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Instrument for assessing digital skills in educational research: design and validation

Instrumento para evaluación de habilidades digitales en investigación educativa: diseño y validación

Instrumento para avaliação de competências digitais em investigação educativa: conceção e validação

教育研究中数字技能评估工具：设计与验证

أداة لتقييم المهارات الرقمية في البحث التربوي: التصميم والتحقق من الصدق والثبات

Chura-Quispe, Gilber [(1)]; Nué Caballero, Patricia R. M.[a] [(2)]; Laura De La Cruz, Bianca D. [(3)]; Flores-Rosado, Cristina Beatriz [(2)]

[(1)] Education Program, Newman Graduate School (Perú); [(2)] Faculty of Education, Communication Sciences, and Humanities, Private University of Tacna (Perú)[(3)] School of Communication Sciences, National University Jorge Basadre Grohmann (Perú)

Abstract

Research aimed at assessing the achievement of digital competences for the research practice of school teachers is still scarce, despite the fact that their development is in the profile of their profession. The aim of this research was to design and validate the questionnaire of teachers' digital competences in educational research (CCDD-IE-24). The study followed a psychometric design carried out with surveys applied to 736 regular basic education teachers in two regions of southern Peru (Tacna and Moquegua) between 21 and 70 years of age. The results revealed that the instrument has the agreement in sufficiency, clarity, coherence and relevance of 9 expert judges (Hernandez Nieto Coefficient > .9) and relevant descriptive statistics. In the exploratory factor analysis, four factors were identified (KMO > .5, Bartlett < .05), then in the confirmatory analysis this model was corroborated with adequate fit indices (X^2/df, p < 0.05, SRMR and RMSEA < .08, TLI, CFI and GFI > .95). In addition, the convergent (AVE > .5), discriminant (√AVE > r) and internal consistency (αordinal and ω > 0.9) validity indices asserted the reliability of the construct. Finally, it was found that there is factorial invariance for its application according to gender and grade of education (ΔCFI < .01, ΔRMSEA ≤ .015 and p > .05). In conclusion, the CCDD-IE-24 has adequate validity, reliability and invariance indices for its application to basic education teachers.

Keywords: design, educational research, teacher qualifications, digitization.

Resumen

Las investigaciones orientadas a la evaluación del logro de competencias digitales para el ejercicio investigativo de los profesores de escuela todavía son escasas, pese a que su desarrollo está en el perfil de su profesión. El objetivo de esta investigación fue diseñar y validar el cuestionario de competencias digitales docente en investigación educativa (CCDD-IE-24). El estudio siguió un diseño psicométrico realizado con encuestas aplicadas a 736 docentes de educación básica regular de dos regiones del sur de Perú (Tacna y Moquegua) entre 21 y 70 años. Los resultados develaron que el instrumento cuenta con la concordancia en suficiencia, claridad, coherencia y relevancia de 9 jueces expertos (Coeficiente de Hernández Nieto > .9) y estadísticos descriptivos pertinentes. En el análisis factorial exploratorio se identificaron cuatro factores (KMO > .5, Bartlett < .05), luego en el confirmatorio se corroboró este modelo con adecuados índices de ajuste (X^2/df, p < .05, SRMR y RMSEA < .08, TLI, CFI y GFI > .95). Además, los índices de validez convergente (AVE > .5), discriminante ($\sqrt{}_{AVE}$ > r) y de consistencia interna ($\alpha_{ordinal}$ y ω > .9) aseveraron la fiabilidad del constructo. Finalmente, se halló que existe invarianza factorial para su aplicación según el sexo y grado de enseñanza (ΔCFI < .01, ΔRMSEA ≤ .015 y p > .05). En conclusión, el CCDD-IE-24 cuenta con adecuados índices de validez, confiabilidad e invarianza para su aplicación a profesores de educación básica.

Palabras clave: diseño, investigación pedagógica, competencias del docente, digitalización.

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Corresponding author / Autor de contacto: Gilber Chura-Quispe. Postal Adress: Av Bolognesi 987, Tacna (Perú). Postal Code: 23001 Email:: gilber.chura@epnewman.edu.pe

Resumo

As investigações destinadas a avaliar a aquisição de competências digitais para a prática de investigação dos professores do ensino básico e secundário ainda são escassas, apesar de o seu desenvolvimento estar no perfil da sua profissão. O objetivo desta investigação foi conceber e validar o questionário de competências digitais em investigação educativa (CCDD-IE-24). O estudo seguiu um modelo psicométrico, utilizando inquéritos aplicados a 736 docentes do ensino básico regular em duas regiões do Sul do Peru (Tacna e Moquegua), com idades entre os 21 e os 70 anos. Os resultados revelaram que o instrumento tem a concordância em termos de suficiência, clareza, coerência e relevância de 9 juízes peritos (Coeficiente da Validade de Conteúdo de Hernández Nieto > 0,9) e estatísticas descritivas relevantes. Na análise factorial exploratória, foram identificados quatro fatores (KMO > 0,5, Bartlett < 0,05), depois, na confirmatória, este modelo foi corroborado com índices de ajuste adequados (X2/df, p < 0,05, SRMR e RMSEA < 0,08, TLI, CFI e GFI > 0,95). Além disso, os índices de validade convergente (AVE > 0,5), discriminante (√AVE > r) e de consistência interna (αordinal e ω > 0,9) atestaram a fiabilidade do constructo. Por último, verificou-se que existe invariância factorial para a sua aplicação em função do sexo e do grau de ensino (ΔCFI < 0,01, ΔRMSEA ≤ 0,015 e p > 0,05). Em conclusão, o CCDD-IE-24 apresenta índices de validade, fiabilidade e invariância adequados para a sua aplicação a professores do ensino básico.

