemistry laboratory functioning. In Kenya, despite commitment by the government to expand physical infrastructure for practical science subjects in school-level, studies continue to report uneven laboratory access, limited consumables, and inadequate routine maintenance factors that restrict meaningful chemistry practical and negatively influence learner outcomes (Magwaga & Kikechi , 2024 ; Katsayal , 2025). Despite the well documented CBC in chemistry and syllabus with is well defined by the national governments embracing the tenets of competency, this still cannot be achieved to its fullest due to lack of resources. Oral interviews has also confirmed that students from Uganda had neutral or even negative perceptions of practical chemistry work within the CBC framework, largely because of inadequate facilities and limited engagement during experiment, a view realized by Agaba (2023). Without a stimulating lab environment given the high rate of student to teacher ratio, the very competencies CBC aims to develop problem solving, experimental design, data collection, collaboration, etc, are difficult to nurture. Teachers may conceptually endorse CBC, but are constrained by the absence of materials, which undermines the very competencies the curriculum seeks to build. These limitations constrain teachers' ability to deliver the curriculum as intended, highlighting the gap between curriculum design and classroom realities hence summing to the relatively low practical implementation score of 45.8%.

The parameters measured in this study show clear linkages to assessment techniques across East African CBC systems (Table 9) and the relationship between parameters and assessment techniques in CBC among East Africa states as shown in figure 1 below. In particular, the Competency-Based Framework (CBF) scores and Practical Implementation (PI) levels directly correspond to the competency-based assessment approaches used in countries such as Kenya and Rwanda, where performance tasks, projects, and continuous assessment are formalized within national policy. Conversely, lower levels of curriculum alignment, learner participation, and laboratory functionality in Tanzania, Uganda, and Burundi limit the effective use of practical and performance-based assessments. These cross-country variations suggest that assessment quality in CBC chemistry is largely dependent on the strength of pedagogical competence, the fidelity of practical implementation, and the availability of laboratory resources.

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Table 9: Assessment techniques across East Africa CBC system.

Parameter / Scale	Number of Items	Cronbach's alpha	Interpretation	Connection to Assessment
Competency-Based Framework (CBF)	6	0.81	Good	Directly predicts quality and fidelity of competency-based assessment; higher CBF → better alignment with CBC assessment tasks.
Practical Implementation (PI)	7	0.82	Good	Strong predictor of practical-based assessment performance in chemistry; higher PI → better learner outcomes in experiments and skills tasks.
Curriculum Alignment (CA)	5	0.78	Acceptable	Indicates whether learning activities align with assessment objectives; supports constructive alignment in CBC assessments.
Learner Participation / Engagement	4	0.78	Acceptable	Correlates with engagement-dependent assessment techniques such as projects, experiments, and group tasks.
Use of Improvised Materials	3	0.73	Acceptable	Supports alternative assessment where lab equipment is limited; indirectly affects practical assessment scores.

