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Development and preliminary validation of the Job Digital Competence Scale

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ABSTRACT. Lo studio descrive la costruzione e la validazione preliminare della *Job Digital Competence Scale,* basata sul modello DigComp 2.2, per valutare le competenze digitali sul lavoro. Gli item sono stati sviluppati tramite revisione della letteratura, interviste a esperti e valutazioni di giudici. La scala è stata testata su 214 partecipanti di vari settori, confermando la natura multidimensionale del costrutto, con un'affidabilità e validità accettabili e correlazioni da moderate a forti con variabili tecnologiche e di performance. Lo strumento risulta breve e adatto a valutare competenze digitali in ambito organizzativo.

SUMMARY. This study describes the development and preliminary validation of the Job Digital Competence Scale, a measure based on the DigComp 2.2 model for the assessment of digital competences in the workplace. Items were created and refined following a literature review, interviews with experts, and a judge evaluation. The psychometric properties of the tool were tested through a study involving 214 participants from various occupational sectors. Results confirmed the multidimensional nature of the construct, with acceptable reliability (omega ranging from .69 to .93) and moderate to strong correlations with technology acceptance, performance, and the use of different digital systems. Results of the preliminary validation suggest that the Job Digital Competence Scale is a reliable and relatively brief tool to assess different dimensions of digital competence in the general working population.

Keywords: *Digital competence, Digcomp 2.2, Job performance, Digital systems, Scale validation, Multiple imputation*

INTRODUCTION

ICTs have steadily improved and become more accessible in different work settings in recent years, changing how people interact with digital systems and the way work is designed (Parker & Grote, 2022). Digital competences, extending beyond technical expertise to include learning readiness and problem-solving, play a crucial role in organisational digital transformation by allowing the adoption of innovative digital systems that can be expertly used by workers, improving work quality and performance (Trenerry et al., 2021).

Among the proposed models to investigate digital competence (DC), the European Digital Competence Framework for Citizens, or DigComp is one of the most comprehensive and utilized frameworks (Oberländer, Beinicke & Bipp, 2020; Peiffer, Schmidt, Ellwart & Ulfert, 2020); first proposed in 2013 (Ferrari, 2013) it is currently in its third revision, Digcomp 2.2 (Vuorikari, Kluzer & Punie, 2022). The framework is based on a KSA (Knowledge, Skills, Attitude) conceptualisation of competence and refers to DC as a multidimensional construct, defined as "the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society" (European Commission, p. 10). The model is composed of 21 competences distributed in five areas: Information and Data Literacy (IDL), Communication and Collaboration (CC), Digital Content Creation (DCC), Safety (S) and Problem Solving (PS).

Despite this comprehensive conceptualization and the interest in assessing DC, research on the working population is limited, with an even more limited choice of tools to evaluate digital competencies in the general workforce, since most of them are aimed at the educational sector (Oberländer et al., 2020). There are many conceptualizations of digital proficiency, and as such some instruments do not measure digital competence (Ulfert-Blank & Schmidt, 2022) or are based on a different theoretical model (Nikou, De Reuver & Mahboob Kanafi, 2022). Other instruments are based on DigComp (Bartolomé, Garaizar & Larrucea, 2022; Clifford, Kluzer, Troia, Jakobsone & Zandbergs, 2020) but they are either too lengthy for organisational research and practice or measure only some of DigComp dimensions (Oberländer & Bipp, 2022). Lastly, some tools are developed for a specific working population (i.e., Reixach et al., 2022).

In light of this context, this study aims to bridge this gap in the literature, presenting the development and the preliminary validation study of the *Job Digital Competence Scale (JDCS)*, a brief self-report tool based on Digcomp 2.2 aimed at the general workforce.

METHOD

We followed the three main steps in the literature for scale development (Morgado, Meireles, Neves, Amaral & Ferreira, 2017): item generation, theoretical analysis, and psychometric analysis. The item generation involved a deductive step (systematic review), which resulted in 125 items, and an inductive step (interviews with experts), after which we refined the items and reduced their number to 61. Items were formulated without reference to specific digital systems, to avoid obsolescence and engage the general working population.