Palavras-chave: Conceção, investigação pedagógica, competências do docente, digitalização

摘要

尽管数字能力的培养已纳入教师职业素养要求，针对学校教师研究能力的数字素养评估工具研究仍较为稀缺。本研究旨在设计并验证“教育研究教师数字能力问卷”（CCDD-IE-24）。研究采用心理测量设计，对秘鲁南部两地区（塔克纳和莫克瓜）736 名 21 至 70 岁的基础教育教师进行问卷调查。结果显示，问卷在充分性、清晰性、一致性和相关性方面获得 9 位专家（Hernández Nieto 系数>0.9）认可，相关统计指标良好。探索性因子分析识别出四个因子（KMO>0.5，Bartlett<0.05），确认性因子分析进一步证实模型的良好拟合（X2/df、p<0.05、SRMR 和 RMSEA<0.08、TLI、CFI 和 GFI>0.95）。聚合效度（AVE>0.5）、区分效度（√AVE>r）和内部一致性（α-ordinal 与 ω>0.9）均表明问卷信效度优良。问卷还具备性别和教学阶段的因子不变性（ΔCFI<0.01，ΔRMSEA≤0.015，p>0.05）。结论认为，CCDD-IE-24 具备良好的信度与效度，适用于基础教育教师。

关键词：设计，教育研究，教师能力，数字化。

ملخص

لا تزال البحوث التي تهدف إلى تقييم مدى تحقيق الكفاءات الرقمية اللازمة لممارسة النشاط البحثي لدى معلمي المدارس قليلة، رغم أن تطوير هذه الكفاءات يُعد جزءًا من مواصفات مهنتهم. وتهدف هذه الدراسة إلى تصميم والتحقق من صدق وثبات "استبيان الكفاءات الرقمية للمعلمين في البحث التربوي" (CCDD-IE-24). وقد اتبعت الدراسة تصميماً سيكومترياً، استُخدمت فيه استبانات طُبقت على عينة مكونة من 736 معلماً في التعليم الأساسي النظامي من منطقتين في جنوب بيرو (تاكنا وموكغوا)، تتراوح أعمارهم بين 21 و70 سنة. كشفت النتائج أن الأداة تتمتع بدرجة عالية من الاتفاق بين تسعة محكمين خبراء في ما يخص الكفاية والوضوح والاتساق والأهمية (معامل هرناندیز نیتو > 0.9)، إضافة إلى إحصاءات وصفية، بينما أكّد التحليل العاملي التوكيدي (KMO > 0.5، اختبار بارليت < 0.05) مناسبة. وفي التحليل العاملي الاستكشافي، تم تحديد أربعة عوامل كما أظهرت النموذج بأداء جيد وفقاً لمؤشرات المطابقة (X2/df، p < 0.05، SRMR وRMSEA < 0.08، TLI وCFI > 0.95). أن الأداة تتمتع بمستوى عالٍ من الثبات الداخلي(√AVE > r) ، والتمييزي(AVE > 0.5) مؤشرات الصدق التقاربي (αordinal وω > 0.9) ، الموثوقية. وأخيراً، تبين وجود اتساق في البنية العاملية (المساواة العاملية) بحسب الجنس ودرجة التعليم (ΔCFI < 0.01، ΔRMSEA ≤ 0.015) يتمتع بمؤشرات مناسبة للصدق والثبات والمساواة العاملية، مما يجعله أداة CCDD-IE-24 وبناءً عليه، يمكن القول إن استبيان (p > 0.05و. صالحة لتطبيقها على معلمي التعليم الأساسي.

الكلمات المفتاحية : التصميم، البحث التربوي، كفاءات المعلم، التحول الرقمي

Introduction

Digital competence (DC) has become a crucial pillar in educational research processes due to its ability to transform and enrich inquiry actions and the dissemination of findings related to teaching and learning. Acquiring advanced skills in technology use could not only accelerate the research pace of faculty but also provide an advantage in big data analysis, the application of innovative methodologies, and facilitate collaboration within the academic community. In pedagogy, it is conceptualised as a set of knowledge, skills, and attitudes for the effective employment of ICT with pedagogical and didactic criteria in educational practice (Domingo-Coscollola et al., 2020; Esteve-Mon et al., 2016). However, it has not yet received sufficient attention in theoretical and research contexts (Černý, 2020).

The connection between digital competencies and the scientific production tasks of educators is increasingly inseparable. Education professionals need to develop skills to explore and tackle new technological situations to solve problems and collaboratively construct knowledge (Calvani et al., 2008). In the Peruvian context, the Framework for Good Teaching Performance highlights that, among the nine competencies for teachers, the fourth focuses on using accessible technological strategies and resources, while the sixth promotes active participation in research and innovation projects (Ministry of Education, 2018). Therefore, research activity is fundamental for teachers in their professional practice, as students' learning is influenced by the investigative and technological competence of the educator (Syahrial et al., 2022).

According to the digital competence mapping, the development of DC in the research process is positioned at the second level of digital competence development (digital use), due to the professional or academic purposes it pursues (Ala-Mutka, 2011). Its development in research practice strengthens teaching capacities in terms of knowledge and skills, further enhanced by the support of technological tools (Paz Saavedra & Fierro Marcillo, 2015). Thus, educational progress demands that teachers research and design pedagogical projects based on the scientific method, requiring them to be trained and demonstrate mastery not only in pedagogical, technological, and knowledge dimensions (Koehler et al., 2015) but also in research.

Digital competencies in research are defined as the ability to search, filter, evaluate, and manage data, information, and digital content for research purposes (Sánchez et al., 2019). Although the use of technologies in the social sciences began in the 1970s and 1980s, initially focusing on processing, coding, retrieving, and analysing information (Díaz Rosabal et al., 2018), today's research increasingly requires the use of digital resources aimed at more complex tasks such as data visualisations, network creation, data and text mining, and mapping. These constitute qualitative and quantitative techniques that respond to increasingly complex needs (Arbeláez, 2014; Lagunes, 2016).

The relationship between technological mastery, digital competence or literacy, and research competence is strong (Indah et al., 2022; Katayev et al., 2023). In addition to possessing disciplinary knowledge, it is essential for educators to acquire mastery of methodological, technological dimensions, and information management. Research competence comprises the knowledge and practical use of technology in methodological procedures, conceptual and procedural aspects, and the ability for scientific communication (Mena & Lizenberg, 2015). The proliferation of devices and tools for research has led to the emergence of new alternatives for research development. From a techno-research perspective, technological tools enhance the increase in publications, greater participation in international studies, increased awareness of the use of infotechnological tools, reflection on copyright and ethical treatment, and the rise of collaborative work and autonomy (Cárdenas Zea et al., 2021). In this context, the use of DC shapes the role of the educator as a knowledge producer.

Technological advancement has revealed a significant and increasingly indispensable contribution to research processes (Amirova et al., 2020). Access, analysis, and ethical treatment of information in academic writing are essential skills developed during university education (Rubio et al., 2018). The ability to share information collaboratively or engage in scientific collaborations through platforms is a predictor that underpins the need to employ technologies today (Arcila-Calderón et al., 2015). Continuous learning platforms, simulations, and efficiency in academic data analysis—products of teaching and learning processes—extend the range of arguments that support the significance of technology in educational research. The new paradigm of the teacher-researcher requires transforming classrooms into spaces for continuous improvement in the development of knowledge (Vega-Ramírez, 2023). The interplay between research and digital literacy leads investigative action towards an epistemological transformation that is dynamic, immediate, and reliable (Castañeda et al., 2020). Thus, the protagonist of disruptive revolutions in pedagogical research is the educator.

