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Validating the Digital Competence (Dig-Comp 2.1) Framework in Higher Education Using Confirmatory Factor Analysis: Non-Western Perspective

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Abstract

This Pilot study aimed at validating the Digital Competence (Dig-Comp 2.1) Framework instrument within the context of a non-Western developing country. With the rapid advancements in technology and the increasing integration of digital tools in various domains, evaluating learners' digital competencies is crucial to ensure the effective utilisation of digital resources in educational settings. However, existing frameworks often lack validation in developing and non-western country contexts. Therefore, this study addresses this gap by assessing the reliability and validity of the Dig-Comp 2.1 Framework Questionnaire in a higher education context, involving a sample of ninety-nine (99) university students from Uganda. By implementing a quantitative design, we collected data through an online survey administered to the selected student samples. The analyses employed confirmatory factor analysis (CFA) and confirmatory composite analysis (CCA). The findings indicated that the Dig-Comp framework portrayed an excellent fit with pilot data as indicated by various model fit indices through CFA. Moreover, the CCA demonstrated satisfactory reliability and validity of the Dig-Comp 2.1 framework, suggesting that the instrument's measures are appropriate and reliable for future investigations. The results of this study can contribute to enhancing the understanding of digital competence and its measurement in non-western countries, thereby informing policies and interventions to bridge the digital divide.

Keywords: Digital Competence, DigComp 2.1, Confirmatory Factor Analysis, CFA, Higher Education

Introduction

The digital revolution has transformed various aspects of society, including education, employment, and communication. Like many other countries, Uganda is witnessing a rapid expansion of digital technologies in multiple sectors, especially in

education (Kibirige, 2023; Lynn & Emanuel, 2021). However, the integration of digital technologies in higher education requires a comprehensive understanding of the digital competence levels of faculty members and students.

Currently, in Uganda, the availability of computers and access to the Internet are separate issues, with computers and mobile phones being more readily accessible than the Internet (Damani et al., 2022; Kibirige, 2023). The introduction of computer studies in the secondary school curriculum, as outlined in the National ICT Policy, is improving computer access in various parts of Uganda (Newby et al., 2013; Oyo & Kalema, 2014). Regardless of location, All public secondary schools now have access to modern networked computers (Oyo & Kalema, 2014). Consequently, students are gaining proficiency in using computers and acquiring basic internet skills by the time they enter higher education institutions (Tusiime et al., 2022). Equipping secondary schools with computers is a strategy to facilitate internet access during tertiary education, paving the way for the effective utilisation of educational technologies. In conclusion, the implementation of digital education in Uganda's tertiary institutions is highly likely due to the country's digital technology adoption, usage, and ICT policy (Andema et al., 2013; Kalinaki, 2019; Kibirige, 2023; Oyo & Kalema, 2014). However, to thrive in the digital era, individuals must possess adequate digital competence - the ability to use digital technologies efficiently, effectively, and ethically to achieve desired outcomes (Vuorikari et al., 2022).

Recognising the importance of digital competence, the European Commission developed the Digital Competence (Dig-Comp) Framework, which provides a comprehensive framework for assessing individuals' digital competence across various domains (Carretero et al., 2017; Vuorikari et al., 2022). The Dig-Comp 2.1 Framework has gained considerable attention due to its comprehensive coverage and relevance to diverse contexts. However, the Dig-Comp 2.1 Framework instrument validation in developing and non-Western countries remains limited. Moreover, two studies in Turkey (Çebi & Reisoğlu, 2019, 2020) applied the Dig-Comp 2.1 Framework and developed the instrument to assess the digital competencies of pre-service teachers. Despite their research instrument questionnaire passing the content validity through two experts, these studies did not report the validity and reliability of their instrument using statistical techniques such as confirmatory factor analysis (CFA). Thus, these two studies inspired the authors to conduct the present research to bridge the missing gap.

Therefore, the primary objective of this pilot study is to validate the Dig-Comp 2.1 Framework Questionnaire used by previous studies (Çebi & Reisoğlu, 2019, 2020) using confirmatory factor analysis (CFA) and confirmatory composite analysis (CCA) in a developing country context, specifically in Uganda. This study evaluates the Dig-Comp instrument’s reliability and construct validity, ensuring its applicability and relevance to individuals in developing and non-Western countries. The findings will enable policymakers, educators, and researchers to gain insights into individuals' digital

competence in these contexts and devise appropriate strategies to enhance digital literacy.

