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Keywords

Africa, critical thinking inventory, higher education in Kenya, assessment validation, confirmatory factor analysis

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Abstract

The global importance of critical thinking in enhancing academic success, employability, civic engagement, and mental health is universally acknowledged. Yet, its cultivation in educational systems, particularly in Kenya, requires further attention. This gap is pronounced in Kenya's higher education, where more research is needed to develop and validate effective critical thinking assessment tools given the paradigm shift in its educational curricular. This study contributes to this need by evaluating the applicability of the Critical Thinking Inventory (CTI) model in Kenyan higher education. Using a convenience sample of 387 undergraduates from Egerton University, the study assessed the alignment between the CTI model, which measures information engagement and seeking, and observed variables in this context. The confirmatory factor analysis (CFA) results indicated a less-than-ideal fit ($\chi 2(169) = 503.204$, $p < .000$; CFI = .835; TLI = .795; RMSEA = .072), suggesting the need for further validation of the CTI model in this setting. Future research should extend to a more diverse and larger sample across various universities to improve the generalizability of these findings beyond a single institution. This study adds valuable insights into the critical thinking literature in higher education and highlights the need for ongoing research in Kenya. There is an evident necessity for future studies to focus on developing and validating contextually appropriate critical thinking assessment tools, following recommended validation procedures. Such efforts are crucial for a meaningful evaluation of critical thinking skills in the Kenyan competency-based educational system.

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Introduction

The agricultural sector faces complex challenges, necessitating skilled management, planning, and policymaking. Early agricultural researchers, such as Shahvali (1997), recognized the importance of education in preparing students for the changing dynamics of agriculture. They highlighted the need for agricultural higher education to focus on competencies, especially incorporating population education paradigms (Shahvali, 1997; van Crowder et al., 1998). These competencies were designed to enable agricultural graduates to tackle population-centered challenges and the intricate human aspect of agriculture. Leadership development and the creation of effective agricultural solutions were key outcomes of this competency-based approach (Roling & de Jong, 1998; Shahvali, 1997; van Crowder et al., 1998), with critical thinking being a central element. Scholars advocated for transnational collaboration to improve population-related skills among agricultural graduates (Roling & de Jong, 1998).

Recent policy documents highlight the importance of critical thinking in agricultural education. The Global Agriculture and Food Security Program (GAFSP, 2019) considers critical thinking essential for graduates facing the sector's complex issues. UNESCO (2015) and the United States Department of Agriculture (USDA; 2018) also emphasize its importance in agricultural pedagogy. The United Nations' Sustainable Development Goals (SDGs, 2015) stress agriculture's key role in sustainable development, requiring critical thinking to address its diverse challenges. Additionally, critical thinking is noted as an important quality in graduates of agricultural institutions, crucial for preparing future agricultural professionals (Association of Public and Land-grant Universities, 2018).

This study investigates the dimensional validity and reliability of the Critical Thinking Inventory (CTI, Lamm & Irani, 2011) in the context of Kenyan higher education. It is based on the Paul-Elder Model of Critical Thinking, aligning with the research objectives. The Paul-Elder model provides a comprehensive framework, including elements like conceptualization, application, synthesis, and knowledge evaluation from various experiences (Paul & Elder, 2006). It focuses on attributes such as clarity, accuracy, precision, and logic, offering a formal framework for assessing critical thinking skills. This study evaluates the relevance and reliability of the CTI within the Paul-Elder theoretical framework, with implications for enhancing critical thinking in agricultural higher education.

Defining Critical Thinking

Critical thinking, widely recognized as a valuable skill, has long been the subject of scholarly debate regarding its definition. Fasko and Fair (2003) observed the lack of a universally accepted definition. Facione (1990) described critical thinking as "purposeful, self-regulatory judgment that includes interpretation, analysis, evaluation, inference, and the consideration of conceptual, methodological, or contextual factors" (p. 2). Paul and Elder (2003) defined it as the ability to control one's own thinking in accordance with established standards. Cottrell (2011) highlighted that critical thinking encompasses problem-solving, drawing inferences, estimating probabilities, and making decisions. Lamm (2015a, 2015b) portrayed critical thinking as a rational and logical cognitive process for deducing results and solving problems. These definitions collectively suggest that critical thinking involves argumentation, inference, and problem-solving (Ongesa, 2020). Carson (2021) expanded this view by stating that students exhibit critical thinking when they form judgments, evaluations, and conclusions based on evidence. Despite the diverse definitions, the importance of critical thinking as a vital

skill for academic success, professional achievement, and everyday decision-making remains undisputed.

