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Validation and Profile of Chinese College Students' Digital Competence Scale

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Abstract: Digital competence is one of the vital competences for lifelong learning. The European Digital Competence Framework for Citizens (DigComp) proposes five areas of digital competence while UNESCO Digital Literacy Global Framework (DLGF) puts forward seven areas of that. The present study seeks to build on these Frameworks by developing and validating an assessment tool that considers a total of seven areas to measure the digital competence of College students, including operation devices and software, and searching, accessing, processing, using and managing digital information, and protecting devices & privacy as well. A questionnaire of 773 random participants was collected to conduct exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). The results showed that the final 7-factor scale with 31 items was formed as a valid and reliable instrument for measuring the digital competence of Chinese college students. The keywords extracted from the feedbacks of open-end questions were about to outline the research direction of digital competence for future study.

Keywords: Digital Competence; Assessment Instrument; College Students; Digital Education

1. Introduction

Since digital competence was defined as one of eight key competences for lifelong learning in digitalized knowledge society (European Commission, 2006), countries around the world have launched their digital competence frameworks, of which the most influential ones include USA's National Educational Technology Standards for Students (NETS-S), EU's Digital Competence Framework for Citizens (DigComp), and UNESCO'S Digital Literacy Global Framework (DLGF). In June 2016, American International Society for Technology in Education (ISTE) published Standards for Students and clearly pointed out the role of students as Digital Citizen. And the digital competence of college students, as a digital generation, is one of the vital factors to the evaluation of educational quality in higher education (López-Meneses, E. et al, 2020; Cronin, 2017; Gisbert & Lázaro, 2015; Bennett, 2014; Buchanan, Sainter, & Saunders, 2013). In recent years, with the popularity of the Internet, the extensive use of digital equipment and the growing demand for digital capabilities in society, the digital transformation of the education system has entered an accelerated stage, especially the promotion of online education by the COVID-19 epidemic. On September 30, 2020, the European Commission released the Digital Education Action Plan 2021-2027, which indicates that the investigation of students' digital competence in digital environment is a research topic worthy of attention in digital education.

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Educators and researchers have never stopped designing assessment tools to measure students' digital literacy or competence (Covello & Lei, 2010). Most of them were developed on the basis of digital frameworks, which inevitably has regional characteristics. Through the literature review, it is found that although the Ministry of Education of China has also released policy documents, such as the Construction Norms of Digital Campus in Primary and Secondary Schools and the Action Plan of Educational Informationization, it has not yet released the assessment instrument of digital competence for college students. Therefore, this paper, referring to DigComp and DLGF and integrating with the characteristics of Chinese college students, was about to develop an instrument to measure the college students' digital competence and its influencing factors with the aim to provide references for the implementation of digital education.

1. Theoretical Background

1.1 Defining Digital Competence

Digital competence evolved from the concepts of computer literacy, information literacy, ICT literacy and digital literacy (Fraillon, Schulz, & Ainley, 2013). It is said that digital literacy and digital competence were overlapping in public discourse (Martin & Grudziecki, 2006; Spante, Hashemi & Algers, 2018). In the EU framework of key competences for all citizens, digital competence is defined as follows:

> "Digital competence involves the confident and critical use of Information Society Technology (IST) for work, leisure and communication. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet" (European Commission, 2006: 16)

In the Digital Education Action Plan (2021-2027), digital literacy was included in the notion of digital competence in the area of digital education (Ferrari, 2013), as shown in Figure 1.

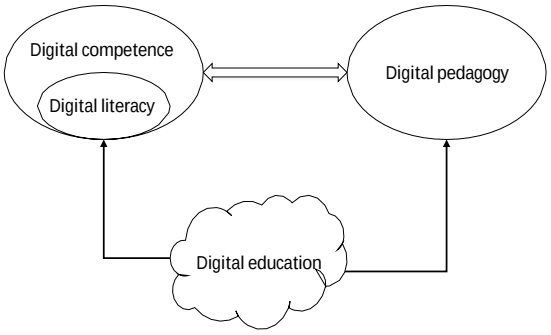

Fig. 1 - Three core concepts of digital education in dig comp.

1.2 Measuring Digital Competence

The European Digital Competence Framework for Citizens proposes 21 competences, organized into 5 areas, which include information and data literacy, communication and collaboration, digital content creation, safety and problem solving (Carretero, Vuorikari & Punie, 2017). In 2018, UNESCO published the Digital Literacy Global Framework (DLGF) and put forward the corresponding assessment indicators (Law, Woo, & Wong, 2018; Laanpere, 2019), which include 26 competences in 7 areas, 2 extra areas compared with the DigComp Framework, that is, devices and

software operations, and career-related competences. Despite a certain focus on digital competence abroad, the literature and policy documents reflect that China's research in this field is slightly backward. It was not until 2018 that the Ministry of Education issued the Education Informationization Action Plan 2.0 and officially put forward to improve information literacy comprehensively (Ministry of Education, 2018), and two years later, issued the Standards for Digital Campus of Vocational Colleges which put forward the overall requirements for students' digital literacy (Ministry of Education, 2020). Despite the importance of digital competence, very little research has been conducted concerning the assessment of students 'digital competence and its affecting factors (Dong, Jin & Yuan,2021; Liu Jing, 2019).