In this context, measuring teachers' digital research competencies in education poses a challenge, given that they are the main agents of educational change. Moreover, it is the role of teachers to foster research skills among school students and to promote continuous improvement through technology-supported research projects. To this end, it is essential to develop instruments aimed at assessing the level of acquisition of this competency.

Several studies have developed instruments to evaluate digital competencies among primary education students (Bastarrachea Rodríguez et al., 2023), secondary school students (Bielba Calvo et al., 2017), university faculty in their pedagogical practice (Betancur-Chicue et al., 2023; Cabero-Almenara, Gutiérrez-Castillo, et al., 2020; Dias-Trindade et al., 2019; Velásquez Cortés & Veytia Bucheli, 2022), basic education teachers (Touron et al., 2018), pre-service teacher education students (Rodríguez et al., 2021; Silva-Quiroz et al., 2022), and graduate students in education (Ramírez-Armenta et al., 2021), mostly from a pedagogical perception.

However, few studies have focused specifically on teachers' digital research competencies. For instance, Guillén-Gámez and Mayorga-Fernández (2021) identified a three-factor model for the use of ICT resources in (1) teaching within subject areas, (2) didactic use in assessment, and (3) conducting and publishing scientific research by university faculty. Another study identified six factors of digital research competence; however, it was conducted with first-year students at a military university and did not assign names to the identified factors (Sánchez et al., 2019). A more recent study proposed a causal model comprising seven factors: (1) integration of ICT resources for research, (2) digital ethics, (3) quality of ICT resources related to research, (4) digital skills for searching, managing, and analyzing data, (5) digital research flow, (6) intention to use ICT in research work, and (7) anxiety about using ICT resources for research (Guillén-Gámez et al., 2024).

Despite these contributions, the scientific literature on digital research competencies remains scarce, indicating a still unexplored threshold.

Based on the aforementioned reasons and the identified knowledge gap, the present study aims to design and validate a questionnaire on teachers' digital research competencies in educational contexts.

Method

The study follows an instrumental design (Ato et al., 2013), as it includes studies analysing the psychometric properties of measurement instruments that have been created, translated, or adapted in new transcultural settings.

Participants

The study was conducted with basic education teachers from the two regions (Tacna and Moquegua) with the highest scores in educational competence in Peru, according to the Regional Competitiveness Index

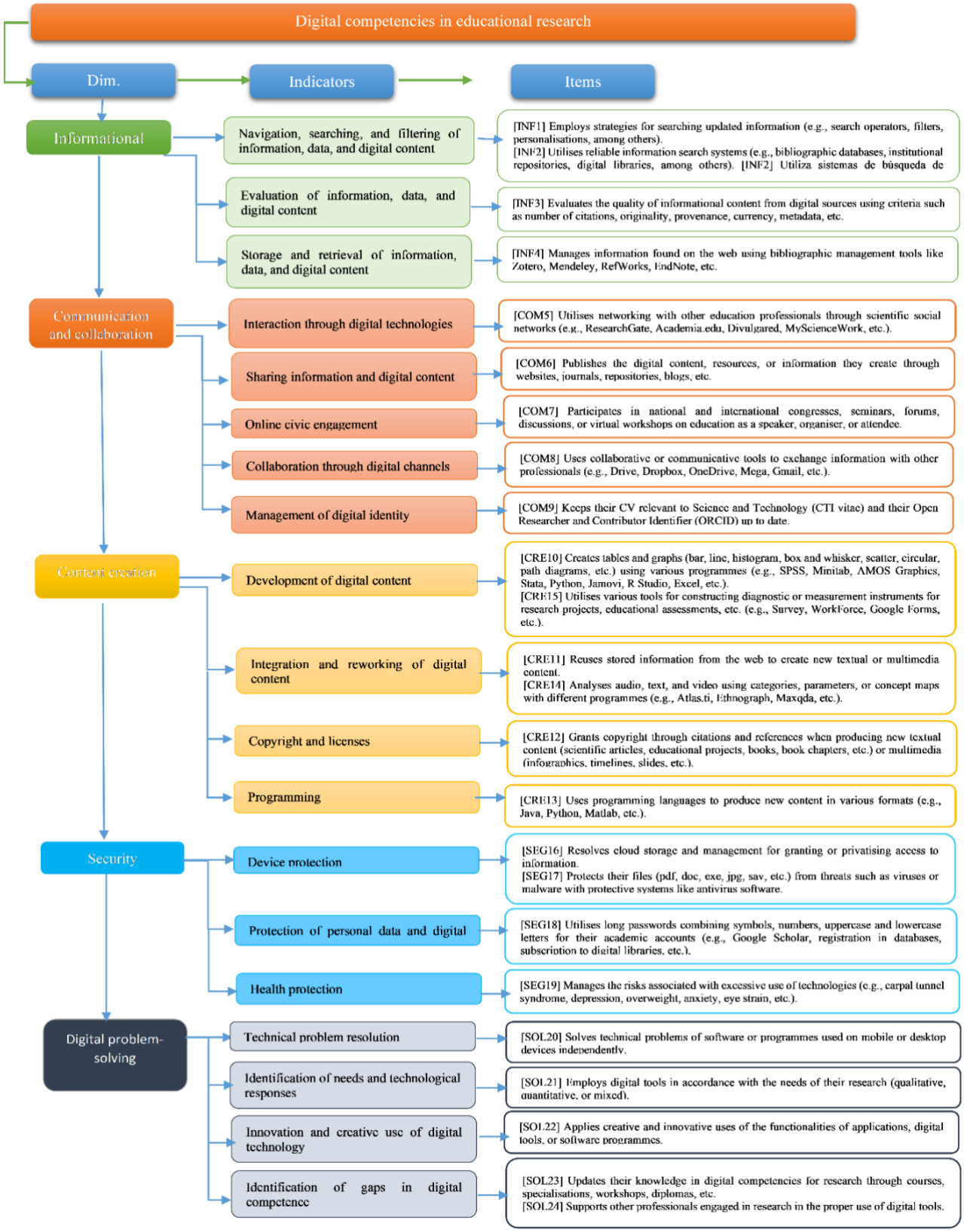
(Peruvian Institute of Economy, 2023). The sample was selected through non-probabilistic intentional criteria, considering the guideline established by Kline (2014), which indicates that a minimum of 300 subjects is necessary for psychometric studies.

