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# Development of a Core Competency Instrument for Research-Focused University Students

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**Abstract:** This study aimed to develop and validate a comprehensive core competency assessment instrument specifically designed for undergraduate students at a research-focused university. Despite growing emphasis on competency-based education (CBE), there are limited psychometrically sound tools tailored to evaluate students' level of core competencies in research-intensive universities. The current study proceeded in three phases: (a) development of a conceptual framework comprising six core competencies: Integrated Thinking, Knowledge Inquiry, Creative Integration, Global Citizenship, Communication & Collaboration, and Self-Management; (b) item generation and expert validation; and (c) validation through exploratory and confirmatory factor analyses. The final instrument included 77 items across the six competencies. CFA confirmed adequate model fit (CFI = .934–.957; RMSEA = .057–.088). The results showed that the validated instrument can provide a reliable and comprehensive assessment for students' core competencies in research-oriented university settings. This instrument can provide guidelines for developing competency-based education (CBE) curricula in higher education, as well as criteria for evaluating and refining existing CBE programs. This instrument functions as both a psychometrically robust assessment tool and a practical guide for institutional enhancement. It enables precise measurement of students' core competencies, offering evidence that can inform curriculum design, academic advising, and policy development. In addition, the validated framework lays a strong groundwork for future research to investigate the long-term effects of competency-based education on student achievement, career readiness, and personal development across various higher education settings.

**Keywords:** *Competency-based education, instrument development, research-focused university students.*

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## Introduction

With a growing emphasis on STEM (science, technology, engineering, and mathematics) education, there has been a notable paradigm shift in the traditional time-based education structures to mastery focused competency-based education (CBE) including competency-based instruction (CBI) and competency-based learning (CBL) (Chappell et al., 1999). In higher education, competency denotes a student's fundamental ability to comprise knowledge, skills, attitudes, and values to advanced capabilities and skills when demonstrating and creating knowledge (Spady, 1977). This definition emphasizes what students know as well as how they apply, integrate, and extend that knowledge in authentic academic and professional contexts.

Spady and Mitchell (1977) explained CBE as an adaptive, performance-oriented process certifying demonstrated learning outcomes as mastery of domain-specific knowledge alongside essential critical thinking skills. At the initial stage of the development of CBE, it was developed in the medical field to assess and evaluate the specific competencies required for medical professionals (Spady, 1977). However, over the past decades, CBE has influenced educational practices across career technical education and professional training, reflecting a pedagogical shift toward personalized, mastery-based, outcome-focused learning aligned with evolving societal and industry needs (Gervais, 2016).

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Within this evolving educational framework, defining and evaluating core competencies becomes critical that core competencies refer to measurable learning and various self-regulation skills that students, regardless of disciplines, are expected to develop and perform critical thinking, problem solving, and communication (Holmes et al., 2021). Whereas academic competencies emphasize specialized expertise and disciplinary knowledge depth, focusing on domain-specific knowledge and capabilities to acquire knowledge. Importantly, scholars have critically examined the distinction between core competencies and academic performance, noting that both dimensions are essential yet operate at different levels within higher education curricula, requiring integrated both approaches to support holistic student development (Brauer, 2021; Henderson et al., 2024).

Further, recognizing the pivotal role of developing competencies, there has been a burgeoning movement to embrace CBE in higher education curriculum development (Long et al., 2020). In the context of higher education, competency-based education refers to a school-based practice of teaching and learning in which students advance through the mastery of knowledge and skills instead of fulfilling a standard seat time (Gyll, 2021; Marzano et al., 2012;). This shift reflects a commitment to develop a more adaptive and skills-focused educational curriculum, aligning necessity of education with the evolving needs of students' critical thinking, collaboration abilities, and self-regulation skills. transitioning to the workforce (DeBacker et al., 2024).