Literature Review

Digital Technologies in Education

In educational settings, digital technologies provide numerous advantages. They enhance student involvement by using interactive and multimedia materials that capture their attention and accommodate different learning preferences (Alamri et al., 2020). Additionally, digital technologies facilitate access to vast information and educational resources (Serin, 2022), broadening the scope of learning beyond traditional classrooms (Abubakari et al., 2022; Kweka & Ndibalema, 2018). Teachers also reap the benefits of digital technologies, as they can utilise online platforms for instructional planning, assessment, and collaboration with colleagues (Martins et al., 2019; UNESCO, 2021). Despite the availability of various digital resources in educational institutions, many individuals fail to fully harness their potential benefits (Abubakari et al., 2021; Imasiku et al., 2019). That is to say, although digital resources, including software and hardware, are widely accessible and prevalent in higher education, there is still a disparity in how these resources are utilised in teaching and learning practices, as well as differences in the competency of individuals in using them, within higher education institutions (Antonietti et al., 2022).

Digital Competence in Education

In today's digitally driven world, it is imperative for individuals to possess the necessary digital competencies to navigate and thrive in various domains, including business and education. In higher education, integrating digital tools and platforms has become increasingly prevalent, necessitating a shift in the skills and competencies required by students to succeed in their academic and professional pursuits (Carvalho & Santos, 2022). Thus, Higher education institutions (HEI) in various countries increasingly recognise the importance of digital competence among students to ensure their success in the digital age (Nyikes, 2018; Wild & Schulze Heuling, 2021). HEIs are pivotal in equipping students with the necessary digital competencies.

As digital technologies continue to play a crucial role in education, it is essential to understand the digital competencies of higher education students (Núñez-Canal et al., 2022; Zhao et al., 2021). However, the absence of a validated instrument to measure digital competencies in the Ugandan context hinders effective assessment and development strategies. Therefore, this study aims to validate the Dig-Comp 2.1 Framework questionnaire using confirmatory factor and composite analyses, specifically focusing on Ugandan higher education students.

Dig-Comp 2.1 Framework and Related Studies

Digital competence has become an essential skill set in the 21st century, influencing various aspects of individuals' personal and professional lives. Recognising the importance of digital competence, the European Commission developed the Digital Competence Framework for Citizens (Dig-Comp) to provide a comprehensive model for assessing and developing digital competencies (Carretero et al., 2017). The DigComp framework is widely used for assessing digital competence. It was developed by the European Union in 2013 and has been updated several times since then. The current version, DigComp 2.1, identifies five areas of digital competence (Schola Europaea, 2020):

1. Information and data literacy (IDL): An ability to effectively find, evaluate, and use information.
2. Communication and collaboration (CC): An ability to communicate and collaborate with others using digital tools.
3. Digital content creation (DCC): An ability to create and share digital content.
4. Digital problem-solving (DPS): An ability to use digital tools to solve problems.
5. Digital safety (DS): An ability to use digital tools safely and securely.

The latest version, Dig-Comp 2.1, offers a holistic approach to understanding and evaluating digital competencies across different domains, including education. There is a growing body of research on the validity of the DigComp 2.1 framework. However, most of these studies have been conducted in Europe. The Dig-Comp 2.1 Framework has gained international recognition (Vuorikari et al., 2022). For instance, some scholars conducted a study in India (Patwardhan et al., 2023) and found the framework valid and reliable in measuring digital competence and its effects on students' perceived learning and learning agility in online learning settings. Another study in Germany (Wild & Schulze Heuling, 2021) confirmed the reliability and validity of a short-scale instrument for digital competencies with less than five items for every of the five competence dimensions of the Dig-Comp framework. However, the confirmatory factor analysis was only moderately satisfying and revealed problems due to the low factor loadings of a few items. Nevertheless, Dig-Comp framework applicability and validity in diverse cultural and educational contexts, such as Uganda, remain largely unexplored. This study aimed to validate the DigComp framework in a different context, namely Uganda.

Methodology

Sampling and Research Design

Through a quantitative design, we collected pilot data through an online survey using Google Forms administered to the selected sample of ninety-nine (99) university students from Uganda, comprised of thirty-six (36) females and sixty-three (63) males. The

age of most participants (81) ranged between 18 and 25, followed by a 26-35 age range (12); few have ages below 18 years (3) and above 35 years (3). Moreover, the education level of the majority was undergraduate (92), followed by a diploma (4) and master's degree (3). It is worth noting that this pilot study is part of an ongoing main project.