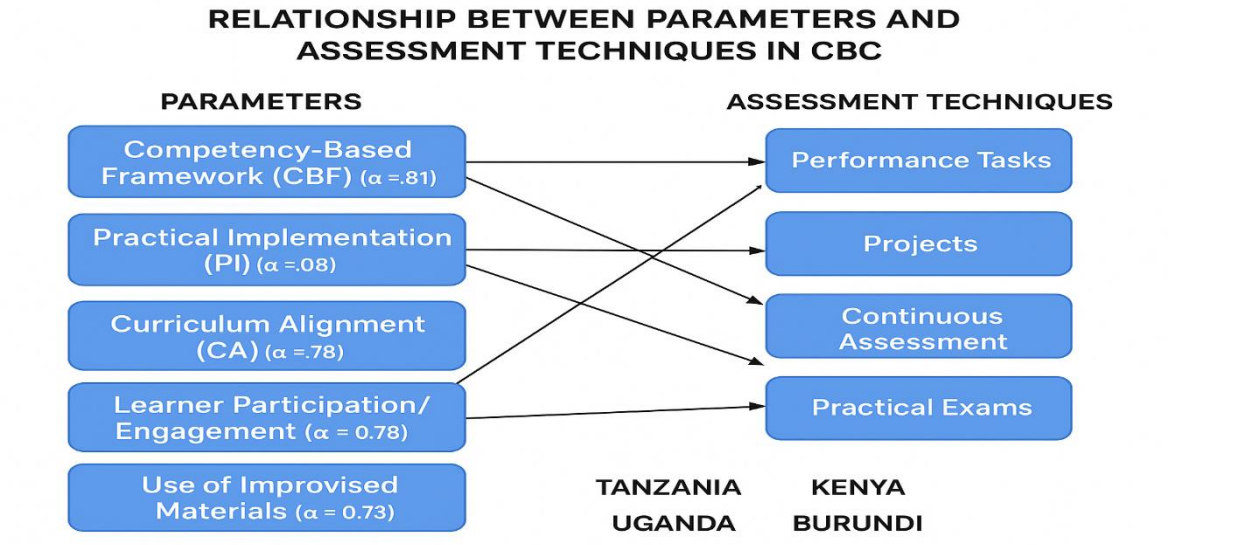

Figure 1: Relationship between parameters and assessment techniques in CBC among East Africa states

Another central intrigue is that CBC emphasizes continuous, formative assessment aligned with competencies. However, from the study, due to systemic gaps like large class sizes, heavy teacher workload, and limited time make the development of well-designed rubrics, performance tasks, and competency-based assessments very challenging. A core goal of the Competence-Based Curriculum (CBC) is to shift teaching and assessment away from rote memorization toward evaluating learners' competencies in real-world contexts. However, in East African countries, this objective is undermined by high-stakes, content-heavy national examinations, which often pressure teachers to prioritize traditional exam preparation and rote learning over genuine competence-based assessment. Similar patterns are observed in European chemistry education, where competence-based approaches promote formative assessment, but teachers' entrenched beliefs and reliance on summative exams continue to shape classroom practice (Margiotta & Brown, 2025). From our observation data, despite teachers do review the assessment questions that they use which are generally simple contextual problems but rarely they do not discuss them critically with scientific approach as required with the peers, hence there is little reflection on what is being assessed. Implementing CBC in chemistry requires alignment not only in classroom practices but also in assessment systems. Without reform at the national exam level, teachers may feel compelled to continue teaching to the test, undermining the formative, competency-driven potential of CBC.

Teacher Preparedness differed significantly across countries ($p = 0.019$), with Kenya scoring highest suggesting that Kenyan teachers may have benefited from stronger CBC-oriented training structures and more sustained professional development(Namubiru et al., 2024). Classroom observations showed that teacher-centered methods remained dominant, particularly in Tanzania and Burundi, where lessons relied heavily on dictation, chalkboard exposition, and prescriptive solution strategies practices aligned with the essentialist, content-delivery traditions critiqued (Gravoso et al., 2008). This is evident from teacher preparedness ($\alpha = 0.76$) though acceptable but comparatively lower consistency, suggesting potential variability in teacher training across contexts Moreover, the dominance of teacher-centered teaching is consistent with other studies from East African states, which report that chemistry lessons often remain lecture-oriented with limited laboratory engagement, even in competence-based curricula (Kirui & Keter, 2020; Kafyulilo et al., 2012). These tendencies were further reinforced by limited exposure to modern chemical industries and inadequate practical resources (Anangisye et al., 2022), which collectively constrained teachers' ability to implement competency-based pedagogies. Country-level disparities in teacher qualifications deepened these challenges for example in Tanzania, chronic shortages of trained chemistry teachers meant that some rural schools shared a single qualified teacher or relied on non-specialist (Chacha, & Onyango, 2022) while similar staffing gaps appeared in parts of Kenya especially northern regions where socio-political instability disrupts teacher deployment and forces schools to depend on non-specialist instructors.