Considering its necessities in Chinese contexts, the object of this paper is to develop and validate a tool that empirically measures and describes the digital competence of college students. Ferrari, Punie & Redecker (2012), after analyzing 15 frameworks of digital literacy and digital competence, pointed out that technical skills constitute a central component of digital competence. After comparing the areas and description of the two most influential frameworks, DigComp and DLGF, and considering the present situation of digital education in China, this paper is to develop an instrument to measure the digital competence of college students from the aspects of Information Society Technology (IST), namely, devices and software operations, searching, accessing, processing, applying and managing of digital information, and network safety awareness and problem-solving competence.

2. Methodology

2.1 Instrument

To develop and validate an instrument that measures the digital competence of college students in China, areas and items were partly adapted from the two most influential frameworks, DigComp and DLGF. The survey comprised three parts: (1) demographic questions; (2) self-assessment of digital competence; (3) open-end questions on the factors affecting digital competence for further study (What do you think are the factors that affect your digital competence from the perspective of external environment and individual internal factors?). And the self-assessment instrument made up of 38 items (see Table 1) distributing among 7 areas on a 5-point Likert scale from strongly-disagree to strongly agree.

Table 1 - Areas of digital competence and items.

Area	Item Description
Operating devices and software (OC)	OC1:I can operate such digital devices as mobile phones, computers etc.
	OC2:I can download, install and uninstall APPs and soft wares.
	OC3:I can apply for network accounts, such as email, WeChat etc.
	OC4:I can process documents using Word, Excel, PowerPoint and other office software
	OC5:I use electronic devices consciously when dealing with daily affairs.
Searching digital information (SC)	SC1:I can consciously search for what information and digital content I want.
	SC2:I have a variety of search engines and methods
	SC3:I can often find what information and digital content I want.
	SC4:I can identify and filter the searched information and digital content
	SC5:I know some authoritative databases, such as CNKI, google scholar, Patent Library, etc.

Accessing digital information (AC)	AC1:I know how to download digital resources such as text, pictures, audio and video.
	AC2:I can download digital resources such as pictures, e-books, audio and video.
	AC3:I know how to use some commonly used download tools, such as Thunder, Baidu network disk ,etc.
	AC4:I know many methods of downloading resources such as resource sniffing and source file analysis.
	AC5:I know screen shots, word recognition and other resource reprinting methods
Processing digital information (PC)	PC1:I can process text resources.
	PC2:I can process image resources.
	PC3:I can process audio and video resources.
	PC4:I can process animation resources.
	PC5:I can convert resource formats, such as cutting, merging, converting , etc.
	PC6:I can create digital content online
Using digital information (UC)	UC1:I can interact with others through digital technologies
	UC2:I can share pictures, texts, websites and videos through digital technologies
	UC3:I can solve problems in my study and life through digital technologies and network
	UC4:I can solve technical problems
	UC5:I can use different electronic tools or software on different situations
Managing digital information (MC)	MC1:I can file and save my digital information consciously.
	MC2:I can manage my digital information using Information Management Soft wares
	MC3:I can clean up and maintain my digital information regularly.
	MC4:I can classify and archive all my digital resources.
	MC5:I can back up and manage my digital information using network disk and mobile disk.
Protecting devices & privacy (WC)	WC1:I know there exists network safety.
	WC2:I can protect personal data and privacy
	WC3:I install anti-virus software
	WC4:I clean up the traces of surfing, kill viruses and check up the devices regularly
	WC5:I set complex network passwords
	WC6:I pay attention to the security of soft wares and registered accounts.
	WC7:I don't share photos, ID numbers and other identity information on the network platform.

2.2 Sample

This questionnaire was sent to the students of 5 colleges in Zhuhai, Guangdong Province which is one of China's special economic zones, bordering Macao and Hong Kong, and a representative both in economy and digital education. The questionnaire was distributed online in various subjects in different faculties. The students were selected by non-probability convenience sampling. A total of 773 respondents completed the questionnaire, including 340 (44%) male and 433 (56%) female respectively. As for participant majors, 342 (44%) were liberal arts and 431 (56%) students in science. School types were also asked. 704 (91%) were from higher vocational colleges while the rest were from universities.