Critical Thinking in Education and the Workplace

The importance of critical thinking in today's rapidly evolving and globally competitive job markets cannot be overstated, emphasizing the need for educational institutions to devote substantial resources to its development in students (Barrick & DiBenedetto, 2019; Ongesa, 2020; Shavelson et al., 2019). Critical thinking is one of six essential intellectual and practical skills undergraduate students should acquire, according to higher education accreditation bodies (American Association of Colleges and Universities, 2007). Various studies affirm critical thinking as an essential skill for the 21st-century workforce (Shavelson et al., 2019; Shaw, 2014; Stauffer, 2020), enabling individuals to engage in systematic and methodical problem-solving (Shaw, 2014; Stauffer, 2020) and address complex societal challenges, including climate change, conflict, insecurity, and pandemics (McCowan, 2019).

Therefore, it is crucial for schools and colleges to adopt a critical pedagogy approach, equipping students with critical thinking skills necessary for the labor market (Crockett, 2016; National Research Council, 2009). Possessing adequate critical thinking skills is associated with academic success, employability, increased civic responsibility, and psychological well-being (Barrick & DiBenedetto, 2019; Stupple et al., 2017). In other words, critical thinking skills enable graduates to make well-informed decisions while contributing significantly to society (Stupple et al., 2017). However, research indicates that many educational institutions put less emphasis on the development of critical thinking skills (Ghadi et al., 2013; Ongesa, 2020), resulting in a workforce largely lacking these skills and contributing to global unemployment (Anisa, 2018; Crockett, 2016).

Critical Thinking and Sub-Saharan Africa

The burgeoning population of Africa, predicted to surpass one billion by 2050, with more than half of its individuals under 24 years old, underscores the critical need to cultivate critical thinking skills among the continent's youth (Winthrop & McGivney, 2017). This demographic surge highlights a pressing challenge: bridging the anticipated skill gap in the workforce, notably in medium- and high-skilled jobs, especially in regions like South Asia and Africa. Dobbs et al. (2012) and Stauffer (2020) emphasize the potential of critical thinking in mitigating the looming shortages in the skilled labor force, positioning it as a crucial factor for Africa to gain a competitive edge in the global marketplace.

However, the current state of critical thinking skills among graduates, particularly in Sub-Saharan Africa, presents a significant obstacle to the region's educational and economic advancement (McCowan, 2019; Schendel et al., 2020). Despite infrastructural and financial challenges, the primary issue remains the need for more cultivation of critical thinking skills among students (McCowan, 2019). This deficiency in critical thinking is more pronounced given its established importance, yet there is a notable scarcity of research on this topic within the Kenyan context. Ongesa (2020) stands out as a rare scholar delving into the flaws of the Kenyan educational system in fostering critical thinking, highlighting a gap in the academic discourse.

In Kenya, since its inception in 1963, the educational system has predominantly focused on knowledge acquisition, often sidelining the integration of critical thinking into its pedagogical framework (Ongesa, 2020; Schendel et al., 2019). Educational reforms over the years, primarily

focusing on curriculum objectives, have seen the introduction of the competency-based curriculum (CBC). This new curriculum aims to address the shortcomings of the previous educational approaches. Nevertheless, despite its ambitions, the CBC falls short in explicitly defining a philosophy and action plan for developing critical thinking, lacking specific methods for measuring learning outcomes in this area (Walton & Ryerse, 2017).

While a substantial body of research on critical thinking exists globally, the investigation of this skill within the Kenyan educational system has been relatively limited (Abrami et al., 2008; Basweti, 2019; Englebert, 2021; Gacheru et al., 1999; Githui et al., 2017; Kimani, 2019; Nicholson et al., 2017; Ongesa, 2020; Rolleston et al., 2019; Schendel et al., 2019). The focus of these studies has varied, with some concentrating on the development of critical thinking instruments and others examining the factors influencing students' critical thinking skill levels, particularly in secondary education (Kimani, 2019; Schendel et al., 2020) and higher education (Ongesa, 2020; Rolleston et al., 2019; Schendel et al., 2020). Ongesa (2020) notably investigated the Kenyan higher education system, identifying fundamental flaws that impede the development and transmission of critical thinking skills.

Ongesa's (2020) findings revealed that higher education institutions in Kenya face significant challenges regarding tasks that demand critical thinking skills. Many Kenyan students were found to pose lower-order questions because their teachers did not introduce them to higher-order questioning techniques. This issue was further compounded by the fact that the teachers themselves needed to be adequately trained in critical thinking methodologies, partly explaining the observed limitations in students' critical thinking abilities.

Similarly, Rolleston et al. (2019) conducted a study using Bigg's two-factor study process questionnaire (R-SPQ2F) in Botswana, Ghana, and Kenya. They aimed to assess how well the R-SPQ2F results could predict incoming students' critical thinking skills concerning deep and surface learning. The revised R-SPQ2F (SPQ) instrument was found to possess high reliability and construct validity in these African higher education settings, effectively measuring significant differences in the critical thinking dimensions of deep and surface learning. These findings imply that universities could leverage this instrument to anticipate areas where students may develop critical thinking skills.