Classroom practices across the region revealed a persistent emphasis on superficial recall rather than higher-order thinking, mirroring the traditional assessment methods that Al-Sabbah et al., (2022) argue suppress critical thinking, innovation, and conceptual understanding competencies central to CBC. Although effective chemistry instruction relies on questioning techniques that activate prior knowledge, guide attention, and stimulate prediction and reasoning such strategies were minimally observed. Jegstad (2023) urges that inquiry-based approaches in which students explore, ask questions, and engage in sense-making instead of passively receiving information have potential benefits for conceptual understanding and meaningful chemical reasoning. Interestingly, despite these structural and pedagogical constraints**,** pedagogical competence emerged as the most reliable construct ($\alpha = 0.84$). ANOVA results showed no significant cross-country differences ($p = 0.136$), indicating that teachers in the region share similar levels of theoretical CBC related pedagogical knowledge. However, the noticeable gap between teachers' conceptual understanding and their actual classroom implementation reinforces (Mosha ,2021), who highlighted that while many teachers from this region understands CBC in theory, they often lack the practical training, resources, and continuous professional development required for effective enactment.

The reliability analysis across both the questionnaire constructs (Table 6) and the classroom observation subscales (Table 7) demonstrates that the instruments used in this study were psychometrically sound and suitable for examining competency-based chemistry instruction in the sampled countries. Across all constructs, Cronbach's alpha values ranged from 0.75 to 0.85, reflecting acceptable to good internal consistency. The questionnaire constructs showed strong performance, with Pedagogical Competence ($\alpha = 0.84$) and Learner Engagement ($\alpha = 0.82$) yielding the highest reliabilities. These findings indicate that items capturing teachers' instructional competencies and learners' active participation were highly coherent. Thus, the overall reliability outcomes of the study combined with cross-country evidence suggest that although teachers possess a baseline understanding of CBC philosophy, systemic constraints such as limited laboratory access, insufficient training, and shortages of specialized chemistry teachers impede effective assessment and classroom practice. These findings highlight a persistent misalignment between CBC ideals and classroom realities across East Africa. Chemistry-specific challenges also played a role. Teachers reported difficulty in facilitating open-ended experimentation, guiding students through inquiry-based processes, improvising scientific materials, and differentiating instruction for mixed-ability learners and this has been a disturbing factor (Ochieng et al, 2019). Additionally, our findings indicate that the kinds of knowledge teachers developed were contingent on the structure of the lesson plan. They rely heavily on general pedagogical knowledge particularly explanation skills and classroom management while under-developing the chemistry-specific pedagogical content knowledge (PCK**)** that CBC implementation demands. These findings imply that while teachers possess foundational

pedagogical skills, their competence in CBC-driven chemistry instruction needs reinforcement through targeted professional development.

Learner Engagement showed no significant cross-country differences ($p = 0.110$), indicating that learner-centered CBC practices face similar regional constraints such as overcrowded classrooms, limited facilities, and traditional teaching habits. This is confirmed via Learner Participation ($\alpha = 0.78$) which mirrors the questionnaire findings, reflecting consistent measurement of student involvement. Nonetheless, observations showed moderate but uneven engagement, with Kenya and Uganda performing better than Tanzania and Burundi. Given that chemistry competencies rely heavily on hands-on, interactive learning, these variations likely stem from differences in teacher confidence, resource availability, and CBC training exposure. In agreement with Ssebbunga (2022), the results show that learner engagement persists as a major weakness in CBC implementation within resource-limited African contexts.