The sample consisted of a total of 736 teachers from Tacna (50.82%) and Moquegua (49.18%). Of these, 73.37% are women and 26.63% are men. The age range of the teachers varies from 21 to 70 years, with 28.40% aged between 21 and 40 years, 34.78% between 41 and 50, and 36.58% between 51 and 70 years. In terms of management type, 23.51% work in the private sector and 76.49% in the public sector. Regarding the level of education, 20.52% work at the initial level, 39.27% at primary level, and 40.22% at secondary level. In terms of academic qualifications, 45.52% hold a pedagogical degree, 8.70% are graduates, 28.67% have a bachelor's degree, 16.30% a master's degree, and 0.82% a doctorate.

Instrument Design

Initially, the literature on the most recent publications concerning the design of instruments to evaluate teachers' digital competencies was reviewed, covering publications from 2015 to 2021. The review process was conducted in both English and Spanish, using the search terms "Digital competence" OR "Digital literacy" AND "teacher" OR "professor." Subsequently, it was confirmed that the main basis for instrument development was the contributions provided by the National Institute of Educational Technologies and Teacher Training (2017). Thus, the instrument was developed with 24 items grouped into 5 dimensions: informational (4 items), communication and collaboration (5 items), content creation (6 items), security (4 items), and digital problem-solving (5 items). For each item, participants responded on a scale from 1 to 5, where 1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5 = always. The instrument was nominally titled "Teacher Digital Competence Questionnaire in Educational Research"(CCDD-IE-24). The appraisal is attributed solely from the teachers' perspective. Its structure is illustrated in Figure 1.

Figure 1. Initial Proposal of the CCDD-IE-24 Model



Procedures

Next, to evaluate the sufficiency (the relevance of an item to a construct), clarity (understanding of the item), relevance (importance of the item to the construct), and coherence (logical relationship of the item with the construct), the opinions of 9 expert judges in education, research, and digital competencies were taken into account. The review involved completing a questionnaire that presented the four aspects for each item. The experts were required to assess the degree of sufficiency, clarity, relevance, and coherence by marking "x" on a rating scale from 1 (does not meet the criterion) to 4 (high level) (Escobar-Pérez & Cuervo-Martínez, 2008). Based on the results obtained, the Content Validity Coefficient (CVC) was calculated for each item and evaluated criterion. After obtaining the evaluators' responses, a focus group of 10 basic education teachers was contacted, who read the questionnaire and provided their qualitative assessment of the instrument. This stage allowed for corroboration of what was provided by the expert evaluators.

Subsequently, the necessary procedures were carried out to obtain permission from the Local Educational Management Unit of Tacna and Moquegua for the application of the instrument. Following this, the questionnaire was developed using Google Forms for virtual dissemination. The form contained information regarding the study's objectives, the role of the participants, and the voluntary, consensual, and anonymous nature of participation. Therefore, data collection was conducted through email channels and WhatsApp groups distributed by the principals and deputy principals of the educational institutions. The teachers had previously given their informed consent to participate in the research. Data were collected between December 2021 and February 2022.

Data Analysis

The evaluation of sufficiency, clarity, coherence, and relevance was analysed considering the CVC of Hernández-Nieto, with an acceptable concordance of > .7 (Pedrosa et al., 2014). In the first stage, a sample of 362 teachers from Moquegua was considered. With the responses from the participants, descriptive statistics of the items (mean, standard deviation, skewness, and kurtosis) were analysed.

Subsequently, exploratory factor analysis (EFA) was conducted to empirically verify the grouping of the items into factors (Mavrou, 2015) using Factor Analysis software (Lorenzo-Seva & Ferrando, 2006). Due to the ordinal nature of the variable, the polychoric relationship matrix was first verified (Bandalos & Finney, 2010), and the direct Oblimin method was employed, assuming correlation among factors (oblique rotation) (Clarkson & Jennrich, 1988). Prior assumptions for verifying the suitability of EFA were conducted through the Kaiser-Meyer-Olkin (KMO) measure, which should exceed > .8, and Bartlett's test of sphericity to evaluate the identity matrix, with a value < .05 (Chan & Idris, 2017). Three criteria were employed to determine the number of factors in the EFA: the first was based on eigenvalues greater than 1 with the Kaiser rule and sedimentation graph (Cattell, 1966); the second utilized the Parallel Analysis method (Timmerman & Lorenzo-Seva, 2011); and the third considered the number of factors from the theoretical model (Conway & Huffcutt, 2003).

Subsequently, the three rotation models were compared based on the cumulative variance expected to be > 60% (Hair et al., 2010), the root mean square error of approximation < .08 (RMSEA), the goodness-of-fit index (GFI), comparative fit index > .9 (CFI), and the Bayesian Information Criterion (BIC) to evaluate parsimony (Lloret-Segura et al., 2014; Schwarz, 1978). Thus, the most appropriate model was selected. Item estimates were required to fit factorial loadings > .3 (Hogarty et al., 2005), and each factor was to group at least 3 items (Velicer & Fava, 1998).

To confirm the model, confirmatory factor analysis (CFA) was employed. The fit was verified using the Weighted Least Squares Mean and Variance adjusted (WLSMV)

estimator with the Lavaan package in R Studio, given that categorical variables were involved. The chosen method does not require normality assumptions, as it is based on polychoric correlations (Li, 2016). The Chi-square index, degrees of freedom, p-value, standardised root mean square residual (RSMR), root mean square error of approximation (RMSEA), Tucker-Lewis index (TLI), comparative fit index (CFI), and goodness-of-fit index (GFI) were estimated (Escobedo et al., 2016). Factor loadings and errors for each item were identified.

For criterion validity, convergent validity was identified using the average variance extracted (AVE), which should be > .7 (Hair et al., 2010). Discriminant validity was also assessed using the criterion of Fornell & Larcker (1981), where relationships should be less than the square root of AVE (< √AVE). Subsequently, the internal consistency analysis of ordinal alpha and ordinal omega was reported (Contreras Espinoza & Novoa-Muñoz, 2018; Ventura-León, 2017). Finally, factorial invariance was tested by sex and education level through structural equation modelling on multi-group factor analysis using the "Lavaan" library; the estimation method was robust weighted least squares (WLSMV), due to the categorical nature of the items (Brown, 2008). The different levels of invariance were progressively evaluated as configural (no restrictions), metric (with factor loadings), scalar (factor loadings and intercepts or tau), and strict (factor loadings, intercepts, and residuals) (Dimitrov, 2010). Finally, the observed changes in Chi-square, degrees of freedom, RMSEA ≤ .08, CFI, and TLI with estimated values ≥ .95 in the last three levels were evaluated (Barrera-Barrera et al., 2015; Hu & Bentler, 1999).