In terms of the evaluation of competencies, several initiatives have been launched to measure and assess competencies. First, the OECD's Assessment of Higher Education Learning Outcomes (AHELO) evaluated both disciplinary domains (economics, engineering) and general skills (critical thinking, analytic reasoning, problem solving, written communication) (Tremblay et al., 2012). Similarly, in the United States, the Collegiate Learning Assessment (CLA) was designed to comprehensively evaluate college students' critical thinking and analytical reasoning competencies (Kuh & Ewell, 2010), while Australia's Graduate Skills Assessment (GSA) focused on graduates' problem-solving, critical thinking, interpersonal, and communication skills (Chang, 2006). In South Korea, K-CESA (Korea Collegiate Essential Skills Assessment) was developed as a national-level diagnostic tool to evaluate undergraduates' essential competencies, applied across numerous universities (Jin et al., 2011). Even if there are several tools to evaluate CBE, there are inherent limitations that overlook the distinctive educational goals, institutional missions, and contextual needs of individual universities.

While ongoing efforts for developing CBE in higher education and evaluation tools, there is a notable shortage of diagnostic instruments specifically designed for research-focused universities (George-Reyes et al., 2023; Mellado-Moreno et al., 2024; Milner et al., 2011). George-Reyes and colleagues claimed that students in research-intensive institutions are required to develop advanced research design, creative integration, and scholarly self-management. To address the pivotal need for validated core competency instruments, this study developed and validated a Core Competency Instrument (CCI) tailored for undergraduate students at research-focused universities. The instrument offers reliable metrics to evaluate and support students' academic and professional development and serves as a guideline for refining competency-based education (CBE) curricula.

## Methodology

This study followed a three-step process (Capella-Peris et al., 2020). First, a literature review and expert consultation developed a competency model for undergraduate students at our research-focused university. Next, an assessment tool was designed based on the developed competency model to measure students' competency levels. Finally, actual student data were collected to evaluate the validity and reliability of the developed assessment tool.