The socio-cultural and economic context adds further layers of complexity .From our studies, it realizes that CBC is not effectively addressing socio-economic needs as intended, at both individual and national level even though the CBC has been introduced in East African countries to enhance the quality of education, the chemistry curriculum is still implemented in traditional ways. This study is fully behind the idea of establishment of special 'laboratory' schools or science education centers as well as school-based communities of practice to enhance teachers' content knowledge and nurture contemporary teaching methods for the successful implementation of the new ideas that is also beneficial to societal. In addition, from our findings, students to take chemistry because education fashioned chemistry man as an intellect and accrued to jobs, this has led to, large chemistry class sizes and the well-intention institutions reforms in chemistry to falter .As observed in broader studies of CBC implementation, inadequate monitoring and evaluation, as well as insufficient stakeholder engagement, exacerbate these challenges (Majiwa et al, 2025)

From table 6, the model explains a substantial proportion of variance in learner engagement ($R^2 = 0.51$), meaning that 51% of the differences in how actively learners engage in chemistry lessons can be attributed to the two teacher-related factors. In educational studies, an explained variance above 50% is considered very strong, indicating that teacher factors play a central role in shaping classroom engagement under the Competence-Based Approach (CBA) hence learning is teacher centered. The overall regression model is highly significant ($F(2,117) = 60.4$, $p < 0.001$), confirming that the combined influence of teacher preparedness and pedagogical competence is not due to chance. Individually, both predictors are statistically significant ($p < 0.001$). However, pedagogical competence ($\beta = 0.42$) contributes more strongly to learner engagement than teacher preparedness ($\beta = 0.35$). This means that how well teachers apply learner-centered strategies, practical activities, and effective questioning techniques has a greater impact on student engagement than simply being prepared for lessons. These findings suggest that improving learner engagement in CBA chemistry classrooms requires enhancing teachers' instructional competence, strengthening professional development, and supporting teachers to effectively implement active,

practice-oriented chemistry pedagogy. These values strongly indicate that teacher quality is central to the success of the competence-based Approach in East African chemistry classrooms.

The results of this study reveal significant disparities in the depth and quality of pedagogical competencies demonstrated by chemistry teachers across the five East African countries. Teachers who adopted a guided yet predominantly teacher-centered approach primarily characterized by delivering prescripted solution procedures rather than facilitating inquiry showed stronger development of General Pedagogical Knowledge (GPK) than Pedagogical Content Knowledge (PCK). This imbalance is evident in our coding analysis from observations and interview data, where 59.73% of the code applications for these teachers aligned with GPK, compared to only 23.12% associated with chemistry-specific PCK. Such a pattern suggests that although teachers possess basic instructional management and explanation skills, they lack the chemistry-specific pedagogical reasoning needed for competence-based instruction most probably due to lack of chemical plants where they can value there specific pedagogical skills rather than teaching for the sake of teaching. This interpretation is strongly supported by the quantitative performance scores, particularly the moderate outcomes in Curriculum Alignment (60%) and Competency-Based Framework (62.5%), contrasted with substantially lower outcomes in Practical Implementation (45.8%) and Compliance with CBC Standards (43.8%). The low compliance and implementation scores affirm that even when teachers understand the goals of the competence-based curriculum on paper, they struggle to translate these goals into meaningful classroom practice where conceptual understanding, laboratory inquiry, and higher-order reasoning are central.

Further strengthening the consistency of these findings, the Cronbach's alpha reliability test for the teacher questionnaire produced a high internal consistency coefficient ($\alpha = 0.82$), indicating that the measured constructs curriculum alignment, competency-based processes, instructional design, and compliance were coherent and reliably assessed. The learner questionnaire also demonstrated satisfactory reliability ($\alpha = 0.78$), suggesting that the learners' perceptions of engagement, clarity of instruction, and opportunities for inquiry were dependably measured. Importantly, the learner data showed that only 37% of students felt they frequently engaged in hands-on chemistry activities, while 62% reported that lesson delivery was predominantly lecture-based. These learner-reported patterns reinforce the teacher-centered observations and further justify the limited development of PCK in chemistry instruction across the sample.

The cross-country comparison of classroom observation scores provides additional contextual insight. Kenya and Uganda scored moderately well on items assessing clarity of explanation and teacher guidance but scored poorly on items related to student inquiry, practical engagement, and conceptual problem-solving. In contrast, Rwanda and Burundi consistently recorded lower scores across both conceptual and procedural domains, indicating broader systemic constraints. Tanzania showed relative strength in procedural demonstration but weakness in inquiry facilitation. These cross-national trends affirm that the constraints are regional and structural, not limited to isolated school contexts.