Table 1. Content Validity Coefficient and Descriptive Statistics of Items

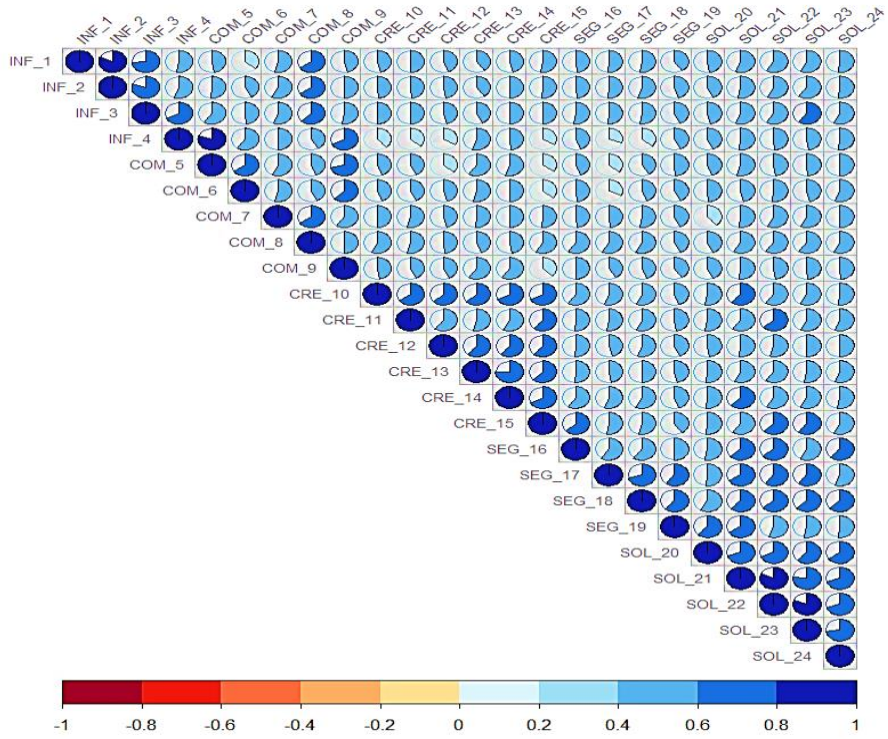
	CVC_{tc}				Descriptives		
Items	**SU**	**CL**	**CO**	**RE**	**M(SD)**	***SK***	***K***
INF1	.92	1.00	1.00	.94	3.81(1.02)	-.751	0.210
INF2	.97	1.00	1.00	1.00	3.79(0.98)	-.749	0.358
INF3	.97	1.00	1.00	.97	3.61(1.01)	-.561	-0.058
INF4	.97	1.00	1.00	.97	2.93(1.12)	-.104	-0.742
COM5	.97	1.00	1.00	.97	2.77(1.12)	.067	-0.786
COM6	.97	1.00	1.00	1.00	2.64(1.15)	.198	-0.774
COM7	1.00	1.00	1.00	1.00	3.21(1.13)	-.385	-0.539
COM8	1.00	1.00	1.00	1.00	3.53(1.16)	-.527	-0.534
COM9	.97	1.00	1.00	1.00	2.66(1.18)	.135	-0.918
CRE10	.97	1.00	1.00	.97	2.46(1.15)	.244	-0.937
CRE11	.92	.97	.97	.94	3.02(1.10)	-.433	-0.647
CRE12	.97	1.00	1.00	1.00	2.51(1.19)	.328	-0.813
CRE13	.97	1.00	1.00	1.00	2.09(1.04)	.521	-0.812
CRE14	.94	.94	.94	.94	2.28(1.16)	.448	-0.839
CRE15	.97	1.00	.97	1.00	2.63(1.17)	.030	-1.032
SEG16	.92	.97	.97	.97	2.94(1.15)	-.034	-0.819
SEG17	.97	1.00	1.00	.97	3.31(1.17)	-.247	-0.783
SEG18	.97	.97	1.00	1.00	3.07(1.16)	-.108	-0.780
SEG19	.97	.97	.97	.97	3.11(1.12)	-.236	-0.686
SOL20	.94	.97	.97	.97	2.90(1.13)	-.018	-0.767
SOL21	.97	1.00	1.00	.97	3.16(1.11)	-.228	-0.670
SOL22	1.00	.97	.97	.97	3.17(1.05)	-.176	-0.549
SOL23	1.00	1.00	.97	.f97	3.24(1.08)	-.168	-0.497
SOL24	1.00	.97	.94	.97	3.02(1.13)	-.126	-0.705
Total	.97	.99	.99	.98			

Note. SU: sufficiency, CL: clarity, CO: coherence, RE: relevance; SK: skewness, K: kurtosis.

Results

The results of the content validity using the Hernández-Nieto Coefficient yielded values > .7 for sufficiency (> .92), clarity (> .94), coherence (> .94), and relevance (> .94) across all items (see Table 1). Regarding the descriptive statistics, the mean scores ranged from 2.09 to 3.81, with standard deviations between 1.02 and 1.18, indicating acceptable values as they fall between 3 and 1. For skewness (As) and kurtosis (K), the items scored between +/- 1.5, which suggests the appropriateness of the items (Forero et al., 2009)The polychoric correlations between the items range from .35 to .9, indicating significant and moderate correlations (see Figure 2). Only the correlations between item 4 and items 12, 15, and 17, as well as between item 15 and item 5, and between item 6 and item 17, were below .4. The remaining correlations exceeded this threshold, revealing adequate relationships that support the decision to adopt an oblique rotation (direct oblimin).

Figure 2. Polychoric Correlations Between the Items of the CCDD-IE-24



The KMO test indicates a score above .50, demonstrating sample adequacy. Additionally, the Bartlett's test is less than .05, indicating the presence of an identity matrix, which allows for the execution of exploratory factor analysis (EFA). Moreover, the three models with 2, 4, and 5 factors are compared. The model with 2 factors appears to explain the highest proportion of variance (79.8%) compared to the 4-factor model (77%) and the 5-factor model (67.8%); however, all three models exceed 50%. In terms of RMSEA and CFI, the 5-factor model shows better fit, whereas the GFI is superior for the 4- and 2-factor models (see Table 2). The BIC parsimony criterion indicates that the 4-factor model is the most parsimonious, making it the most relevant and suitable for the present study (Hair et al., 2010).