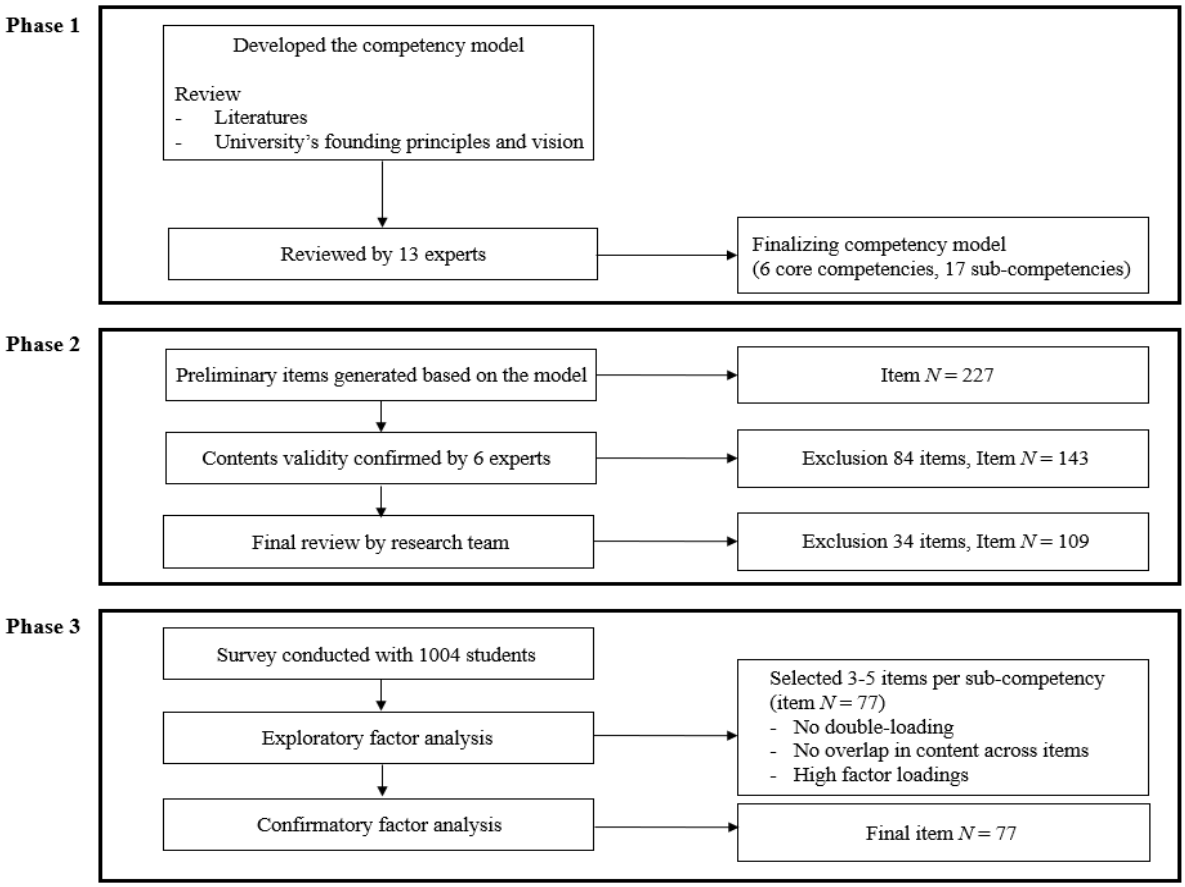


*Figure 1. The Study Flow Chart*

To develop a competency model for undergraduate students at our research-focused university, we conducted a comprehensive review of domestic and international competency frameworks and assessment tools. Specifically, we referred to internationally recognized assessments such as PIAAC (OECD, 2019), OECD-AHELO (Tremblay et al., 2012), CLA (Klein et al., 2007), and GSA (Australian Council for Educational Research, 2001). We Also reviewed K-CESA which is widely used to evaluate core competencies of Korean universities. In addition, we analyzed the founding principles and long-term vision for student development of a research-focused university located in Seoul, South Korea, to ensure that the model aligned with institutional goals. Several key elements were considered during the construction of the model: (a) review of competencies emphasized in the existing frameworks, (b) identify core competencies frequently highlighted in empirical studies on university students (e.g., critical thinking, problem-solving, communication), and (c) refine competencies that reflect the university's unique educational philosophy and priorities. Furthermore, we incorporated findings from previous institutional studies conducted at the university, which captured the perspectives of faculty and students regarding essential competencies for academic and professional success. Based on these considerations, we developed an initial draft of the competency model, outlining six core competencies and their subcomponents. The six competencies were mutually reciprocal and collectively demonstrated their potential for academic exploration, the creation of educational values, and the pursuit of social values. The six competencies are integrated thinking, knowledge inquiry, creative integration, global citizenship, communication and collaboration, and self-management. Table 1 presents the conceptual definitions and subcomponents of these competencies.

*Table 1. Six Core Competencies and Definitions*

| Core competency | Sub-competency | Definition |
|---|---|---|
| Integrated thinking | analytical thinking<br>inferential thinking<br>evaluative thinking | the ability to critically explore the core of problems encountered in the process of academic inquiry and derive valid solutions for individuals and organizations through logical analysis and reasoning |
| Knowledge inquiry | knowledge information processing<br>understanding and exploration of fundamental disciplines<br>specialized knowledge application | the ability to systematically explore specialized knowledge and skills based on a foundational understanding of humans, nature, and the world, and to critically assimilate and apply new knowledge |
| Creative integration | open-mindedness<br>integrative thinking<br>creative thinking | the ability to understand phenomena with an open attitude, integrate diverse knowledge and skills, and solve problems creatively |
| Global citizenship | community awareness<br>global competency<br>social contribution | the ability to understand rights and responsibilities as a member of society, respect cultural diversity, and actively engage in solving issues at both international and local community levels to contribute to community development |
| Communication & Collaboration | communication<br>collaborative leadership | the ability to effectively communicate and share one's ideas to maintain harmonious relationships with others, actively contribute to the community, and take a leading role in achieving shared goals |
| Self-management | learning strategy utilization<br>management of learning motivation<br>self-regulation | the ability to proactively lead strategies and manage processes necessary to achieve academic goals, based on an interest in and commitment to academic inquiry |

*Development of the Assessment*

Based on the derived conceptual model of six core competencies and their subcomponents, we developed an initial pool of 227 items to assess students' competency levels. These items were informed by a comprehensive review of prior studies and existing assessment tools. A content validation process was conducted with six domain experts, working in cross-disciplinary pairs. Seven experts from different fields were assigned to each core competency to evaluate items for clarity, relevance, and appropriateness (Wynd & Schaefer, 2002). As a result, the item pool was reduced to 143 items. Following additional review and refinement by the research team, a final set of 109 preliminary items was selected for empirical validation.