Our interview and document analysis findings provide explanatory depth to the observed patterns. Many chemistry teachers reported entering the profession primarily for employment stability rather than from a strong disciplinary or pedagogical passion. This reflects evidence from previous studies (Ochieng & Ndayambaje, 2023; Mwakapenda, 2008)) showing that a number of teachers under developed nations in often lack comprehensive grounding in subject-specific pedagogy. This structural deficiency helps explain why chemistry teachers in our study performed acceptably in curriculum alignment yet struggled significantly with practical implementation, which requires advanced pedagogical content knowledge elements such as diagnosing misconceptions, linking macro, sub-micro, symbolic representations, designing inquiry tasks, and scaffolding chemical reasoning.

Intrigues, Paradoxes, and Contextual Complexities

One of the most compelling intrigues of implementing a Competence-Based Curriculum in East African regions lies in the paradox between high policy ambition and low practical capacity. While the CBC is designed to promote 21st-century competencies such as critical thinking, problem-solving, and applied knowledge, many teachers in these contexts report feeling ill-prepared to actualize these lofty aims. Some studies also suggest that teachers feel marginalized in the design of the CBC, which can affect their motivation and sense of agency. In Kenya, for instance, many teachers reported that their voices were not adequately considered during curriculum development, leading to a lack of clarity about their role and responsibility (Owidi et al, 2023).Without a strong sense of ownership, implementation becomes more superficial.

Another paradox emerges in assessment: the CBC emphasizes continuous, formative assessment aligned with competencies. However, in Uganda, research shows that many teachers lack proficiency in designing CBC-aligned assessment tools(Nakawuki et al,2025).This deficit is not necessarily due to unwillingness but often due to systemic gaps such as large class sizes, heavy teacher workload, and limited time make the development of well-designed rubrics, performance tasks, and competency-based assessments very challenging.

Socio-economic and systemic constraints further complicate the narrative. For example, Namatende-Sakwa et al., (2025) emphasize that transitioning from a knowledge-based to a competence-based curriculum in Uganda brings not only pedagogical challenges but also structural threats such as inequitable distribution of resources, insufficient stakeholder engagement, and inadequate infrastructure in rural districts. These structural barriers make the CBC seem aspirational, rather than readily achievable.

Yet, there is a bright side in this intrigue. The moderate scores in curriculum alignment and competency framework from your study indicate that teachers are not entirely resistant to the approach. They understand the philosophy and importance of CBC. This foundation offers a window of opportunity: with targeted and context-sensitive support, the CBC could be better realized. For instance, professional development that emphasizes *practical, chemistry-specific*

pedagogy, peer mentorship, and the use of low-cost or improvised laboratory materials could help bridge the theory-practice gap.

Finally, the very struggle to implement CBC in underdeveloped contexts reveals a deeper, systemic paradox: education reform in these regions often demands more resources and capacity than exist, yet is justified precisely by the need to develop skills that will help societies overcome underdevelopment. In other words, the CBC aspires to build capacity, but requires capacity to function this circular challenge is deeply intriguing and demands careful attention from policymakers.

Conclusion and Recommendations for Future Research

Conclusion

In sum, the "intrigues" of applying a competence-based approach to chemistry teaching are multidimensional, shaped by systemic resource scarcity, assessment misalignment, limited teacher capacity, and entrenched examination-driven practices that undermine the curriculum's transformative aims. This study shows that competence-based chemistry instruction remains significantly constrained by limited pedagogical competence and weak practical implementation. Although Kenya, Uganda, Tanzania, and Burundi exhibit modest differences in teacher preparedness and resource availability, they share common systemic barriers such as inadequate laboratory access, overcrowded classrooms, and insufficient professional development. While most teachers understand competence based curriculum principles conceptually, classroom practice remains predominantly teacher-centred, reflecting a structural not merely methodological and capacity gap. Overall, these tensions continue to impede meaningful realization of competence goals. Strengthening chemistry-specific pedagogical content knowledge, improving laboratory provisioning, and aligning assessments with authentic competencies are essential steps forward. These challenges do not render competence based curriculum unworkable, but they demand deliberate, context-responsive strategies to support sustainable implementation.