Table 2. Preliminary Assumptions and Comparison of Factor Decision Models

Models	N° factors	σ^2 explained	RMSEA	CFI	GFI	BIC (IC 95%)
Eigenvalue Criterion	2	.798	.078	.992	1.000	1151.94 (1014.39 -1250.68)
Parallel Analysis Method	4	.770	.039	.998	1.000	995.37 (934.01 - 1021.64)
Initial Model	5	.678	.028	.999	.999	1061.07 (1025.30 - 1074.68)
Bartlett	4054.5 (df = 276; p = .001)					
KMO (IC95%)	.920(.921 - .929)					

Table 3 presents the factor loadings following the rotation of the items. It is identified that items 10, 11, 12, 13, 14, and 15 clustered in factor 1, termed "Content Creation." Items 1, 2, 3, 7, and 8 formed factor 2, labelled "Informational and Communicative Competence." Subsequently, items 16, 17, 18, 19, 20, 21, 22, 23, and 24 grouped into the third factor, named "Digital Security and Problem Solving," while items 4, 5, 6, and 9 were categorised into factor 4, titled "Management of Collaborative Networks." The loadings exceed 0.3, and there are at least 3 items per construct, with communalities greater than .5, indicating that the items adequately explain the underlying structure (Hair et al., 2010). Furthermore, the ordinal alpha index is satisfactory for each emerging factor (αordinal > .7), and the variance explained by each factor, as indicated by the Orion index, exceeds 90%, suggesting that the included factors are sufficient (Ferrando & Lorenzo-Seva, 2016).

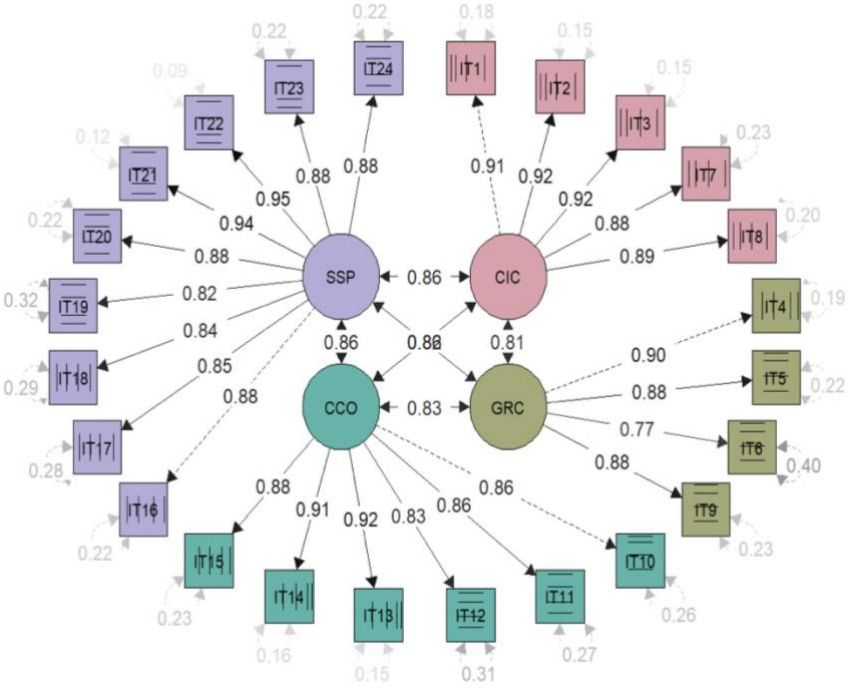
Table 3. Factor Loadings of the CCDD-IE-24 Model with 4 Factors

Variable	λ_{CCO}	λ_{CIC}	λ_{SSP}	λ_{GRC}	$\lambda_{IC\ 95\%}$	H^2
CRE_10	.766				(.615 - .866)	.741
CRE_11	.551				(.396 - .734)	.652
CRE_12	.757				(.631 - .889)	.649
CRE_13	.726				(.618 - .856)	.776
CRE_14	.727				(.584 - .843)	.751
CRE_15	.765				(.631 - .904)	.758
INF_1		.838			(.739 - .948)	.833
INF_2		.924			(.870 - 1.012)	.944
INF_3		.713			(.614 - .795)	.828
COM_7		.311			(.175 - .442)	.581
COM_8		.482			(.361 - .606)	.664
SEG_16			.433		(.266 - .592)	.620
SEG_17			.713		(.490 - .946)	.683
SEG_18			.683		(.481 - .854)	.697
SEG_19			.826		(.625 - .993)	.582
SOL_20			.886		(.744 -1.030)	.686
SOL_21			.932		(.809 - 1.093)	.882
SOL_22			.819		(.648 - .959)	.859
SOL_23			.724		(.552 - .875)	.773
SOL_24			.701		(.547 - .871)	.703
INF_4				.760	(.677 - .838)	.891
COM_5				.798	(.721 - .860)	.917
COM_6				.546	(.383 - .661)	.601
COM_9				.586	(.493 - .676)	.711
Alfa ordinal	.967	.980	.982	.969		
Orion	.935	.960	.964	.940		
Variance	4.779	3.614	6.528	2.860		

Note. H^2 = Communalities, CCO: Content Creation, CIC: Informational Competence, SSP. Digital Security and Problem Solving, GRC: Gestión de redes colaborativas, λ: Factor Loading

The factor loadings (λ) from the exploratory factor analysis based on the sample of teachers from Tacna (n = 374) indicate that in factor 1 (CCO), the factor loadings range from .83 to .92. In factor 2 (CIC), the loadings vary between .88 and .92. For factor 3 (SSP), the loadings are between .82 and .95. Finally, in factor 4 (GRC), the loadings range from .77 to .90. In conclusion, it is asserted that there are adequate factor loadings. The fit indices indicate that p > .05, and the values for TLI, CFI, and GFI were above .95, indicating optimal goodness of fit. Similarly, the RMSEA (< .08) and SRMR (< .05) indices also achieved expected values (see Figure 3). Therefore, it can be concluded that the instrument reached a level of construct validity.

Figure 3. Factor Loadings of the Final CCDD-IE-24 Model



Note. $X^2/df = 735.780/246$, $p = .000$, $SRMR = .042$, $RMSEA = .073$, $TLI = .997$, $CFI = .998$, $GFI = .997$

The internal consistency indices of the instrument according to the factors CIC, GRC, CCO, and SSP achieved high scores greater than .9 in both αordinal and Ωordinal (see Table 4). Additionally, the convergent validity of each latent variable also showed optimal scores (AVE > .5). Regarding discriminant validity, it was evidenced that the √AVE scores are higher than the correlations between the factors, thus confirming the distinct identity of each factor relative to the others.