In summary, while there have been valuable insights provided by the limited studies on critical thinking in Kenya's university system, these studies collectively highlight the need for a standardized, reliable, and valid tool to assess a broader range of critical thinking dimensions. This includes but is not limited to, the skills of seeking and engaging with information essential for the holistic development of students in Kenyan educational institutions.

Critical Thinking Inventory

As the world grows more interconnected, the importance of critical thinking skills has become increasingly evident for individuals and nations. Nonetheless, the ability of current instruments to effectively evaluate these skills in diverse contexts, such as Kenya, still needs to be fully understood. This study assessed the validity, construct reliability, and measurement model fit of the Critical Thinking Inventory (CTI; Lamm & Irani, 2011) for undergraduate students in Kenya. The findings not only have implications for the implementation of the competency-based curriculum in Kenya but also for the development of critical thinking skills among graduate students preparing to enter the workforce. Additionally, the study highlights the need for further research to establish a valid and reliable instrument for international and cross-cultural comparisons of critical thinking skills, an area underscored by critical thinking scholars

(see Rolleston et al., 2019). Although the CTI has been validated in several contexts, as evident in research by Akins et al. (2019), Baker et al. (2021), Gorham et al. (2014), and Leal et al. (2017), its effectiveness in the context of Sub-Saharan Africa remains unexplored. Therefore, using an established instrument like the CTI in a new context could be a more cost-effective approach than creating a new one, as suggested by Kimberlin & Winterstein (2008), making it essential to conduct further studies to determine the effectiveness of CTI in higher education settings in Kenya and other Sub-Saharan African nations.

The CTI is designed to assess critical thinking styles (Lamm & Irani, 2011) and comprises 20 Likert-type items, ranging from engagement to knowledge seeking (Lamm, 2015a). These items are scored on a scale from 1 (Strongly Disagree) to 5 (Strongly Agree), with 13 questions dedicated to assessing information seeking and seven to evaluating engagement. Students scoring 79 or higher are identified as seekers and strongly inclined towards learning and understanding multifaceted issues, even those that challenge their beliefs. Those scoring 78 or lower are categorized as engagers who are actively involved in their environment and excel in demonstrating their reasoning and problem-solving skills. Lamm and Irani (2011) noted that engagers are confident in their communication abilities and skilled at articulating their decision-making processes.

Over approximately a decade, the CTI has been extensively used in various fields, including agricultural extension and higher education, evidencing its solid psychometric properties and consistency across different settings. Its application spans a range of topics, from opinion leadership and extension communication (Putnam et al., 2017) to agricultural issues (Akins et al., 2019) and food safety behavior (Leal et al., 2017). Additionally, agricultural education research has utilized the CTI to explore critical thinking in traditional and online classroom environments (Stedman & Adams, 2014) and among agriculture students in study abroad programs (Roberts et al., 2018). Baker et al. (2021), referencing these various studies (Akins et al., 2019; Gorham et al., 2014; Leal et al., 2017), reported that the CTI's reliability, as measured by Cronbach's alpha, varied from 0.79 to 0.95, with the seeker construct scoring between 0.87 and 0.92 and the engager construct between 0.87 and 0.90.

Transforming Kenya's educational system, particularly transitioning from rote learning to a focus on developing critical thinking skills through a competency-based curriculum, is a formidable challenge. Measuring the effectiveness of this new pedagogical approach is crucial for its success. Although the CTI is widely utilized in the United States, its applicability in Sub-Saharan Africa, specifically in Kenya, is yet to be ascertained. However, the CTI offers a cost-effective solution for the Kenyan government to establish a credible criterion-referenced instrument for evaluating critical thinking across the nation amidst this significant paradigm shift in the higher education system. By doing so, Kenya can ensure that its new curriculum aligns effectively with its students' critical learning style needs and equips them with the critical thinking skills essential for the future workforce.

Theoretical Framework

Psychometric theory elucidates the complex relationships between psychological attributes and observable behaviors, typically evaluated through various means such as questionnaires, tests, or other forms of assessment (Nunally, 1978). Within this theoretical framework, numerous psychological attributes are conceptualized as latent constructs, which, while not directly observable, can be inferred through specific behaviors or responses. These latent constructs are quantified using validated scales and criteria. This process involves

sophisticated techniques such as multidimensional scaling, factor analysis, item response theory, and applying corrections for guessing to enhance the accuracy of the measurements (Nunally, 1978). The Critical Thinking Inventory (CTI) was selected as the primary measurement instrument for this research because of its strong foundation in psychometric theory, offering a comprehensive means to assess critical thinking skills (Lamm & Irani, 2011).