6.2 Implications

The study highlights several implications for CBC implementation in chemistry:

Strengthening Teacher Capacity

Effective CBC adoption requires ongoing, practice-oriented professional development rather than one-off workshops. Capacity-building must focus on hands-on pedagogy, inquiry facilitation, and assessment literacy.

Investment in Laboratory Resources

Schools need low-cost, scalable laboratory solutions to support practical chemistry activities and develop learners' scientific competencies.

Assessment Reform

Misalignment between CBC competencies and national examination formats continues to reinforce memorization-based teaching. Assessment frameworks must be restructured to support inquiry, problem-solving, and practical skills.

Policy and System-Level Support

Effective CBC implementation depends on adequate teacher deployment, equitable resource allocation, and monitoring mechanisms that prioritize competency development.

These implications point to the need for multi-level collaboration involving teachers, policymakers, curriculum developers, exam bodies, and school administrators.

Recommendations for Future Research

Building on the gaps identified in this study, several research trajectories are recommended to strengthen CBC implementation in chemistry education and these include:

Enhancing Chemistry Teachers' PCK for CBA through Professional Learning and Comparative Analysis

Future research should investigate how different professional development models—such as peer mentoring, laboratory-focused workshops, school-based coaching, and long-term in-service training—enhance chemistry teachers' Pedagogical Content Knowledge (PCK), while also conducting comparative studies across STEM subjects to determine whether PCK challenges in chemistry differ from those in biology, physics, or mathematics. Such longitudinal and cross-disciplinary analyses would clarify how PCK evolves over time and identify the interventions that yield the most sustained and subject-specific pedagogical improvement.

Strengthening CBA Implementation through Systemic Policy Reforms and Low-Cost Laboratory Innovations to Enhance Practical Competencies

Future research should adopt both systemic and classroom-level perspectives to strengthen CBA implementation in chemistry education. On one hand, studies should investigate the effectiveness of low-cost laboratory innovations such as improvised apparatus, mobile laboratory models, and micro-scale experiments in improving learner engagement, inquiry competencies, and teacher confidence within resource-limited environments. On the other hand, policy-oriented research is needed to examine how broader systemic factors, including resource allocation, teacher deployment strategies, stakeholder engagement, and monitoring and evaluation frameworks, shape the quality and consistency of CBA delivery. Integrating these classroom-level and policy-level insights through comparative policy analyses will help identify scalable, context-responsive models capable of sustainably strengthening chemistry education across diverse settings

Assessment Reform and CBC Alignment

Investigations into the alignment between CBC-based assessments and high-stakes national examinations can reveal structural contradictions that undermine competency development.

Research should explore how performance-based tasks, rubrics, and science portfolios influence chemistry learning outcomes.

Ethnographic Studies of Classroom Practice

Ethnographic and micro-analytic studies can provide rich insight into how teachers adapt CBC principles within everyday instructional constraints. Such work will illuminate the nuanced pedagogical decisions often missed in survey-based studies.

Locally adaptive inquiry models through action research

Teacher-led action research is needed to develop locally relevant, resource-sensitive inquiry models that align with CBC principles. Such studies can generate practical frameworks for promoting scientific reasoning and experimental skills in low-resource chemistry classrooms.

Socio-economic and Political Instability

These studies can generate a peaceful environment whereby qualified chemistry teachers can crisscross boundaries, sharing of resources and knowledge for the betterment of the region

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Conflict of interest

The Corresponding author declare that the research was conducted in the absence of any Institution, commercial or financial relationships that could be construed as a potential conflict of interest.

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