Table 4. Internal Consistency, Convergent Validity, and Discriminant Validity

Factors	$\alpha_{ordinal}$	$\Omega_{ordinal}$	AVE	$\sqrt{}_{AVE}$	CIC	GRC	CCO	SSP
CIC	.95	.95	.82	.90	.90*			
GRC	.91	.91	.74	.86	.81	.86*		
CCO	.95	.96	.77	.88	.86	.83	.88*	
SSP	.97	.97	.78	.88	.86	.82	.86	.88*

Note. AVE: Convergent Validity with Average Variance Extracted, * and $\sqrt{}_{AVE}$: Discriminant Validity.

To assess the degree of measurement invariance, a multigroup analysis was conducted based on the variables of sex (V1) and educational level (V2) of the CCDD-IE-24. The modelling includes the mean structure for the configurational invariance models (M1), metric invariance (M2), scalar invariance (M3), and strict invariance (M4). Initially, the M1 (configurational model) was tested as a baseline model with a four-factor latent model without constraints, where adequate fit indices were found, such as RMSEA < .08, CFI > .95, TLI > .95 (Hu & Bentler, 1999). Subsequently, M2 was examined for metric invariance with restrictions on the factor loadings for V1 and V2, and the fit indices were also deemed appropriate. The difference between M2 and M1 showed minimal differences in fit indices with ΔCFI < .01, ΔTLI ≤ .01, ΔRMSEA ≤ .015, and p > .05, indicating that the factor loadings are equivalent (Chen, 2007). In the scalar invariance (M3), both the intercepts and factor loadings were constrained. The obtained indices were satisfactory, and when compared to M2, no significant changes exceeding the established criteria were observed for either variable (V1 and V2). Finally, in the strict invariance (M4), where the loadings and intercepts, as well as the residuals or error variances, were additionally constrained, it was found that, although the fit indices and differences with M3 showed adequate values for ΔCFI, ΔTLI, and ΔRMSEA, the obtained χ^2 value ($p < .05$) was significant, contrary to expectations for V1 and V2. Therefore, the results support the good fit of the items within the four-factor model of the CCDD-IE-24 and maintain invariance across sex and educational level of the teachers. However, in one parameter of M4, the expected value was not found, leading to the assumption of partial invariance due to the excessive constraints of strict invariance (Dimitrov, 2010), although the scores remain predominantly comparable across groups.

Table 5. Factorial Invariance by Sex and Educational Level

Modelos	χ^2(gl)	$\Delta\chi^2$(gl)	*p*	CFI	ΔCFI	TLI	ΔTLI	RMSEA (IC 90%)	ΔRMSEA
V1									
M1	1432.6 (540)	-	-	.974	-	.973	-	.067 (.063 - .071)	-
M2	1448.8 (560)	21.244 (20)	.383	.975	.001	.976	.003	.066 (.062 - .070)	.001
M3	1470.3 (580)	31.685 (20)	.057	.975	.000	.977	.001	.065 (.061 - .069)	.001
M4	1588.2 (604)	46.879 (24)	.003	.980	.005	.982	.005	.067 (.063 - .071)	.002
V2									
M1	1661.4 (834)	-	-	.975	-	.976	-	.064 (.059 - .068)	-
M2	1703.9 (874)	53.502 (40)	.075	.976	.001	.977	.001	.062 (.058 - .067)	.002
M3	1737.2 (914)	48.457 (40)	.169	.977	.001	.979	.002	.061 (.056 - .065)	.001
M4	2104.9 (962)	155.557 (48)	.001	.978	.002	.981	.002	.070 (.066 - .074)	.009

Note. V1: Sex, V2: Educational level; M1 = Configural model, M2: Metric model, M3: Scalar model y M4: Strict model; N = 736

Discussion and Conclusions

The participation of basic education teachers in pedagogical research processes requires continuous updating and mastery of digital competencies. Therefore, it is essential to have suitable tools that assist in evaluating these competencies. The objective of the study was to design and validate the CCDD-IE-24 questionnaire for application and to obtain appropriate and reliable results.

The results have demonstrated that the CCDD-IE-24 shows adequate levels of validity and reliability. On one hand, expert opinions confirmed that the findings regarding content validity reveal the suitability of the items for measuring the assessed construct. On the other hand, evidence of construct validity through Exploratory Factor Analysis (EFA) showed that the four-factor model has greater parsimony than the two- and five-factor models. Confirmatory Factor Analysis (CFA) corroborated that the factor loadings are pertinent, and the fit indices allow us to assert that the instrument accurately represents and measures the explored theoretical model. In terms of convergent and discriminant validity, it was found that the latent constructs of the CCDD-IE-24 maintain a strong internal relationship while being distinct from other constructs. The reliability indices were adequate for each factor and confirm that the instrument is partially invariant concerning the sex and educational level of the teachers.

The findings are consistent with the literature that has explored the contributions of different instruments on digital competencies in the educational sector among aspiring teachers (Rodríguez et al., 2021; Silva-Quiroz et al., 2022), basic education teachers (Touron et al., 2018), and university-level educators (Betancur-Chicue et al., 2023; Cabero-Almenara, Barroso-Osuna, et al., 2020; Velásquez Cortés & Veytia Bucheli, 2022). However, these studies have addressed the role of digital competencies in the learning processes of students and the teaching processes of educators. There were also similarities with another study focusing on technological proficiency for the research processes of multidisciplinary professors at Spanish universities (Guillén-Gámez & Mayorga-Fernández, 2021b), differing in that this study addressed underlying factors related to 1) technology use for teaching, 2) assessment, and 3) research. It appears that only the latter factor was linked to aspects related to ICT proficiency for conducting pedagogical research. Another study focusing on digital competence in research was conducted with Mexican university students in engineering (Sánchez et al., 2019), which also concluded with three latent factors: 1) information and information literacy, 2) communication and collaboration, and 3) creation of digital content, which revealed adequate evidence of validity and reliability. However, our model comprises four emerging factors that assess different digital competencies of educators in the research field of education.