2.3 Data Collection and Analysis

To develop and validate the assessment instrument, exploratory factor analyses (EFAs) using SPSS 22 were performed to identify scale clusters. After that, confirmatory factor analyses (CFAs), after removing items with low factor loadings and cross-loadings, were used to test the stability of factor structure by using AMOS 24. Finally, the score reliability of the final version of assessment instrument was presented. Meanwhile, the feedback texts of the open-end questions were sent to NVIVO 12 for words frequency analysis in order to provide core words for factors affecting digital competence in future study.

3. Results

3.1 Exploratory factor analyses

EFAs were conducted to identify a number of latent factors and varimax rotation of SPSS was used to reset the correlation between factors and to interpret the factors. Strong factor loadings, larger than 0.60, were remained in the instrument and finally, a 7-factor solution was accepted along with 31 items.

The KMO sample competency is measured to test the sample validity statistically (Sang, Tondeur & Dong, 2016). According to Field (2005), the KMO value ranges between 0 and 1, and the closer this statistic is to 1, the greater the internal consistency of the items in the scale. The resulting KMO value was .973 and Bartlett was less than .05 (sig=0.000), which was considered highly acceptable. Gorsuch (1983) pointed out that a variance value above 40% is considered sufficient for social science studies. The 7-factor instrument accounted for the 72.89% of the variance, which means the total variance was perfectly acceptable in statistics.

3.2 Confirmatory factor analyses

CFAs were also conducted with AMOS 24 to determine if these factors efficiently represented the variable groups in terms of individual item loadings, reliability of measures, convergent validity and discriminant validity. Table 2 presents a summary of the unstandardized factor loadings, P value, standardized factor loadings, Cronbach's α, composite reliability, and variance extracted estimate, etc. Firstly, all values of the Cronbach' s α exceeded 0.7, showing perfect internal consistency reliability for the 7 constructs. Meanwhile, Fornell and Larcker (1981) proposed that the item reliability and composite reliability of each construct and average variance extracted were three measures of assessing convergent validity of the measurement items. As shown in Table 2, the standardized loading values exceeded 0.7, ranging from 0.736 to 0.937, thus indicating convergent validity at the item level according to the threshold proposed by Gefen, Straub, and Boudreau (2000). As for the composite reliability, all values were above the recommended threshold 0.7 suggested by Nunnally and Bernstein (1994). Turning to the average variance extracted, all values reached the acceptable limits, ranging from 0.0.69 to 0.85. To sum up, the convergent validity for the proposed constructs of the instrument was adequate statistically.

Table 2 - Reliability and validity test of the scale.

Latent variables	Items	Unstd.	S.E.	Z value	P value	Std.	Mean	SD	Cronbach's α	CR	AVE
OC	Q5	1.000				0.806	4.165	0.786	0.926	0.928	0.722
	Q6	0.941	0.033	28.846	***	0.871					
	Q7	0.973	0.032	30.282	***	0.900					
	Q8	0.978	0.038	25.460	***	0.798					
	Q9	0.995	0.035	28.717	***	0.868					
AC	Q15	1.000				0.936	4.082	0.822	0.943	0.944	0.850
	Q16	0.973	0.020	49.324	***	0.937					
	Q17	0.946	0.022	42.162	***	0.892					
PC	Q20	1.000				0.826	3.660	0.874	0.944	0.945	0.743
	Q21	1.085	0.035	31.090	***	0.883					
	Q22	1.159	0.036	32.147	***	0.901					
	Q23	1.143	0.041	27.901	***	0.826					
	Q24	1.140	0.037	31.224	***	0.886					
	Q25	1.119	0.039	29.033	***	0.847					
WC	Q36	1.000				0.832	4.031	0.776	0.933	0.936	0.710
	Q37	1.025	0.034	30.023	***	0.859					
	Q38	1.057	0.035	29.805	***	0.855					
	Q39	1.073	0.035	30.772	***	0.872					
	Q40	1.005	0.042	23.855	***	0.739					
	Q41	1.082	0.034	31.784	***	0.889					
MC	Q31	1.000				0.911	3.792	0.841	0.948	0.949	0.787
	Q32	1.048	0.024	43.541	***	0.924					
	Q33	1.004	0.028	36.248	***	0.862					
	Q34	0.974	0.026	37.397	***	0.873					
	Q35	0.972	0.027	36.610	***	0.865					
SC	Q12	1.000				0.891	3.862	0.804	0.860	0.869	0.690
	Q13	0.966	0.030	32.124	***	0.857					
	Q14	0.940	0.038	24.735	***	0.736					
UC	Q26	1.000				0.900	4.056	0.841	0.939	0.939	0.838
	Q27	1.019	0.025	41.516	***	0.924					
	Q28	0.985	0.024	41.273	***	0.922					

3.3 Reliability of the Final Instrument

Five items of the original instrument were deleted due to their low factor loadings and cross-loadings. And the score reliability of the final scale was determined using Cronbach's alpha coefficient. Henson (2001) said that the test score should have reliability of 0.8 or better. And the resulting score of the final scale was 0.978, which means it had acceptable reliability coefficients.