*Validation of the Assessment Tool*

An online survey was administered to currently enrolled students at one of renown research focused university in South Korea, between March and June 2023. A total of 1,004 students completed the 109 preliminary items, with no missing data observed, enabling the use of the entire dataset for analysis. The sample included 47.6% male and 52.4% female respondents. By academic year, 19.9% were first-year students, 18.7% were second-year students, 19.7% were third-year students, and 41.6% were fourth-year students or above. Participants represented a diverse range of academic fields: 24.4% from humanities and social sciences, 20.5% from natural and life sciences, 17.1% from engineering, 7.2% from medical and health sciences, 7.5% from education, 4.1% from business, 2.0% from arts and music, and 17.2% did not respond.

To confirm the construct validity of the instrument, we employed a cross-validation approach using sequential exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). The dataset was randomly split into two equal subsamples (n = 502 each). First, EFA was conducted on the first subset using principal axis factoring with oblimin rotation. Factor extraction was based on eigenvalues greater than 1.0 and visual inspection of scree plots (Hair et al., 2010). Items were excluded if they exhibited low factor loadings (< .40), significant cross-loadings (>.30 on multiple factors), or content ambiguity.

Following EFA, the retained items were reviewed to ensure coverage of each subcomponent, clarity, and non-redundancy. For each subcomponent, 3 to 5 items with the highest factor loadings were selected to improve content validity and reduce participant fatigue. The CFA was then performed on the second subset to validate the factor structure derived from EFA. A model fit was assessed using multiple indices, including the chi-square statistic ($\chi^2$), Tucker-Lewis Index (TLI), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA), with

thresholds of TLI/CFI > .90 and RMSEA < .08 considered acceptable (Hu & Bentler, 1999). All analyses were conducted using Mplus 7.0.

## Results

*Results of Exploratory Factor Analysis (EFA)*

To examine the factor structure of the instrument and refine the items, EFA was conducted using principal axis factoring with oblimin rotation. Sampling adequacy was confirmed through KMO values above .70 and significant results for Bartlett's test of sphericity (Hair et al., 2010; Tabachnick & Fidell, 2006). The EFA was performed separately for each of the six competencies. Items showing low loadings (< .40) or cross-loadings across multiple factors were excluded. After refinement, each competency retained a clear multi-factor structure, aligned with theoretical subcomponents. For example, Integrated Thinking and Creative Integration retained three distinct subdimensions each, while Communication & Collaboration showed a two-factor structure. All subcomponents demonstrated moderate to high factor loadings, supporting construct coherence. Table 2 presents the finalized structure, loading ranges, and explained variance for each competency domain.

*Table 2. Exploratory Factor Analysis (EFA) for Core Competencies*

| Core competency | Sub-competency (number of items) | Range of factor loadings | Variance Explained (%) |
|---|---|---|---|
| Integrated thinking | analytical thinking (6) | 0.53-0.81 | 48.7 |
| | inferential thinking (5) | 0.43-0.73 | |
| | evaluative thinking (3) | 0.41-0.55 | |
| Knowledge inquiry | knowledge information processing (5) | 0.67-0.79 | 56.4 |
| | understanding and exploration of fundamental disciplines (6) | 0.56-0.80 | |
| | specialized knowledge application (5) | 0.65-0.85 | |
| Creative integration | open-mindedness (5) | 0.41-0.73 | 50.2 |
| | integrative thinking (7) | 0.55-0.86 | |
| | creative thinking (6) | 0.64-0.88 | |
| Global citizenship | community awareness (3) | 0.42-0.54 | 59.6 |
| | global competency (6) | 0.47-0.86 | |
| | social contribution (7) | 0.61-0.94 | |
| Communication & collaboration | communication (6) | 0.51-0.74 | 45.6 |
| | collaborative leadership (7) | 0.63-0.70 | |
| Self-management | learning strategy utilization (7) | 0.50-0.75 | 44.9 |
| | management of learning motivation (7) | 0.52-0.80 | |
| | self-regulation (5) | 0.49-0.62 | |

*Results of Confirmatory Factor Analysis (CFA)*

To validate the factor structure refined through EFA, CFA was conducted using the second half of the sample (n = 502). To ensure parsimony and reduce participant fatigue, the final set of 77 items was selected by retaining 3–5 items per subcomponent, based on content relevance and the strength of factor loadings from EFA.