Following this step we further refined the items by conducting a survey with expert judges, resulting in the final set of items ($n = 21$) included in a study to test the instruments' psychometric properties.

Item generation

In the first step, we conducted a systematic review of DigComp-based instruments used in studies published since 2013 involving the working population, by performing two searches on Scopus and Web of Science in January 2023. The review was aimed at understanding how DC was operationalized and examining the characteristics of the tools used to assess it in the working population.

Following this analysis, we conducted semi-structured interviews between February and March 2023 involving nine experts in the field of technology at work. We asked the experts to express their beliefs on the following themes concerning DC for the general working population:

- essential DC required for workers;
- most important DC in the workplace;
- commonly lacking DC among workers;
- DC requiring future investment and development.

The interviews aimed at identifying the level and type of competences needed in the labour market today for a wide range of occupations, to prepare items that could adequately discriminate between participants of different proficiency levels, from the most basic areas to slightly more advanced competences, without being too easy or too technical to understand.

To better capture the wide range of DC in different work contexts and hierarchical levels, we aimed to obtain a heterogeneous sample in terms of age, work sector, and job position. Participants' mean age was 44.45 ($SD = 14.19$), most of whom were males ($n = 7$). Four participants were employed in the research, teaching, and training sector, while the remaining three were employed in IT.

The interviews were analyzed through template analysis (King, 1998), using the paragraph as the analysis unit. A priori themes derived from the areas and single competences described in the DigComp 2.2 were used as an initial template. The five dimensions of the model were used as superordinate families, with each competence serving as a separate code. Following the first coding, the interviews were analyzed again to further refine the codes and find potential new themes, resulting in additional subthemes for each competence.

Theoretical analysis

To assess the face and content validity of the scale, we presented it to seven judges. The sample was composed of four females and three males, with a mean age of 32.3 years (*SD* = 10.10). Four of the judges were employed in the teaching and research sector and thus considered experts in the target construct while the remaining three were technical profiles using ICT for daily work. Judges rated wording clarity and item relevance on a scale from 1 = not at all to 5 = very much and categorized the items as knowledge, skills, or attitude to ensure greater content validity. For item selection, we used the sum score decision rule (total score for an item for clarity and relevance across all judges; Hardesty & Bearden, 2004), retaining only items scoring 52 or higher (range: 14-70) and with a concordance of at least four out of seven judges. Subsequently, we selected the highest-rated items and checked their relevance with the interview themes, resulting in the final set of 22 items.

Psychometric analysis

Participants and procedure

The JDCS was included in an online questionnaire hosted on the Limesurvey platform. Data collection took place between July and October 2023. Participants were recruited through a research invitation disseminated through social networks, which included a brief description of the study and the survey link. Informed consent was collected from all participants on the first page of the survey, which also presented the research and the data management policy in further detail. The anonymous and voluntary participation and the right to withdraw from the study at any time with no consequences were also emphasized. The Bioethical Committee of the University of Turin approved the study (document no. 0558878, July 18, 2023).

The sample included 214 participants. Mean age was 38.39 years (*SD* = 12.46), ranging from 18 to 67 years. The sample was quite balanced concerning gender, with a slight majority of women (53.4%). Most of the sample was employed as an office worker (63.7%), followed by factory workers (18.1%), middle managers (12.9%) and executives (4.1%). Most of the sample worked in the private sector (80.6%), full-time (86.4%), with a permanent contract (64.9%); 16.3% had a fixed-term contract, while 10.1% defined themselves as freelancers. Finally, average job seniority was 11.47 years (*SD* = 11.50).

Measures

The JDCS consisted of 22 items answered on a 7-point Likert scale. The questionnaire included additional measures to test the instruments' convergent validity.

Organizational digital culture was assessed with three items (e.g. "There is a clear orientation to digital technology changes inside the company's culture") adapted from Martínez-Caro and colleagues (Martínez-Caro, Cegarra-Navarro & Alfonso-Ruiz, 2020). Participants were asked to answer on a 7-point Likert scale. McDonald's Omega was .90.