Factor 1, "Content Creation," explains the set of capabilities for creating and editing new content that integrates knowledge (tables and figures), as well as the reuse of existing information on the web to produce new content using programming language while maintaining copyright. This construct has been employed in other instruments (Betancur-Chicue et al., 2023; Sánchez et al., 2019; Silva-Quiroz et al., 2022). Factor 2, "Information and Communicative Competence," supports the skills for searching, evaluating, and using updated and reliable information, as well as active participation and collaboration in educational academic settings. The measurement of the set of skills related to information management has been developed in previous validations from a pedagogical perspective (Bielba Calvo et al., 2017; Restrepo-Palacio & Segovia Cifuentes, 2020). Factor 3, "Digital Security and Problem Solving," explains the protection of devices, personal data, and the health of educators, as well as the ability to resolve technological problems during research and the continuous updating of their competencies. This latent

variable expresses the importance of technical knowledge to address potential issues and has been employed by other authors (Rodríguez et al., 2021; Touron et al., 2018), albeit independently of security and problem-solving. Finally, Factor 4, "Management of Collaborative Networks," concerns the appropriate handling of academic communication networks that allow for the dissemination of research results. Although this construct was not explicitly used in previous studies, some similar expressions such as online collaboration impact other instrumental constructions (Silva-Quiroz et al., 2022). Therefore, it can be said that this last factor represents a poorly explored construct.

The CCDD-IE-24 is an instrument that can be administered to basic education teachers; however, it would be convenient to make adaptations to teachers who train teachers in university and non-university higher education (pedagogical institutes). The latent variables proposed in the research obey answers given by teachers whose region has occupied high positions in the national educational ranking during the last years and who are located in the urban area, where the educational precariousness is lower than in the rural area. It would be convenient to implement the instrument in other educational contexts in rural areas. Educational research represents a threshold little explored and executed by Peruvian basic education professionals, although in higher education this problem has been increasingly addressed, it is still necessary to strengthen it through training. A previous step is the knowledge of the digital competences they have.

The implications of the study make it possible to use the instrument to open spaces for descriptive, relational, explanatory or psychometric research aimed at proposing continuous improvements of the teaching staff and of the instrument itself. The benefit of having a validated instrument can be seen in stricter and more reliable measurements, although it is a questionnaire oriented to self-perception, it is a preliminary step for the development of future tools that address peer evaluation or heteroevaluation. At the pragmatic level, the transformation of educational processes led by educational managers and educational policies increasingly requires the development of new competencies aimed at directing changes in teaching and learning. The acquisition of digital competencies in quantitative or qualitative research (Lagunes, 2016) gives rise to teachers who are more aware of their decisions when making pedagogical innovations. Becoming digitally literate for the execution of practical and theoretical actions such as research represents an indispensable alliance (Katayev et al., 2023). The scope generated by the abundance of technological tools for research conditions the pedagogical professional to acquire a techno-research perspective conditioned by reflection and increased collaboration in pedagogical research processes (Cárdenas Zea et al., 2021). The teaching and learning scenario not only requires disciplinary and pedagogical knowledge, but also technological knowledge (Koehler et al., 2015). Having an instrument that favors the evaluation of this competence is an important advance in this line of research.

Regarding the limitations of the study, in the first place, the sample was by convenience and from only two regions of the country, which makes its national and international scope difficult. Secondly, the cut-off points were not presented, thus opening a gap to propose them according to the reality of the context in which they are adapted. Third, a limitation of the instrument is that it is based on the perception of teachers. Future research could consider these limitations and address studies aimed at strengthening the construct of the instrument and proposing efficient improvements in educational research.

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Authors / Autores

Chura-Quispe, Gilber (gilber.chura@epnewman.edu.pe) 0000-0002-3467-2695

Research professor at the Newman Graduate School. He belongs to the National Scientific, Technological and Technological Innovation Registry (RENACYT) at level IV of CONCYTEC and has a certificate of Responsible Conduct in Research. He holds a PhD in Educational Sciences, a Master in Scientific Research and Innovation, a Master in University Teaching and Educational Management, and a Second Specialization in Information and Communication Technology. He has a Postdoctorate in Educational Innovation in Emerging Scenarios at the Intercontinental University of Mexico. She has more than 7 years of experience as a specialist in technopedagogy applied to reading and writing and in design, construction and validation of educational instruments. She has 20 scientific articles published in journals indexed in Scopus, Web of Science and Scielo, 3 book chapters and 1 book published.

Author Contribution (GCQ)**:** Project development, data collection and processing, writing and final review.

Conflict of interest statement (GCQ)**:** There are no conflicts of interest in writing the article.

Nué Caballero, Patricia Rosa María (pnue@upt.pe) 0000-0003-0485-6626

She is a professor and dean of the Faculty of Education, Communication Sciences and Humanities of the Universidad Privada de Tacna. She holds a PhD in Education, a Master's degree in Education with a specialization in Curriculum, and a Bachelor's degree in Education with a specialization in Literature from the Catholic University of Santa Maria. Member of the Research Group Humanities at the Service of Sustainable Development (HUDDES) of FAEDCOH-UPT. She is currently conducting research on issues related to innovation in teaching and learning processes in higher education. She has published scientific articles in the Scopus database.

Author Contribution (PRNC): Methodology, writing, data collection and final review.

Conflict of interest statement (PRNC): There are no conflicts of interest in writing the article.

Laura De La Cruz, Bianca Daisa (bianca.laura@unjbg.edu.pe) 0000-0002-0579-5944

She has a degree in Social Communication with a major in Journalism and Public Relations from Universidad Nacional Jorge Basadre Grohmann, and a Master's Degree in Public Management from the same institution. She has a diploma in Proofreading from the Peruvian Academy of Language, Research Teaching and specializations in the areas of Graphic Design, Digital Marketing, Advertising and Content Management of Communication Campaigns. Bianca has participated in several research projects related to her specialty and related areas, and is a RENACYT researcher.

Author Contribution (BDLC): Methodology, writing, final revision, layout and design.

Declaration of conflict of interest (BDLC): There is no conflict of interest in writing the article.

Flores-Rosado, Cristina Beatriz (cbflores@upt.pe) 0000-0002-1159-2692

University professor in the Faculty of Education, Communication Sciences and Humanities of the Universidad Privada de Tacna. Doctor in Education with mention in Educational Management, Master in University Teaching and Educational Management. Degree in Psychology from the Faculty of Education, Communication Sciences and Humanities of the Universidad Privada de Tacna. She has a Second Specialization in Clinical and Health Psychology. She is a qualified researcher in the National Registry of Science, Technology and Technological Innovation (RENACYT) in Peru. Her line of research is the study of the person, society, human development and quality education.

Author Contribution (CBFR): Methodology, writing and final review.

Conflict of interest statement (CBFR): There are no conflicts of interest in writing the article.

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