This study followed a deductive approach to thoroughly assess the CTI, recognized as a multidimensional tool, in terms of its reliability, validity, latent features, scaling, and item analysis (Nunally, 1978). This methodical approach allowed for a deep exploration of the CTI's psychometric properties, aiming to affirm its accuracy and robustness as a tool specifically for evaluating critical thinking within the context of Kenya's higher education system. A vital aspect of this theoretical approach is the strong emphasis on the validity and reliability of psychometric assessments (Nunally & Bernstein, 1994). Validity is crucial as it ensures that the instrument accurately measures its intended assessment construct (Ary et al., 2018). Following stringent psychometric standards, this study carefully evaluates validity through various lenses, including predictive, content, and construct validity. These criteria provide a comprehensive and robust foundation for applying the CTI within Kenya's agricultural education landscape.

On the other hand, reliability refers to the instrument's ability to produce stable and dependable results over time consistently (Ary et al., 2018). Given the diverse linguistic and cultural landscape within the Kenyan Higher Education System, conducting a thorough psychometric analysis is essential. This analysis ensures the instrument is adaptable, maintaining its validity and reliability across different cultural and educational contexts (Geisinger, 1994). Therefore, this study not only focuses on the technical aspects of the CTI but also delves into its applicability and relevance in a culturally diverse educational environment like Kenya.

Purpose and Objectives of the Study

The purpose was to conduct a confirmatory factor analysis (CFA) of the CTI among undergraduates at Egerton University, Kenya. Specifically, the study sought to determine whether the CTI model effectively captures the critical thinking styles of Egerton University undergraduates, as it is traditionally applied in diverse educational contexts. This research intends to contribute to the broader understanding of the applicability and relevance of CTI in different cultural and educational environments. The findings of this study have implications for the adoption and adaptation of CTI in similar settings and offer valuable insights for educators and researchers in the field of critical thinking assessment. The study was guided by one research objective:

RO: To determine the fit of the CTI model in assessing the critical thinking styles of undergraduates at Egerton University, Kenya.

H_0: The CTI model does not adequately fit the data from Egerton University undergraduate students.
H_1: The CTI model adequately fits the data from Egerton University undergraduate students.

Methods

Research Design and Sampling

This study utilized a CFA to assess the model fit, validity, and reliability of the CTI (Lamm & Irani, 2011) in Kenya's higher education following pre-determined standards by several scholars (Hair et al., 2019; Hooper et al., 2008; Kline, 2015). The target population for the study was undergraduate students in Kenya. The study utilized a convenience sample of 387 undergraduate students from Egerton University. The ease of obtaining a sample is the researcher's primary selection standard in convenience sampling (Hibberts et al., 2012). Gall et al. (1996) justified using a convenience sample if the researcher explained the selection procedure and rationale. Meanwhile, Keiser (1960) recommended a minimum of 300 to improve the validity of CFA results.

Data Collection

After obtaining research authorization from the University of Georgia and Egerton University administration, students were given access to the online survey via a link hosted on Qualtrics. Two reminder emails were sent weekly through Egerton University's mass communication system to ensure consistency and enhance the response rate. Of the 553 students invited to participate in the study, 387 responded, resulting in a 70% response rate. This response rate aligns with established social science research standards (Baruch & Holtom, 2008) and effectively represents the target demographic. However, it is essential to acknowledge that the findings are specific to Egerton University, the sole source of data collection. As such, these results are indicative of the critical thinking styles of only a segment of Kenyan university students. This study is part of a larger research project that will culminate in multiple publications derived from a common dataset (Kirkman & Chen, 2011).

Instrumentation and Study Variables

The Critical Thinking Inventory (CTI; Lamm & Irani, 2011) was formatted for an online survey and distributed to participants using Qualtrics. The CTI comprises 20 Likert-type items, each rated on a five-point scale from Strongly Disagree (1) to Strongly Agree (5). Of these questions, thirteen are designed to assess information seeking, while seven focus on engagement. Considering that English is the primary language of instruction in Kenyan educational institutions, the CTI was administered in its original language and format. The post hoc reliability analysis of the instrument yielded Cronbach's alpha coefficients (1951), which are within the acceptable range, with values of .70 and above, aligning with established psychometric standards (Nunally, 1978).