Task performance was assessed with the Italian version of the *Individual Work Performance Questionnaire* (Casu, Mariani, Chiesa, Guglielmi & Gremigni, 2021). Only the 5 items about task performance were used in this study (e.g. "I was able to perform my work well with minimal time and effort"). To reduce the possibility of response sets and socially desirable answers, the authors added 3 reverse items, with one referring to the perceived quality of one's work, an aspect that was missing from the original scale ("The quality of my work was not always up to the demands"). Participants were asked to indicate the frequency of eight statements on a scale from 0 = rarely to 4 = always. McDonald's Omega was .81.

Technology acceptance was assessed with eight items six of which were adapted from the TAM-3 (e.g. "The system improves my performance in my job"; Venkatesh & Bala, 2008). Three items measured perceived usefulness, three perceived ease of use, and two more items, one of which reversed ("Given the choice, I would reduce the use of digital systems at work"), were added by the authors to assess behavioural intention, following the formulation from Rojas-Osorio and Alvarez-Risco's instrument (2019). Participants answered on a 5-point Likert scale. McDonald's Omega was .92.

The frequency of use of digital systems was measured with eight ad hoc items. Each item was dedicated to one of the following digital technologies or services: e-mails; internet to search for information; spreadsheet programs; online conferencing or chats; word processing programs; programming languages; social networks; and artificial intelligence. Participants indicated the frequency of use of each item on a scale from 1 to 5 (1 = never, 2 = less frequently than once a month, 3 = at least once a month, 4 = at least once a week, 5 = daily).

Data analysis

We conducted Little's MCAR Test, which was significant (χ^2 = 4681.18, *df* = 4447, *p* = .007). Multiple imputation was performed in R using the package *mice*, employing the predictive mean matching method (10 imputations, 5 iterations). Kolmogorov-Smirnov and Shapiro-Wilk tests confirmed non-normality for every JDCS item. Kaiser-Meyer-Olkin (KMO) test yielded values greater than .80, and Bartlett's test of sphericity was non-significant. Confirmatory factor analysis (CFA) was performed in R using the packages *semTools* and *lavaan*, employing a Weighted Least Square Mean and Variance adjusted (WLSMV) estimator.

Consistent with the literature, we evaluated several fit indices: the χ^2 index, Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI) and Standardized Root Mean Square Residual (SRMR). We considered the following cut-off values: >.95 for CFI, <.08 for both RMSEA and SRMR (Hooper, Coughlan & Mullen, 2008). Composite reliability and convergent validity were assessed by calculating McDonald's omega and average variance extracted (AVE), respectively. After confirming the scale's factorial structure we conducted correlation analyses using the mean scores of the JDCS dimensions and technological variables to further assess convergent validity. Performance, being theoretically linked to competence and paramount in the relationship between DC and workplace digital transformations, was also included in the analyses. Reported results are pooled estimates across 10 imputed datasets.

Literature review

The literature search yielded 441 sources, which after further rounds of analysis and selection resulted in 16 studies, most of which (*n* = 12) were in the educational sector; only two studies included a general workforce sample. The construct was predominantly described as multidimensional, although there was disagreement concerning the number of dimensions; furthermore, almost half of the studies that intended DC as multidimensional opted to present a general competence score, thus treating the construct as one-dimensional. Ten sources included a relatively short tool suitable for our objective, ranging from 19 to 29 items; however, six were based on DigCompEdu and four of them specifically employed the same instrument. Of the remaining four not using this framework, one tool was specifically developed for the healthcare sector, two lacked adequate psychometric properties, and one measured digital self-efficacy, although the tool was quite robust concerning sampling and psychometric properties and presented minimal differences with the conceptualization of digital competence. Since most of the shorter tools employed the same instrument based on the DigCompEdu, the most common response scale was a proficiency scale ranging from zero to four; the other studies all employed different ones, with three employing an agreement scale.

After reviewing the instruments included in the studies, we cross-checked the item formulations with the examples provided in DigComp 2.2 and the DigCompSat assessment instrument, resulting in the first set of items (*n* = 125).

