Educación XX1
ISSN: 1139-613X · e-ISSN: 2174-5374

Psychometric validation of the scale «Technological Pedagogical Knowledge of Content TPACK-ES» and assessment of self-efficacy perceived by prospective teachers

Validación psicométrica de la escala «Conocimiento Tecnológico Pedagógico del Contenido TPACK-ES» y evaluación de la autoeficacia percibida por el futuro profesorado

Delfín Ortega-Sánchez [1] *

[1] University of Burgos, Spain
* Correspondence author. E-mail: dosanchez@ubu.es

How to reference this article:

Ortega-Sánchez, D. (2023). Psychometric validation of the scale «Technological Pedagogical Knowledge of Content TPACK-ES» and assessment of self-efficacy perceived by prospective teachers. *Educación XX1*, *26*(2), 209-244. https://doi.org/10.5944/educxx1.34484

Date received: 03/09/2022
Date accepted: 06/02/2023
Published online: 13/06/2023

ABSTRACT

Despite the usefulness of the analysis of the perception of self-efficacy in the success and performance of teachers and students in the teaching-learning process proposed by the TPACK (Technological Pedagogical Content Knowledge) model, there is little research focused on the beliefs and perceptions of future teachers. The present research has a double objective: on the one hand, it seeks to validate the psychometric properties of the TPACK-ES scale in the Spanish context; and on the other hand, to analyse the perceptions of self-efficacy in the model of Primary and Secondary Education teachers in initial training. A total of 303 university students with a mean age of 23.12 ± 3.21 years, enrolled in a university in the north of Spain, agreed to participate in this study. The results obtained confirm the heptafactorial structure of the model, its internal consistency, structural stability and adaptation to optimal fit indices. Likewise, statistically significant differences are identified in the TK and TPK dimensions, in structuring variables of the model and in the PK (pedagogical knowledge), PCK (pedagogical knowledge of content), TPK (pedagogical technological knowledge) and TPACK dimensions, depending on the level of teacher training and the gender of the future teacher. These results indicate the need to continue to analyse the contextual factors of the TPACK model in order to ensure its suitability and true effectiveness in initial teacher training.

Keywords: TPACK, validation, digital gap, higher education, teacher training

RESUMEN

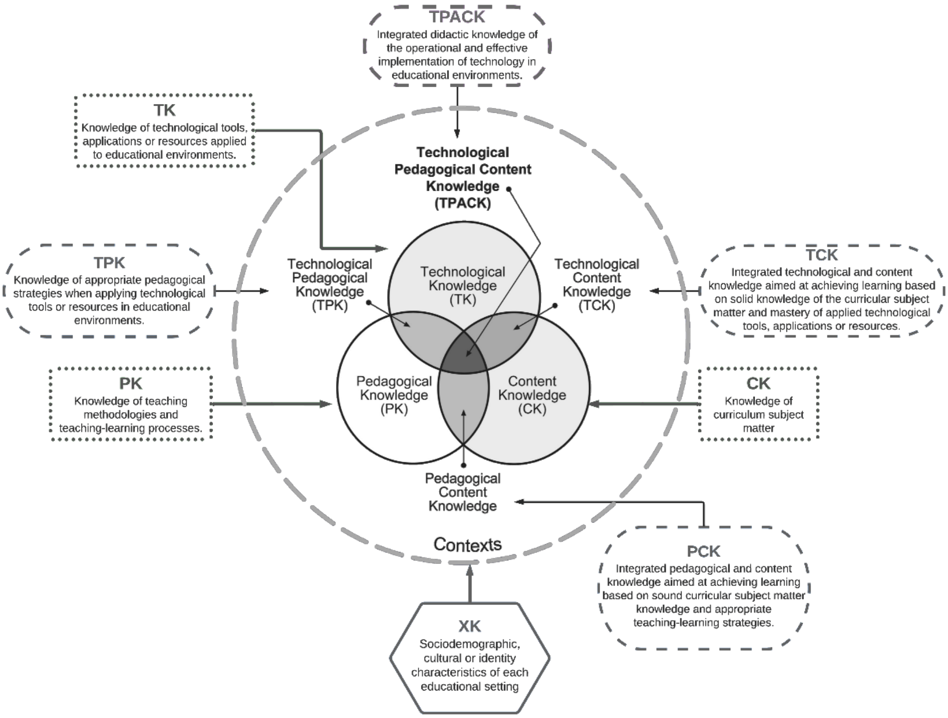
A pesar de las utilidades del análisis de la percepción de la autoeficacia en el éxito y rendimiento del profesorado y alumnado en el proceso de enseñanza-aprendizaje propuesto por el modelo TPACK (Conocimiento Tecnológico Pedagógico del Contenido), resultan escasas las investigaciones focalizadas en las creencias y percepciones del futuro profesorado. La presente investigación tiene un doble objetivo: por una parte, busca validar las propiedades psicométricas de la escala TPACK-ES en el contexto español; y por otra, analizar las percepciones de la autoeficacia en el modelo del profesorado de Educación Primaria y Educación Secundaria en formación inicial. Accedieron a participar en este estudio 303 estudiantes universitarios con una media de edad de 23.12 ± 3.21 años, matriculados en una universidad del norte de España. Los resultados obtenidos confirman la estructura heptafactorial del modelo, su consistencia interna, estabilidad estructural y adaptación a índices de ajuste óptimos. Igualmente, se identifican diferencias estadísticamente significativas en las dimensiones TK y TPK, en variables estructurantes del modelo y en las dimensiones PK (conocimiento pedagógico), PCK (conocimiento pedagógico del contenido), TPK (conocimiento tecnológico pedagógico) y TPACK, en función del nivel formativo-docente y del género del futuro profesorado. Estos resultados informan de la necesidad de continuar atendiendo al análisis de factores contextuales al modelo TPACK para su adecuación y verdadera efectividad en la formación inicial del profesorado.