Data Analysis Procedure

The analysis aimed to rigorously assess the structural validity of the CTI in a Kenyan university setting. The data were analyzed and interpreted using the statistical software AMOS (Version 17). CFA requires large samples to construct repeatable and reliable factors; however, researchers differ on what constitutes an adequate sample size for a CFA. Several scholars concur that a minimum of 300 observations are sufficient for a CFA (Comrey & Lee, 2013;

Keiser, 1960; Tabachnick & Fidell, 2019). The sample size needed for the study was also calculated under the guidance of Cochran (1963) using the following equation:

$$n_0 = \frac{Z^2 pq}{e^2} = \frac{1.96^2 \times 0.5(1-0.5)}{0.05^2} = 385$$

In the equation, the standard distribution of the confidence interval (Z) is 1.96 which is the associated Z value for a 95% confidence interval. Maximum variability in the population is accounted for with p = 0.5. The margin of error (e) is 5%. Therefore, the present study's sample of 387 respondents was deemed sufficient for CFA. Missing data were estimated in AMOS using full information maximum likelihood (FIML) estimation, which is commonly used by structural equation modeling programs as it produces unbiased parameter estimates and standard errors when missing values are considered missing at random (MAR; Enders & Bandalos, 2001).

Model fitness in the present CFA was evaluated using the chi-square (χ^2) goodness of fit, the root means square error of approximation (RMSEA), comparative fit index (CFI), and Tucker-Lewis index (TLI; Hair et al., 2019; Hooper et al., 2008). A model with a nonsignificant χ^2 test indicates good model fit, but it is frequently overly sensitive with large samples such that almost all models are rejected (Hooper et al., 2008). Model fit indices included RMSEA values of .07 and below indicates reasonable model fit, and models with RMSEA above 0.1 should not be employed (Browne & Cudeck, 1992; Hooper et al., 2008). Additionally, for continuous data, RMSEA values between .06 and .08 are considered acceptable, while for categorical data, the values should be less than .06 (Schreiber et al., 2006). CFI values greater than .90 indicate satisfactory model fit, while values greater than .95 indicate excellent model fit (Hooper et al., 2008). TLI values greater than .90 indicate a good fit for the model (Hooper et al., 2008; Hu & Bentler,1999). Lastly, the squared multiple correlations (R^2) for each endogenous variable were conducted to identify how much of the indicator variable's variance explained the two critical thinking factors (Hooper et al., 2008). Any indicator with an R^2 value less than .20 is deemed insufficient in describing the latent variable and is, therefore, subject to removal (Hooper et al., 2008).

Robustness and Validity of the Study

Several steps were taken to validate the study. The Critical Thinking Inventory (CTI) survey was chosen after a thorough literature analysis and its proven efficacy in testing critical thinking skills (Lamm & Irani, 2011). This first step ensured content validity since the CTI measures critical thinking. To retain linguistic validity in Kenyan higher education, where English is the teaching language, the CTI was used in its original English version. This option minimized measuring inaccuracies from translation or cultural adaptation. The CTI survey was administered via Qualtrics, a popular online survey platform, to ensure data gathering was uniform and controlled, which improved construct validity. It also simplified response data administration, decreasing data entering errors. Reliability: The study stressed data reliability. A post hoc reliability test showed Cronbach's alpha coefficients above.70 (Nunally, 1978). This test verified the CTI survey items measured information seeking and engagement, improving its internal consistency and dependability.

Robustness was achieved by analyzing data through AMOS (Version 17) because it supports Confirmatory Factor Analysis (CFA), a method known for confirming measurement models. CFA required 387 responders, as recommended by the literature (Comrey & Lee, 2013;

Keiser, 1960; Tabachnick & Fidell, 2019). Furthermore, the CTI survey was selected systematically based on its relevance and applicability to the research environment. The study also used Qualtrics for survey administration and frequent reminders to encourage high response rates. The study's data analysis was further strengthened by using CFA and model fit indices (RMSEA, CFI, TLI). The acknowledgment of potential limitations, such as the study's focus on a particular university and the lack of data from all Kenyan universities, brings transparency to the research and allows readers to evaluate its generalizability.

Results

Measurement Model Fit

The CFA results showed that the hypothesized model did not adequately fit the data from Egerton University ($\chi^2(169) = 503.204$, $p < .000$; CFI = .835; TLI = .795; RMSEA = .072). The chi-square value was examined but not solely relied upon due to its known sensitivity to sample size. The model did not meet any of the established fit parameters (Hu & Bentler, 1999). Consequently, the confirmatory factor analysis results do not provide sufficient evidence to reject the null hypothesis, implying that the CTI model may not adequately fit the data from Egerton University (Shek & Yu, 2014). The fit indices are presented in Table 1.