Instrument and Analysis Methods

The instrument of the Dig-Comp 2.1 framework consists of five constructs based on the five competence areas: DCC, CC, DS, IDL, and DPS, which was adapted from a previous study conducted in Turkey (Çebi & Reisoğlu, 2020). However, three items (CC5, DCC5, and DCC6) were added from another study (Guitert et al., 2021), making every construct with six indicators each. All indicators were measured using a 5-point Likert scale, from Strongly Disagree (= 1) to Strongly Agree (=5). Based on Cronbach's alpha, the overall reliability of the research instrument scored 0.959, suggesting a high measures' reliability. Data analysis implemented confirmatory factor analysis (CFA) through the JASP software (JASP Team, 2023) to estimate the model fit and confirmatory composite analysis (CCA) through Smart-PLS v4 (Ringle et al., 2022) for evaluating the validity and reliability parameters of the Dig-Comp's instrument.

Results and Discussions

Normality and Multicollinearity Test

The Skewness and excess Kurtosis parameters were applied to diagnose the data normality. The scores of Skewness ranged from -1.52 to -0.40, and that of Kurtoses was from -0.66 to 2.84 for each indicator, suggesting there was no serious violation of the Multivariate normality whose values should be between –3 and +3 (Kline, 2016). As for Multicollinearity, the variance inflation factor (VIF) values of individual indicators ranged from 1.34 to 2.81, and that of construct relationships (between independent and dependent constructs) ranged from 1.0 to 1.94, achieving the recommended values below the maximum score of 3 (Hair, Black, et al., 2019; Kock, 2022); thus, no redundancy issues were observed among indicators (Kline, 2016). These results indicate that neither Multicollinearity issues nor common method bias were observed in the research questionnaire and survey design (Kock, 2022).

Results of Model Fitting Test

For ordinal data, as in the case of this pilot study, the diagonally-weighted least squares (DWLS) technique is suitable for parameter estimation (Forero et al., 2009). Thus, DWLS was implemented through CFA to assess the model fit of the Dig-Comp 2.1 framework. The results showed the chi-square test ($\chi 2 = 437.673$, $df = 395$, $p = 0.068$) as a good indicator of model fit (Hu & Bentler, 1999). Besides that, additional six fit indices,

the $\chi 2/df$ ratio, TLI, RMSEA, NFI, GFI, and CFI, were further applied to confirm the model's goodness-of-fit. Table 1 exhibits each fit index's score. Table 1 portrays that each of the following indices: CFI, GFI, TLI and NFI, achieved a score above the threshold of 0.95, indicating an adequate fit to the data. Meanwhile, the $\chi 2$/df ratio (1.11) is below 3, proving an acceptable fit. In addition, the RMSEA score was 0.03, which is less than 0.08, indicating an adequate fit to the data (Hu & Bentler, 1999). Note that the model was fitted without any modifications to the model's specifications.

Table 1: Fit Indices Results of Dig-Comp 2.1 Framework

Fit Index	Value Recommended	Measurement Model Value
$\chi 2$	N/A	437.673 (P = 0.068)
df	N/A	395
$\chi 2$/df	< 3.0	1.11
TLI	> 0.95	0.998
NFI	> 0.95	0.982
GFI	> 0.95	0.984
CFI	> 0.95	0.998
RMSEA	< 0.08	0.03

Measurement Model Evaluation

Confirmatory composite analysis (CCA) followed the model fitting process to assess the validity and reliability of the measurement model. Thus, Cronbach's alpha (CA) and composite reliability (CR) were applied to analyse each construct's measurement reliability of the Dig-Comp framework. The results suggested a high internal consistency for each construct of the Dig-Comp framework. As Table 2 depicts, the CA scores ranged from 0.854 to 0.873, while that of CR ranged from 0.863 to 0.883, which are all above 0.7, indicating strong reliability (Hair, Risher, et al., 2019).