Palabras clave: TPACK, validación, brecha digital, educación superior, formación de docentes

INTRODUCTION

The Technological Pedagogical Technological Content Knowledge (TPACK) model is one of the most recognised major theoretical-methodological frameworks for the assessment of teacher competence levels. The integrated combination of its dimensions includes the effective implementation of technology during the teaching process and the teaching-learning process, especially influential in the period of the COVID-19 health crisis (Manokore & Kuntz, 2022). As can be seen in Figure 1, this model provides a coherent integrated alignment of the basic levels of digital competence in teaching, guiding decision-making and promoting digital literacy.

Figure 1
TPACK Model



Note: Prepared by author based on Janssen et al. (2019).

Despite the abundant international scientific literature available on their potential in teacher professional development from different curricular disciplines, classroom practices (Anderson & Kyzar, 2022; Kartal & Çınar, 2022; Sun et al, 2022; Tan & Chen, 2022) and teaching-learning spaces (Assis & Vieira-Santos, 2021; Ortega-Sánchez & Gómez-Trigueros, 2020), there is still a need to evaluate their effects in the field of initial teacher education (Aktaş & Özmen, 2020; Ismaeel & Aktas, 2022; Widyasari et al., 2022). In this line, its usefulness and impact on the professional development of in-service teachers through the improvement of knowledge, self-efficacy, digital competence and skills for technology integration in the classroom has been demonstrated (Chen & Cao, 2022; Oda et al., 2020).

Studies aimed at analysing its impact on the operational and effective use of technology from the specific field of teacher training are recent (Schmidt-Crawford et al., 2021), inseparable from the other components of the TPACK model (Ortiz-Colón et al., 2020), and few studies consider its impact in terms of the level of teacher training of future teachers and active teachers (Castéra et al., 2020; Cheng & Xie, 2018). Despite the usefulness of the analysis of perceived self-efficacy in the success and performance of teachers and students in the quality of teaching-learning processes, there is little research focused on prospective teachers' beliefs and perceptions of their self-efficacy in the multidimensional framework of the TPACK model (Alpaslan et al., 2021; Diamah et al., 2022; Nazari et al., 2019; Tondeur et al., 2019; Wang et al., 2020), particularly in the social sciences (Ciriza-Mendívil et al., 2022). Similarly, "although [practising] teachers' beliefs about TPACK influence [the] incorporation of technology in the classroom, few studies analyse them" (Liu, 2022, p. 305). Indeed, "the use of TPACK-based training to promote trainee teachers' perceptions of TPACK remains limited" (Diamah et al., 2022, p. 3).

Technological inclusion, for pedagogical purposes, for the acquisition and development of digital competences from an integrated perspective has been one of the most significant teaching and research concerns in the field of education (Cabero & Martínez, 2019). In this sense, the TPACK model has been proposed as an appropriate framework for teacher professional development, based on the coherent interrelation between curricular content, didactics and technology in specific contexts. Part of its complexity lies in this last element. Indeed, the "context makes the TPACK model unique, located in a time and place, idiosyncratic, adaptive, specific and different for each teacher; hence the difficulty generated by its measurement" (Jiménez & Cabero, 2021, p. 7).

The benefits of TPACK need to be complemented by specifying the factors that influence its development (Huang et al., 2020). From this perspective, the gender effect is presented as one of its fundamental components (Castéra et al., 2020). According to Long et al. (2020), divergences according to this factor could be due to “different attitudes of male and female teachers towards the use of technology and perceived self-confidence in teaching. Female teachers tend to have higher PK but lower TK than male teachers, while male teachers tend to have higher self-efficacy in using technology” (p. 5). Similarly, gender and level of teacher training in ICT were recorded as influential personal factors in Greek Primary School teachers’ perceptions of their TPACK skills (Roussinos & Jimoyiannis, 2019). The same study pointed to the relevance of the educational context.