Table 1

Fit Indices for the CFA Model of Kenyan Undergraduate Students

Model Tested	χ^2	*df*	TLI[1]	CFI[2]	RMSEA[3]
Model performance	503.204	169	.795	.835	.072
Criterion for the goodness of fit	-	-	≥.90	≥.90	≤.70

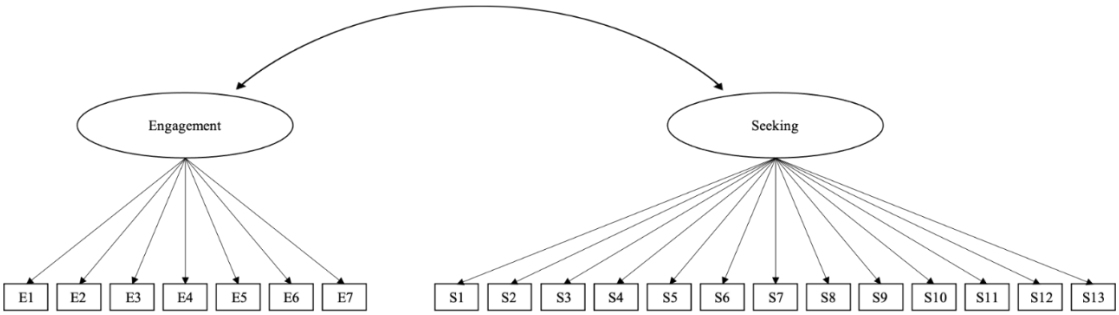
Note. Chi-square (χ^2) was significant, $p < .001$; [1]Tucker and Lewis's index of fit; [2]comparative fit index; [3]root mean square error of approximation; Citation for the goodness of FIT is [1](Hooper et al., 2008; Hu & Bentler,1999), [2](Browne & Cudeck, 1992; Hooper et al., 2008; Hu & Bentler, 1999), [3](Browne & Cudeck, 1992; Hu & Bentler, 1999; Schreiber et al., 2006)

Construct Validity

The CTI consists of 20 items used to determine critical thinking style. The 20 items are used to create two dimensions: engagement and seeking (see Figure 1).

Figure 1

Factor Structure for the CTI in Egerton University



Note. E1 = I look for opportunities to solve problems, E2 = I am interested in many issues, E3 = I am able to relate to a wide variety of issues, E4 = I enjoy finding answers to challenging questions, E5 = I am a good problem solver, E6 = I am confident that I can reach a reasonable conclusion, E7 = I present issues in a clear and precise manner, S1 = I listen carefully to the opinions of others even they disagree with me, S2 = I enjoy learning about many topics, S3 = I ask lots of questions in a learning environment, S4 = It is important to be well informed, S5 = I am willing to change my opinion when I am given new information I find to be credible, S6 = I try to consider the facts without letting my biases affect my decisions, S7 = I enjoy learning even when I am not in school, S8 = I can get along with people who do not share my opinions, S9 = I search for the truth even when it makes me uncomfortable, S10 = I will go out of my way to find the correct answers to a problem, S11 = I try to find multiple solutions to problems, S12 = I ask many questions when making a decision, and S13 = I believe that most problems have more than one solution.

The engagement items were recorded for the CFA. The standardized factor loadings, which should be greater than 0.50 (Hair et al., 2019), for the engagement dimension, ranged from 0.40 to 0.67, and the standardized factor loadings for the seeking dimension ranged from 0.32 to 0.65. Convergent validity and discriminant validity were used to assess the construct validity of the CTI at Egerton University. Convergent validity is tested to determine if measures in a scale are related to other measures that make up the same construct (Hair et al., 2019). The average variance extracted (AVE) above 0.50 is used to assess convergent validity (Hair et al., 2019). AVE measures the amount of variance explained by the construct related to the amount of variance caused by measurement error (Hair et al., 2019). The following equation was used to determine AVE:

$$AVE = \frac{\sum \lambda^2}{n}$$

In the equation, λ represents the factor loadings of each item in the scale, and *n* represents the number of items on the scale. The standardized factor loadings used to calculate AVE are presented in Table 2. The AVE for the engagement construct was 0.34, and the AVE for the seeking construct was 0.29. If the AVE is not greater than 0.50, convergent validity can also be established with an AVE greater than 0.40 and composite reliability greater than 0.60 (Hair et al., 2019). However, the AVE was not greater than 0.40 for either construct, so composite reliability was not assessed to determine construct validity. These results indicate that convergent validity for the hypothesized CTI model was not established in the context of Egerton University.