Interviews

Participants depicted the digitally competent worker as someone who is relatively autonomous in the use of digital systems to perform basic navigation for searching information and solutions, manage data, develop content, communicate and collaborate with others, and solve simple technical problems. Concerning higher levels of specialization or more technical occupations, participants highlighted being able to apply the fundamentals of computational thinking and perform some light task automation, with higher proficiency in navigating digital systems to find the best answers and apply them creatively. Competences perceived as lacking and important for the future were almost always equivalent, namely communication and collaboration, data management, and identifying needs and answers autonomously. Although competences concerning copyright, well-being, and environment were almost never cited by participants, we still included them in the set of items resulting from the analysis (n = 61)

Expert evaluation

46 items out of 61 obtained a summed score of at least 52. One item was eliminated since it did not reach the minimum agreement of four judges, leaving 45 items for further evaluation. After choosing the best-rated items for each competence, the number of items was further reduced to 38. Finally, we checked which items aligned best with the results of the interviews. Items regarding citizenship, personal health, and the environment were not prominent in the interviews and additionally did not pass the sum score cut-off, so we excluded them. On the other hand, an item concerning copyright, a theme which was never mentioned, had high scores and agreement ratio, and thus we included it. Another item concerning data analysis and decision making, a competence that was often cited as important for the future, was slightly below the cut-off score but we decided to keep it. The relatively lower score resulted from one of the judges not answering the question: the other judges assigned acceptable scores both in clarity (M = 4.67) and congruence (M = 3.5). The final scale consisted of 22 items, at least one for each competence for which the items passed the sum score cut-off; Table A1 in the Appendix reports the original Italian formulations and corresponding English translation, with the items numbered according to the DigComp 2.2 competence area (first number) and single competence (second number).

Psychometric analysis

We employed a CFA to test the dimensionality of the scale. We tested the following models: a g-factor model, where all items directly load on a general DC factor (M1); a higher-order model, where the five factors following the five competence areas described in the DigComp 2.2 model load on a general factor (M2); a first-order correlated factor model (M3).

The following residuals covariance were specified in each model according to thematic relations: 4.2 with 4.3, since one refers to general cybersecurity threats and one mentions phishing; 3.1a with 3.2, since creating and editing digital content are closely related. Results showed that M1 did not have satisfactory fit statistics, in line with the multidimensionality of the construct. Conversely, M2 had an acceptable fit, with only CFI having a value below the suggested cut-off of .96, but resulted in a Heywood case, possibly due to the small sample size. Finally, M3 presented a marginally better fit, with a significant χ^2 difference test, and thus was the preferred model (see Table 1)

Table 1 – Structural models of the JDCS with robust fit indices

	χ^2	*df*	CFI	RMSEA	SRMR	$\Delta\chi^2$	Δdf	*p*
M1	842.87	209	.89	.12 [.12;.13]	.10			
M2	477.64	202	.95	.08 [.07;.09]	.07	428.79	5	<.001
M3	457.62	197	.96	.08 [.07; .09]	.07	20.02	5	.001

Legenda. *df* = degree of freedom; CFI = Comparative Fit Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual.

Note. Robust indices pooled across 10 imputations.

The fully standardized factor loadings (see Table 2) ranged from .50 to .92, indicating that the factors and the variables are sufficiently related. Composite reliability is higher than .60 (Hair et al., 2014) for all variables. For what concerns AVE, all factors exceed the threshold of .50 (Fornell & Lacker, 1981), suggesting a good convergent validity, except for IDL (see Table 3).

After assessing the factorial structure of the scale, we computed composite scores by averaging the manifest variables. The scale means were all above the central point of the scale, with CC having the largest mean. Standard deviations indicate a moderate dispersion, showing sufficient variation in scores among the sample (see Table 4).

To assess the convergent validity of the construct, we conducted correlations between the single dimensions of DC, three ICT-related variables, performance, age and gender (see Table 5).