Next, in the CFA, an overall model fit was evaluated using several indices: chi-square ($\chi^2$), the Tucker–Lewis Index (TLI), the Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA). Following conventional thresholds (Hu & Bentler, 1999), values of TLI and CFI above .90 and RMSEA below .08 indicate good model fit. As shown in Table 3, all six competencies demonstrated acceptable to strong fit based on these criteria. All standardized factor loadings were statistically significant ($p < .001$) and exceeded .50, indicating strong associations between items and their respective latent factors (Hair et al., 2010). Table 4 provides the standardized loadings for each item within its respective subcomponent.

*Table 3. Model Fit Indices for Core Competencies*

| Core competency | Number of factors | $X^2$ | *df* | TLI | CFI | RMSEA |
|---|---|---|---|---|---|---|
| Integrated thinking | 3 | 405 | 62 | 0.946 | 0.957 | 0.063 |
| Knowledge inquiry | 3 | 405 | 87 | 0.923 | 0.936 | 0.078 |
| Creative integration | 3 | 316 | 87 | 0.931 | 0.942 | 0.057 |
| Global citizenship | 3 | 122 | 24 | 0.931 | 0.954 | 0.088 |
| Communication & collaboration | 2 | 160 | 34 | 0.926 | 0.944 | 0.084 |
| Self-management | 3 | 295 | 87 | 0.920 | 0.934 | 0.066 |

*Table 4. Confirmatory Factor Analysis (CFA) for Core Competencies*

| Core competency | Item | | Sub-competency | β | B | S.E. | p |
|---|---|---|---|---|---|---|---|
| Integrated thinking | a1 | ← | analytical thinking | 0.67 | 0.49 | 0.03 | <.001 |
| | a2 | ← | analytical thinking | 0.74 | 0.55 | 0.03 | <.001 |
| | a3 | ← | analytical thinking | 0.76 | 0.58 | 0.03 | <.001 |
| | a4 | ← | analytical thinking | 0.78 | 0.56 | 0.03 | <.001 |
| | a5 | ← | analytical thinking | 0.74 | 0.48 | 0.02 | <.001 |
| | a8 | ← | inferential thinking | 0.72 | 0.61 | 0.03 | <.001 |
| | a9 | ← | inferential thinking | 0.73 | 0.60 | 0.03 | <.001 |
| | a10 | ← | inferential thinking | 0.73 | 0.53 | 0.03 | <.001 |
| | a11 | ← | inferential thinking | 0.66 | 0.58 | 0.04 | <.001 |
| | a12 | ← | inferential thinking | 0.74 | 0.53 | 0.03 | <.001 |
| | a16 | ← | evaluative thinking | 0.70 | 0.58 | 0.04 | <.001 |
| | a17 | ← | evaluative thinking | 0.64 | 0.49 | 0.04 | <.001 |
| | a18 | ← | evaluative thinking | 0.57 | 0.53 | 0.04 | <.001 |
| Knowledge inquiry | b2 | ← | knowledge information processing | 0.80 | 0.58 | 0.03 | <.001 |
| | b3 | ← | knowledge information processing | 0.77 | 0.54 | 0.02 | <.001 |
| | b4 | ← | knowledge information processing | 0.82 | 0.60 | 0.03 | <.001 |
| | b5 | ← | knowledge information processing | 0.85 | 0.55 | 0.02 | <.001 |
| | b6 | ← | knowledge information processing | 0.71 | 0.60 | 0.03 | <.001 |
| | b8 | ← | understanding and exploration of fundamental disciplines | 0.70 | 0.71 | 0.04 | <.001 |
| | b9 | ← | understanding and exploration of fundamental disciplines | 0.71 | 0.65 | 0.04 | <.001 |
| | b10 | ← | understanding and exploration of fundamental disciplines | 0.72 | 0.70 | 0.04 | <.001 |
| | b11 | ← | understanding and exploration of fundamental disciplines | 0.69 | 0.63 | 0.04 | <.001 |
| | b12 | ← | understanding and exploration of fundamental disciplines | 0.70 | 0.65 | 0.04 | <.001 |
| | b14 | ← | specialized knowledge application | 0.75 | 0.68 | 0.03 | <.001 |
| | b15 | ← | specialized knowledge application | 0.80 | 0.73 | 0.03 | <.001 |
| | b16 | ← | specialized knowledge application | 0.78 | 0.67 | 0.03 | <.001 |
| | b17 | ← | specialized knowledge application | 0.80 | 0.71 | 0.03 | <.001 |
| | b18 | ← | specialized knowledge application | 0.77 | 0.71 | 0.03 | <.001 |
| Creative integration | c1 | ← | open-mindedness | 0.66 | 0.50 | 0.03 | <.001 |
| | c2 | ← | open-mindedness | 0.56 | 0.47 | 0.04 | <.001 |
| | c4 | ← | open-mindedness | 0.60 | 0.44 | 0.03 | <.001 |
| | c5 | ← | open-mindedness | 0.78 | 0.59 | 0.03 | <.001 |
| | c6 | ← | open-mindedness | 0.76 | 0.54 | 0.03 | <.001 |
| | c8 | ← | integrative thinking | 0.70 | 0.52 | 0.03 | <.001 |
| | c10 | ← | integrative thinking | 0.74 | 0.60 | 0.03 | <.001 |
| | c11 | ← | integrative thinking | 0.77 | 0.65 | 0.03 | <.001 |
| | c12 | ← | integrative thinking | 0.80 | 0.59 | 0.03 | <.001 |
| | c13 | ← | integrative thinking | 0.80 | 0.55 | 0.03 | <.001 |
| | c14 | ← | creative thinking | 0.83 | 0.76 | 0.03 | <.001 |
| | c15 | ← | creative thinking | 0.80 | 0.78 | 0.04 | <.001 |
| | c17 | ← | creative thinking | 0.65 | 0.50 | 0.03 | <.001 |
| | c18 | ← | creative thinking | 0.81 | 0.70 | 0.03 | <.001 |
| | c20 | ← | creative thinking | 0.74 | 0.62 | 0.03 | <.001 |