Table 2

Descriptive Statistics, Factor Loadings, and Reliability Measures of the CTI in Egerton Data

Construct	Item	*n*	*M*	*SD*	*SFL*[1]	*AVE*[2]	*CR*[3]	*α*[4]
Engager*		**347**	**24.79**	**7.61**		**0.34**	**.78**	**.82**
E1	I look for opportunities to solve problems	387	1.82	0.98	0.50			
E2	I am interested in many issues	385	2.08	0.99	0.40			
E3	I am able to relate to a wide variety of issues	384	1.98	0.92	0.57			
E4	I enjoy finding answers to challenging questions	385	1.81	0.96	0.66			
E5	I am a good problem-solver	383	2.17	0.97	0.66			
E6	I am confident that I can reach a reasonable conclusion	384	1.81	0.88	0.67			
E7	I present issues in a clear and precise manner	354	1.91	0.82	0.59			
Seeker		**346**	**53.13**	**7.06**		**0.29**	**.83**	**.76**
S1	I listen carefully to the opinions of others, even if they disagree with me	387	4.08	0.97	0.52			
S2	I enjoy learning about many topics	386	4.01	1.02	0.49			
S3	I ask lots of questions in a learning environment	384	3.67	1.05	0.48			
S4	It is important to be well-informed	384	4.54	0.87	0.58			
S5	I am willing to change my opinion when I am given new information, I find to be credible	353	4.24	0.92	0.48			
S6	I try to consider the facts without letting my biases affect my decisions	352	4.17	0.88	0.63			
S7	I enjoy learning even when I am not in school	354	3.89	1.14	0.51			
S8	I can get along with people who do not share my opinions	353	3.51	1.18	0.32			
S9	I search for the truth even when it makes me uncomfortable	352	4.15	0.94	0.59			

S10	I will go out of my way to find the right answers to a problem	354	4.17	0.86	0.59
S11	I try to find multiple solutions to problems	353	4.11	0.88	0.65
S12	I ask many questions when deciding	353	4.10	0.96	0.43
S13	I believe that most problems have more than one solution	354	4.38	0.86	0.58

Note. *Engager items were reverse coded prior to analysis; [1]SFL = standardized factor loading; [2]AVE = average variance explained; [3]CR = composite reliability; [4]α = scale reliability using Cronbach's alpha; Citation is [123](Hair et al., 2019) and [4](Cronbach, 1951; Nunnally, 1978).

Discriminant validity measures the degree to which a construct differs from other constructs (Anderson & Gerbing, 1988). Anderson and Gerbing (1988) asserted that each construct in a model should be distinctly different from other constructs. Fornell and Larcker's (1981) criterion, which compares the construct correlations with their corresponding average variance extracted, was used to assess discriminant validity. According to the Fornell and Larcker criterion, discriminant validity is met when the square root of AVE is greater than the inter-construct correlation. The correlation estimate for the seeker and recoded engager construct was -.94. The absolute value of the correlation was used in the comparison because the square root of the AVE is always positive. The square root of the AVE for the seeker construct was 0.59, and the square root of the AVE for the engager construct was 0.53. Considering the square root of the AVE for both constructs was below the absolute value of the correlation, discriminant validity for the hypothesized CTI in the Egerton University model was not met.

Reliability

Overall, Cronbach's (1951) alpha for the scale was calculated before recording the engagement items and indicated good item consistency (α = .88). The Cronbach's alpha for the recoded engagement dimension of the scale indicated good item consistency (α = .82). Cronbach's alpha for the seeking dimension of the scale indicated acceptable item consistency (α = .76). Similar to Cronbach's alpha, composite reliability measures overall scale reliability but is preferred for a CFA. Composite reliability should be above 0.60 (Hair et al., 2019). The following equation was used to determine composite reliability:

$$Composite\ Relaibilty = \frac{\sum \lambda^2}{\sum \lambda^2 + \sum \varepsilon}$$

In the equation, λ represents the factor loadings of each item in the scale, and ε represents the error variance. The composite reliability for the recoded engagement construct was 0.78, and the composite reliability for the seeking construct was 0.83, indicating acceptable composite reliability (Hair et al., 2019).

Additionally, the analysis of multiple squared correlations revealed that some observed variables, specifically items S8, S12, and E2, exhibited R^2 values less than .20. According to the recommendations of Hooper et al. (2008), such items with R^2 values equal to or less than .20 are generally considered for removal during the process of instrument validation, as they contribute

minimally to the construct they are intended to measure. This suggestion is based on the premise that higher R^2 values indicate stronger relationships between observed variables and their underlying latent constructs, thereby enhancing the overall validity of the measurement model.

The R^2 values and error variances for each observed variable, as presented in Table 3, offer a detailed insight into the strength of associations within our model. The lower R^2 values for items S8, S12, and E2 suggest a weaker correlation with the underlying constructs of the CTI model, raising questions about their efficacy in accurately reflecting critical thinking as conceptualized in this context. This observation necessitates a careful consideration of these items, possibly leading to their revision or exclusion in future iterations of the CTI for use in similar contexts.