Table 2: Reliability, Convergent Validity, and Item Loadings Results

Construct	Item	IL	CA	CR	AVE
Communication & Collaboration (CC)	CC1	0.789	0.858	0.863	0.591
	CC2	0.844			
	CC3	0.769			
	CC4	0.853			
	CC5	0.720			
	CC6	0.612			
Digital Content Creation (DCC)	DCC1	0.800	0.871	0.878	0.614
	DCC2	0.789			
	DCC3	0.606			
	DCC4	0.849			
	DCC5	0.848			
	DCC6	0.782			
Digital Problem Solving (DPS)	DPS1	0.819	0.873	0.883	0.611
	DPS2	0.745			
	DPS3	0.722			
	DPS4	0.814			
	DPS5	0.834			
	DPS6	0.748			
Digital Safety (DS)	DS1	0.790	0.854	0.867	0.579
	DS2	0.686			
	DS3	0.756			
	DS4	0.777			
	DS5	0.718			
	DS6	0.830			
Information & Data Literacy (IDL)	IDL1	0.819	0.871	0.882	0.610
	IDL2	0.862			
	IDL3	0.795			
	IDL4	0.724			
	IDL5	0.701			
	IDL6	0.773			

Furthermore, discriminant and convergent validities were assessed to confirm the measures' validity. First, convergent validity was examined using indicator loadings (IL) and average variance extracted (AVE) of each latent construct of the Dig-Comp framework. Table 2 indicates that IL scores ranged from 0.606 to 0.862, and all constructs have AVE scores above 0.50, ranging from 0.579 to 0.614, indicating an adequate convergent validity. Note that the score of 0.7 is the strictest criterion for indicator loadings, and the relaxed criterion is between 0.5 and 0.6, as proposed by previous scholars (Hair, Black, et al., 2019; Hair Jr et al., 2017). Therefore, as indicated in red in Table 2, three items (CC6, DCC3, and DS2) have scored less than 0.7, suggesting that they can be

rephrased in future studies. Besides that, the Fornell-Larcker Criterion (FLC) and Heterotrait-Monotrait Ratio (HTMT) were used to verify the discriminant validity of Dig-Comp 2.1. For FLC, the results (as depicted in Table 3) indicate that each construct's AVE's square root is greater than the correlation scores between the construct and other constructs (Hair, Risher, et al., 2019). Further, as shown in Table 3, HTMT values (italicised in brackets) are smaller than the cutoff of 0.90, indicating adequate discriminant validity (Hair, Risher, et al., 2019). The HTMT ratio provides a measure of discriminant validity by comparing the correlation between constructs to the correlation between constructs and their indicators. This finding confirms the satisfactory discriminant validity of Dig-Comp's constructs.

Table 3: HTMT and Fornell-Larcker Criterion Results

Construct	CC	DCC	DPS	DS	IDL
Communication & Collaboration (CC)	**0.769** *(0)*				
Digital Content Creation (DCC)	0.727 *(0.842)*	**0.783** *(0)*			
Digital Problem Solving (DPS)	0.729 *(0.845)*	0.751 *(0.846)*	**0.782** *(0)*		
Digital Safety (DS)	0.657 *(0.764)*	0.696 *(0.804)*	0.709 *(0.796)*	**0.761** *(0)*	
Information & Data Literacy (IDL)	0.759 *(0.872)*	0.738 *(0.851)*	0.745 *(0.843)*	0.615 *(0.694)*	**0.781** *(0)*

Overall, the analysis results suggest that the Dig-Comp framework portrayed an excellent fit with pilot data as indicated by various model fit indices. Moreover, the CCA demonstrated satisfactory reliability and validity of the Dig-Comp 2.1 framework, suggesting that the framework's instrument measures are appropriate for the main study and other future investigations. The study's findings support the previous literature (Patwardhan et al., 2023; Wild & Schulze Heuling, 2021), which also found the Dig-Comp 2.1 framework's validity and reliability in different contexts.

Conclusion and Future Directions

The present study validated the applicability of the Dig-Comp 2.1 Framework instrument within the context of a non-western developing country. The study's findings contribute to digital competence literature by validating the Dig-Comp 2.1 Framework in the Ugandan context. The analysis results confirmed the empirical evidence for the validity and reliability of the Dig-Comp 2.1 model using both confirmatory factor and composite analyses. The study is limited to a pilot design based on a cross-sectional survey and convenience sampling to assess the validity and reliability of the Dig-Comp framework

due to sample size constraints. Thus, using adequate samples, future investigations should further validate the Dig-Comp 2.1 framework using more samples and implementing various analyses such as *t-tests* to investigate if there is a gender difference in digital competencies. Additionally, future studies can implement a structural equation modelling (SEM) technique to assess if digital competence significantly influences digital informal learning among university students in non-Western countries. Finally, the present study's findings can enhance the understanding of individuals' digital competence and facilitate the development of strategies to promote digital literacy. By bridging the digital divide, developing countries can harness the potential of digital technologies to foster economic growth, improve educational outcomes, and empower individuals in various spheres of life.

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