*Table 5. Continued*

| Core competency | Item | Sub-competency | | β | B | S.E. | p |
|---|---|---|---|---|---|---|---|
| Global citizenship | d1 | ← | community awareness | 0.63 | 0.44 | 0.03 | <.001 |
| | d2 | ← | community awareness | 0.80 | 0.64 | 0.03 | <.001 |
| | d3 | ← | community awareness | 0.72 | 0.68 | 0.04 | <.001 |
| | d8 | ← | global competency | 0.70 | 0.71 | 0.04 | <.001 |
| | d12 | ← | global competency | 0.76 | 0.74 | 0.04 | <.001 |
| | d13 | ← | global competency | 0.77 | 0.77 | 0.04 | <.001 |
| | d16 | ← | social contribution | 0.84 | 0.81 | 0.04 | <.001 |
| | d17 | ← | social contribution | 0.79 | 0.71 | 0.03 | <.001 |
| | d18 | ← | social contribution | 0.88 | 0.82 | 0.03 | <.001 |
| Communication & Collaboration | e1 | ← | communication | 0.76 | 0.53 | 0.03 | <.001 |
| | e2 | ← | communication | 0.75 | 0.60 | 0.03 | <.001 |
| | e3 | ← | communication | 0.67 | 0.53 | 0.03 | <.001 |
| | e4 | ← | communication | 0.76 | 0.56 | 0.03 | <.001 |
| | e6 | ← | communication | 0.68 | 0.52 | 0.03 | <.001 |
| | e8 | ← | collaborative leadership | 0.66 | 0.49 | 0.03 | <.001 |
| | e9 | ← | collaborative leadership | 0.72 | 0.53 | 0.03 | <.001 |
| | e10 | ← | collaborative leadership | 0.72 | 0.62 | 0.03 | <.001 |
| | e11 | ← | collaborative leadership | 0.75 | 0.61 | 0.03 | <.001 |
| | e12 | ← | collaborative leadership | 0.59 | 0.58 | 0.04 | <.001 |
| Self-management | f1 | ← | learning strategy utilization | 0.63 | 0.44 | 0.03 | <.001 |
| | f2 | ← | learning strategy utilization | 0.60 | 0.46 | 0.03 | <.001 |
| | f3 | ← | learning strategy utilization | 0.72 | 0.64 | 0.04 | <.001 |
| | f5 | ← | learning strategy utilization | 0.62 | 0.52 | 0.04 | <.001 |
| | f6 | ← | learning strategy utilization | 0.73 | 0.68 | 0.04 | <.001 |
| | f9 | ← | management of learning motivation | 0.78 | 0.69 | 0.03 | <.001 |
| | f11 | ← | management of learning motivation | 0.64 | 0.47 | 0.03 | <.001 |
| | f12 | ← | management of learning motivation | 0.78 | 0.65 | 0.03 | <.001 |
| | f13 | ← | management of learning motivation | 0.81 | 0.73 | 0.03 | <.001 |
| | f14 | ← | management of learning motivation | 0.71 | 0.63 | 0.03 | <.001 |
| | f16 | ← | self-regulation | 0.68 | 0.68 | 0.04 | <.001 |
| | f17 | ← | self-regulation | 0.68 | 0.66 | 0.04 | <.001 |
| | f18 | ← | self-regulation | 0.69 | 0.67 | 0.04 | <.001 |
| | f19 | ← | self-regulation | 0.59 | 0.59 | 0.04 | <.001 |
| | f20 | ← | self-regulation | 0.58 | 0.62 | 0.05 | <.001 |