Table 3

Error Variances and R^2 Values for Indicator - Latent Variable Relationship in the CFA Model

Seeking Construct	*SE*	R^2
S1	0.70	.26
S2	0.79	.23
S3	0.85	.22
S4	0.52	.31
S5	0.67	.20
S6	0.54	.32
S7	1.04	.22
S8	1.29	.08
S9	0.70	.25
S10	0.49	.30
S11	0.50	.36
S12	0.79	.16
S13	0.51	.30
Engaging Construct	*SE*	R^2
E1	0.73	.23
E2	0.84	.15
E3	0.58	.32
E4	0.52	.43
E5	0.54	.43
E6	0.43	.44

Conclusion

Although the Critical Thinking Inventory (CTI) has demonstrated a valid factor structure in various contexts, this study indicates that its application to Kenyan undergraduates may be constrained. The model fit parameters in the Confirmatory Factor Analysis (CFA) did not meet the pre-established thresholds, suggesting that the CTI's proposed measurement model did not sufficiently assess critical thinking in this demographic.

The discriminant validity analysis, employing the Fornell and Larcker (1981) criterion, revealed that the measures of the constructs for the proposed CTI model in Kenya did not satisfy the necessary criteria. This finding implies that the CTI may not effectively differentiate between the constructs it aims to measure, thereby limiting cross-cultural and national comparisons of undergraduate critical thinking (Geisinger, 1994).

The results also suggest potential avenues for refining the CTI to better align with Kenya's educational system, culture, and other critical thinking factors. Hooper et al. (2008) recommend including only pertinent items in the instrument to enhance its measurement of critical thinking in Kenya. Additionally, Shek and Yu (2014) propose identifying and addressing model misfits by either removing parameters or pathways that do not align with the data, leading to simpler models with greater degrees of freedom. Conversely, introducing new parameters might improve model fit, but they should undergo cross-validation with new samples to ensure robustness (Shek & Yu, 2014).

While other validity assessments confirmed the CTI's inter-item consistency and composite reliability, the squared multiple correlations (R^2) test data indicated that items S8, S12, and E2 might not represent critical thinking factors for Kenyan students. The instrument could potentially be enhanced by omitting these components (Kline, 2015). Nevertheless, the CTI remains a valid and useful tool for collecting data on critical thinking among students in the U.S. and China.

In conclusion, the study's findings underscore the significance of cultural and environmental factors in understanding undergraduate critical thinking styles. For researchers and educators in similar settings, understanding the limitations of the CTI's applicability in Kenya is beneficial. Addressing these limitations and adapting the instrument to better suit the local context may enhance its efficacy in measuring critical thinking styles among Kenyan students and in other cultural and educational environments.

Recommendations/ Implications

Critical thinking is essential for 21st-century learners, making it imperative for curricula, particularly in countries like Kenya that have transitioned to a competency-based system, to consistently promote this skill. Reliable instruments are needed to measure the effectiveness of critical thinking teaching strategies. Educators can tailor their teaching techniques to align with their students' diverse critical thinking styles by employing reliable tools to assess critical thinking styles.

Despite the Cronbach's alpha coefficients for the 'seeking' and 'engaging' domains being within acceptable ranges ($\alpha = .76$ and $\alpha = .88$, respectively), it is crucial to be aware of potential measurement errors. Solely depending on alpha coefficients might not provide a comprehensive understanding, particularly if the underlying assumptions of the scale are not met. This highlights Nunally's (1974) emphasis on adhering to rigorous psychometric standards. Consequently, the reliability levels achieved in this study should be interpreted with caution, and other instruments

commonly used in this field should undergo a similarly rigorous psychometric review, mainly when applied in new geographic regions.

Future research should include test-retest and parallel-form reliability strategies to comprehensively understand measurement inaccuracies (Geisinger, 1994). This approach could enhance the current findings and contribute further to academic literature. Considering the findings that indicate limitations of the CTI in the Kenyan context, it is recommended that the validation of the CTI continues across diverse global populations. Additionally, an opportunity exists to develop a new instrument tailored to the Kenyan educational system, drawing inspiration from the CTI's development process. Future studies should also examine critical thinking within specific training programs or courses. Such detailed inquiries could provide better fit indices and identify specific curricular activities that effectively develop students' critical thinking styles.

Limitations

It is crucial to acknowledge that this study's sample of only 387 respondents were exclusively from Egerton University, which constrains the generalizability of the results to the wider Kenyan undergraduate population. Conducting a similar study across multiple universities in Kenya, with a sample size more representative of the broader population, could potentially lead to different findings. Although the sample size in this study was not far from the minimum requirement for a factor analysis, existing literature highlights that larger samples typically produce better fit indices, enhancing the robustness of the findings (Kline, 2015; Tabachnick & Fidell, 2019). Additionally, the online mode of conducting the survey introduces uncertainties regarding the accurate representation of the respondents' critical thinking capabilities.

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