DISCUSSION

Concerning technological variables, organizational digital culture and technology acceptance were positively related to DC, with the latter showing stronger effects. Correlations with the frequency of use were all positive and significant, with a few exceptions. Social network use was correlated only with IDL and CC, and in a similar way conferencing/chat was not related to Safety and Problem Solving. Considering that these dimensions refer to a finer understanding of digital systems, compared to more basic competence domains like IDL, it is not surprising that they show stronger correlations with more advanced aspects of DC.

Referring to demographic variables, as expected age is negatively correlated with all dimensions of DC, except IDL. Being female is negatively correlated with all dimensions, except CC. Effect sizes are smaller compared to the relationships with the technological variables, although the correlations between age and problem solving and especially gender and safety show comparatively higher coefficients.

CONCLUSIONS

The results of this preliminary validation show that the JDCS possess adequate psychometric properties, in terms of internal consistency, reliability, and convergent validity. Specifically, results support the multidimensional nature of the underlying construct, reproducing the five factors of the DigComp framework. However, it must be noted that the first dimension showed worse psychometric properties, which should be investigated more in-depth in further research. The pattern of correlation showed that the frequency of use of more sophisticated digital systems is correlated with the last two dimensions of DigComp, Safety and Problem Solving, which not only refer to more complex aspects of digital technology but are also considered more transversal competences areas.

Overall, the JDCS appeared to fill the gap in the literature for a relatively brief, context-free self-report measure of DC for the general working population. The scale could be employed for large-scale assessment, as well as training and vocational guidance, to contribute to the systematic self-assessment of DC from a development perspective. Furthermore, due to the multidimensional structure, single dimensions could be used to investigate specific facets of technology use at work, especially considering that different occupational groups could require different sets of DC.

In order to overcome the preliminary nature of this study, further research must: a) involve a larger and even more diverse population, to support the tool's generalizability and test its invariance; b) include variables to further assess criterion and divergent validity; c) test the predictive power of DC with longitudinal designs, taking into account dependent variables like performance, satisfaction and engagement, but also controlling for organisational culture dimensions. Taken together, these developments may help identify the most effective strategies for improving DC, given the centrality of human capital in supporting digital transformation in organisations.

Table 2 – Fully standardized factor loadings for each competence area

	IDL	CC	DCC	S	PS
1.1	.71				
1.2	.60				
1.3	.65				
2.1		.84			
2.2		.86			
2.4a		.85			
2.4b		.79			
2.5		.75			
2.6		.50			
3.1a			.78		
3.1b			.81		
3.2			.76		
3.3			.66		
3.4			.84		
4.1				.83	
4.2				.75	
4.3				.66	
5.1					.80
5.2a					.92
5.2b					.83
5.3					.85
5.4					.84

Legenda. IDL = Information and Data Literacy; CC = Communication and Collaboration; DCC = Digital Content Creation; S = Safety; PS = Problem Solving.

Note. All loadings were significant at $p<.001$.

Table 3 – Composite reliability and AVE for the five factors

	OMEGA	AVE
IDL	.69	.43
CC	.90	.60
DCC	.88	.59
S	.79	.56
PS	.93	.72
Full scale	.97	.60

Legenda. AVE = average variance extracted; IDL = Information and Data Literacy; CC = Communication and Collaboration; DCC = Digital Content Creation; S = Safety; PS = Problem Solving.

Note. Calculations are done on pooled estimates.

Table 4 – Pooled means and standard deviations of the manifest scales scores

	M	*SD*
IDL	4.73	1.37
CC	5.19	1.23
DCC	4.60	1.43
S	4.01	1.68
PS	4.25	1.62
Full scale	4.63	1.20

Legenda. IDL = Information and Data Literacy; CC = Communication and Collaboration; DCC = Digital Content Creation; S = Safety; PS = Problem Solving.