Based on the finalized 77-item instrument, internal consistency reliability was assessed for each of the six core competencies and their subcomponents. All core competencies demonstrated strong reliability, with Cronbach's α coefficients exceeding .80, indicating high internal consistency (Nunnally, 1978). At the subcomponent level, all α values were above .70, confirming that each subscale met acceptable standards for reliability. The final number of items and Cronbach's α for each subscale are also presented in Table 5. These findings confirmed that the assessment tool was valid and reliable for measuring the six core competencies in the context of a research-focused university.

*Table 6. Final Composition and Reliability Test for Core Competencies*

| Core competency | Sub-competency | Number of items | Cronbach's α |
|---|---|---|---|
| Integrated thinking | total | 13 | 0.896 |
| | analytical thinking | 5 | 0.855 |
| | inferential thinking | 5 | 0.839 |
| | evaluative thinking | 3 | 0.642 |
| Knowledge inquiry | total | 15 | 0.901 |
| | knowledge information processing | 5 | 0.874 |
| | understanding and exploration of fundamental disciplines | 5 | 0.848 |
| | specialized knowledge application | 5 | 0.889 |

*Table 7. Continued*

| Core competency | Sub-competency | Number of items | Cronbach's α |
|---|---|---|---|
| Creative integration | total | 15 | 0.900 |
| | open-mindedness | 5 | 0.772 |
| | integrative thinking | 5 | 0.870 |
| | creative thinking | 5 | 0.883 |
| Global citizenship | total | 9 | 0.865 |
| | community awareness | 3 | 0.726 |
| | global competency | 3 | 0.812 |
| | social contribution | 3 | 0.878 |
| Communication & Collaboration | total | 10 | 0.872 |
| | communication | 5 | 0.831 |
| | collaborative leadership | 5 | 0.800 |
| Self-management | total | 15 | 0.872 |
| | learning strategy utilization | 5 | 0.774 |
| | management of learning motivation | 5 | 0.863 |
| | self-regulation | 5 | 0.768 |

In sum, the selection and elimination of items were based on factor loadings and content redundancy. Each sub-factor comprised 3-5 items based on item characteristic analyses, factor loadings, and content redundancy considerations. Items with low factor loadings compared to others in their respective sub-factors and items with overlapping content were removed. Similarly, items with relatively high factor loadings but similar content within the same domain, nine items, or two items across different domains were excluded from the final selection. As a result, each sub-factor consisted of 3-5 final items. Confirmatory factor analysis confirmed the adequacy of the factor structure for all factors. Moreover, reliability analysis showed consistent reliability ranging from .865 to .901 across all competencies (with sub-factors ranging from .642 to .889), indicating relatively high reliability of the scales.