3.4 Discriminant Validity

As shown in Table 2, the seven subscales 'mean scores, varying from 3.660 (SD=0.874) to 4.165 (SD=0.786), show that students' perceptions about digital competence were relatively high.

Table 3 - Discriminatory validity test of potential variables.

	UC	SC	MC	WC	PC	AC	OC
UC	***0.915***						
SC	0.760	***0.831***					
MC	0.809	0.745	***0.887***				
WC	0.827	0.756	0.812	***0.842***			
PC	0.711	0.719	0.803	0.673	***0.862***		
AC	0.783	0.867	0.711	0.722	0.723	***0.922***	
OC	0.787	0.812	0.680	0.723	0.639	0.846	***0.850***

Note: The square root of the average variance extracted for each construct is denoted in bold and italic, while the inter-construct correlations are shown off-diagonally

At last, the correlation coefficients for variable pairs were derived from the bivariate correlation analysis results (see Table 3). According to Fornell & Larcker(1981), a construct is more closely related with its indicators than with the other constructs if the square root of the AVE of a construct is greater than the off-diagonal elements in the corresponding rows and columns. The data in Table 3 indicate that the discriminant validity appears relatively satisfactory.

3.5 Open-end question

Some open-end questions were also attached in the questionnaire to collect qualitative feedbacks about what factors may affect the development of digital competence from the perspective of students. After analyzed with Nvivo 12, some keywords were extracted and listed on Figure 2 for further studies.

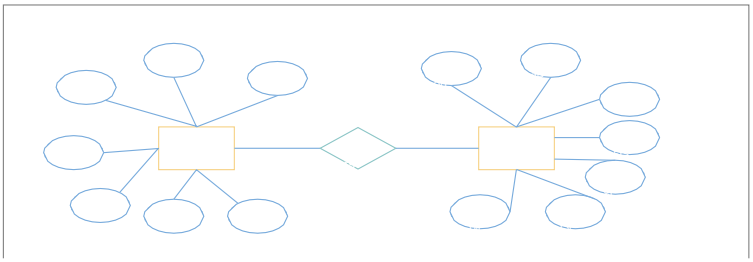

Fig. 2 - Potential factors of digital competence.

4. Conclusion

Many countries and regions have realized the changes in talent demand brought about by the advent of the digital age, and attached great importance to cultivating learners' related qualities or competences (Li & Ranieri, 2010; Zhao, Llorente & Gómez, 2019 & 2021). Past decades have witnessed some national and international organizations try to formulate a unified standard digital literacy framework for self-assessment or educational or training courses design (Covello, 2010; Calvani, Cartelli & Ranieri, 2008; China's Ministry of Education,2020). However, it cannot be ignored that the implementation of these frameworks should be region-oriented and its assessment tools have to be un-unified in different contexts (Lopes-Meneses, Sirignano, 2020; Guzman-Simon, Garcia-Jimenez, 2017; Zhao, Liorente & Gómez,2021).

In light of the above, and in order to contribute to the assessment of students' digital competence, this study was to develop and validate a questionnaire that builds on the existing DigComp Framework and DLGF Framework in Chinese contexts. Those competences in "operating devices and software", "searching, accessing, processing, using and managing digital information" , "protecting devices and privacy" are regarded as fundamental items of digital competence in the questionnaire. After collecting the feedbacks from 773 college students, both EFAs and CFAs were conducted to test the reliability and validity, thus verifying that this 7-factor scale with 31 items was a valid and reliable tool for assessing the digital competence of college students. The proposed tool was validated in the city with relatively advanced economic and educational level in China where students, from basic education to higher education, are at the forefront in digital education.

This study is obviously limited by the fact that the questionnaire investigated students' digital competences from the dimension of digital technology, which was inevitably slightly one-sided, not involving in the aspects of digital thinking, digital etiquette and profession-or career-related digital competences as Zheng Caihua proposed in his framework (2019). A task for future research is, therefore, to adapt the instrument to other cities and types of higher educational organizations, or for students from other levels of education, thus developing more comprehensive tools for measuring students' digital competence. It would also be necessary to incorporate the views of educators or other educational researchers and management personnel or even employers regarding the digital competence of their educatees and employees and the potential factors affecting digital education. As a recommendation for further research, the keywords extracted from the open-end questions can be explored as potential determinants or factors.

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Conflict of Interest
The authors declare no conflicts of interest.

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