Table 5 – Correlations among JDCS dimensions and study variables (pooled estimates)

	IDL	CC	DCC	S	PS
Age	.02	–.16*	–.15*	–.04	–.20**
Gender (1=F)	–.16*	–.02	–.15*	–.27**	–.19*
Performance	.11	.24**	.14*	–.04	.08
Organizational digital culture	.16*	.24**	.22**	.18*	.24**
Technology acceptance	.29***	**.53*** **	**.44*** **	**.30*** **	**.50*** **
Frequency of use:					
Mail	.28***	.25**	.23**	.16*	.20**
Internet	.26***	.28***	.21**	.06	.14*
Spreadsheets	.28***	.28***	**.33*** **	.24**	.25***
Conferencing/chat	.21**	**.30*** **	.17*	.10	.13
Word processing	**.33*** **	**.35*** **	**.35*** **	.20**	.24**
Programming languages	**.36*** **	.23**	**.33*** **	**.37*** **	**.41*** **
Social network	.19***	**.35*** **	.12	.01	.13
Artificial intelligence	.24**	**.31*** **	.28***	**.31*** **	**.31*** **

Legenda. IDL = Information and Data Literacy; CC = Communication and Collaboration; DCC = Digital Content Creation; S = Safety; PS = Problem Solving.

Note. * p<.05; ** p<.01; *** p<.001. Effects ≥|.30| are reported in bold.

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APPENDIX

Table A1 – JDCS items in English and Italian

ID	English	Italian
1.1	I understand the factors that can influence the results of an online search	Conosco i fattori che possono influenzare una ricerca online
1.2	When I search for information online, I always check more than one source	Quando cerco un'informazione online consulto sempre più di una fonte
1.3	I know how to use data analysis software to make decisions and solve problems at work	So utilizzare software di analisi dati per prendere decisioni e risolvere problemi durante la mia attività lavorativa
2.1	I know how to use various advanced functions in video conferencing tools	So utilizzare una serie di funzioni avanzate degli strumenti di videoconferenza
2.2	I know how to use online services to share digital content with my colleagues	So utilizzare servizi online per condividere contenuti digitali con le persone con cui lavoro
2.4a	I am familiar with the main digital services that facilitate collaboration with my colleagues	Conosco i principali servizi digitali che facilitano la collaborazione con le persone con cui lavoro
2.4b	I know how to use digital services to plan my work activities with other people	So utilizzare servizi digitali per pianificare le mie attività lavorative insieme ad altre persone
2.5	I can evaluate the appropriateness of digital communication	So valutare l'adeguatezza di una comunicazione digitale
2.6	I maintain a consistent professional digital identity across all digital platforms I use	Mantengo un'identità digitale professionale coerente in tutte le piattaforme digitali che utilizzo
3.1a	I know how to use digital content creation tools, such as text editors or spreadsheets, to support my work activities	So utilizzare strumenti di creazione di contenuti digitali, come editor di testo o fogli di calcolo, per supportare la mia attività lavorativa
3.1b	I am highly proficient in specific software required for my work	Ho un'ottima padronanza dei software specifici necessari per la mia attività lavorativa
3.2	I can edit digital content created by others to adapt it to my needs	So modificare contenuti digitali creati da altre persone per adattarli alle mie esigenze
3.3	I am familiar with copyright law regarding digital content	Conosco la normativa del diritto d'autore rispetto ai contenuti digitali
3.4	I understand the logical foundations of how digital technologies work	Conosco i fondamenti logici che regolano il funzionamento delle tecnologie digitali
4.1	I can adjust the settings of a firewall	So modificare le impostazioni di un firewall
4.2	I am familiar with the main cyber security threats	Conosco le principali minacce per la sicurezza informatica
4.3	I know how to recognize phishing attempts	So riconoscere i tentativi di phishing
5.1	I can troubleshoot the operating system of my devices independently	So risolvere autonomamente problemi relativi al sistema operativo dei miei dispositivi

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ID	English	Italian
5.2a	I know how to choose different digital solutions to complete my work tasks more efficiently	So scegliere diverse soluzioni digitali per portare a termine i miei compiti lavorativi in modo più efficace
5.2b	I know how to adjust the setting of a software to fit my work needs	So modificare le impostazioni di un programma per adattarlo alle mie esigenze lavorative
5.3	I enjoy using digital technologies to creatively solve my work problems	Mi piace utilizzare le tecnologie digitali per risolvere in modo creativo i miei problemi lavorativi
5.4	I continuously develop my digital competences	Sviluppo in modo continuativo le mie competenze digitali