## Discussion

Competency-based education (CBE) is a teaching and learning approach that supports students' progression through the instructional system based on demonstrated mastery of content and skills. This is separate from a curriculum that requires fulfillment of a standardized seat time. Since it focuses on mastering skills rather than time spent in class, CBE involves the development of various assessment methods and is seen as a more efficient way to equip students with employer-valued skills (Edwards, 2022). Previous studies collectively emphasize the necessity of validated evaluation tools to improve current CBE with various competencies within educational frameworks to better prepare students for the demands of the modern workforce. Furthermore, the transition from traditional education models focusing solely on curriculum to recognizing the importance of extracurricular education programs demonstrates the evolving landscape of higher education.

Therefore, current study contributed to a comprehensive competency assessment tool development. Particularly, it tailored for undergraduate students at a research-focused university. The tool exhibits robust psychometric properties, achieved through a systematic process of item refinement and extensive validation procedures, including an evaluation of construct validity, internal consistency, and practical usability. These results highlight the refinement of evaluation tool's reliability and effectiveness by measuring six core competencies central to competency-based education for research-focused university.

By offering a standardized and accurate means to assess and support student development, the tool serves as a valuable resource for educators and administrators aiming to enhance educational outcomes. Moreover, this validation research establishes a solid foundation for competency-based education and evaluate the impact of targeted interventions on students' academic performance, professional preparedness, and overall development.

The results underscore the importance of core competencies to develop academic competencies refer to the specific knowledge and skills essential for success in a particular field of study or profession. These core competencies encompass the technical expertise and specialized knowledge students need to master their chosen discipline (Janssens et al., 2023). Further, this instrument provides specific set of competencies that are associated with critical thinking, communication, teamwork, problem-solving, and adaptability that applicable across various fields and industries (Cano et al., 2023).

Note that this line of investigation requires follow-up study to refine independent definitions for six competencies based on educational objectives within each disciplinary field. Future research should consider the diverse expertise of faculty members across different disciplines, which may lead to the identification of more universal competencies rather than discipline-specific or emphasized competencies. Future studies should focus on developing competency

items tailored to specific academic disciplines rather than attempting to reach a consensus on common competencies. The next step will involve creating items for each competency to develop a measurement tool, followed by a validation study. Once a validated instrument is available, researchers should conduct surveys to assess students' competencies developed through extracurricular courses. Further studies may address the contribution of various extracurricular courses to competency development and their relationship with students' academic competencies and overall academic performance.

Lastly, this study primarily focused on assessing competencies within an academic context. Further research can investigate how well these competencies translate to real-world applications, particularly in professional and workforce settings. Expanding the scope to include employer perspectives and longitudinal tracking of students' competency development would provide deeper insights into the tool's effectiveness and practical relevance.

## Limitations

While this study presents a robust competency assessment tool, some limitations are need be addressed. This study focused on a specific research-focused university, which may limit the generalizability of the findings to other educational contexts. Future studies should replicate this research across diverse institutions to assess the tool's applicability in different academic settings. Next, while confirmatory factor analysis and reliability testing confirmed the tool's validity and internal consistency, however additional studies should explore its predictive validity by examining its relationship with academic achievement, career outcomes, and other external benchmarks.

### Ethics Statement

This study was conducted in accordance with the ethical standards of research involving human participants and was approved by the Faculty of Education, Seoul National University. All participants provided informed consent prior to their participation, and confidentiality and anonymity were strictly maintained throughout the research process.

### Generative AI Statement

In the preparation of this manuscript, generative AI tools (e.g., ChatGPT by OpenAI) were used solely for the purpose of improving grammar, sentence structure, and language clarity. We, as the authors, take full responsibility for the content of our published work.

### Authorship Contribution Statement

Lee: Conceptualization, Design, Data acquisition. Kim: Data analysis/interpretation, Statistical analysis, Drafting manuscript. Park: Administration, Drafting manuscript. Park: Critical revision of manuscript, Drafting manuscript, Supervision

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