Considering its complexity, context has recently been proposed as an eighth domain (contextual knowledge, XK) about teachers’ knowledge of technological resources and educational policies (Mishra, 2019). However, for this dimension we propose to consider the contextual factors derived from the socio-demographic, cultural or identity characteristics of the educational environments in which the TPACK model is developed. In this line, the present research has a twofold objective: on the one hand, it seeks to validate the psychometric properties of the TPACK-ES scale in the Spanish context; and on the other hand, to analyse the perceptions of self-efficacy in the model of Primary and Secondary Education teachers in initial training. In relation to this second objective, it formulates four hypotheses, based on the suggestion of Chai et al. (2016) on the examination of the effect of teacher gender on the domains of the TPACK model, the results of Roussinos and Jimoyiannis (2019) and Castéra et al. (2020), and the study of the educational level proposed by Ibrohim et al. (2022) and Long et al. (2020). We complete these hypotheses with the analysis of the potential interaction of both variables.

- $H_{1(1)}$ The dimensional values of the TPACK model are higher in male than in female future teachers.
- $H_{1(2)}$ The dimensional values of the TPACK model are higher in females than in males future teachers.
- $H_{1(3)}$ There are statistically significant differences in the values obtained in the self-perception of efficacy in the TPACK domains and the level of education of the prospective teacher.
- $H_{1(4)}$ There is an interaction between the factors gender and university studies in the perceived self-efficacy of future teachers on the dimensions of the TPACK model.

METHOD

Participants

Participants were selected by means of purposive or convenience sampling, in accordance with the research team's possibilities of access to the field of study and according to their degree of suitability to the objectives formulated. A total of 303 students of Primary and Compulsory Secondary Education (68% female and 32% male) with a mean age of 23.12 ± 3.21 years, enrolled in a university in the north of Spain, agreed to participate in the research. With a margin of error of 5% and a confidence level of 95%, the sample is considered significant with respect to the total population from which it is drawn (N = 1265) (Otzen & Manterola, 2017) (Table 1).

Table 1
Socio-demographic characteristics

Gender		Studies			
♂	♀	1	2	3	4
$f_i(p_i)$	$f_i(p_i)$	$f_i(p_i)$	$f_i(p_i)$	$f_i(p_i)$	$f_i(p_i)$
97(32)	206(68)	107(35.5)	93(30.7)	56(18.5)	47(15.5)

Note. 1 = First year of the Bachelor's Degree in Primary Education. 2 = Second year of the Degree in Primary Education. 3 = Third year of the Bachelor's Degree in Primary Education. 4 = Master's Degree in Secondary Education.

Instrument

Consistent with the TPACK model as the most widespread and frequent measurement method, both in terms of its effectiveness and cost-effectiveness, the self-report questionnaire was selected as the data collection instrument. In all cases, the development of the scales has evidenced the expected factor structure (Kadioglu-Akbulut et al., 2020; Schmidt-Crawford et al., 2020).

The applied instrument (TPACK-ES) consists of 32 items distributed in 7 dimensional blocks or TPACK domains [*TK-Technological* Knowledge (4 items), *CK-Content* Knowledge (4 items), *PK-Pedagogical* Knowledge (7 items), *PCK-Pedagogical Content Knowledge* (3 items), TCK-Technological Content Knowledge (3 items), TPACK-Technological Pedagogical Content Knowledge (9 items) and TPACK-Technological Pedagogical Content Knowledge (2 items), *TCK-Technological Content*

*Knowledge (*3 items), *TPK-Technological Pedagogical Content* Knowledge (9 items) and *TPACK-Technological Pedagogical Content* Knowledge (2 items)], measured on a five-point Likert-type scale, where 1 corresponded to *strongly disagree* and 5 to *strongly agree*.

The applied instrument was adapted according to the criteria developed by Schmidt-Crawford et al. (2009, 2020), so the theoretical dimensions of the TPACK were known. In order to determine the goodness of fit, structure and stability of the instrument for the data collection of this research, tests of validity, reliability and between-group invariance were conducted by applying the methods of Confirmatory Factor Analysis (CFA), Cronbach's alpha and McDonald's omega, and factorial invariance analysis, respectively, from the study population.

In order to generalise the results and the final CFA model, we estimated and diagnosed the model by analysing the total data, as the "recommendation to split the sample leads to a reduction of the initial sample size, which is not irrelevant considering that most studies use smaller sample sizes than those required by the general rule" (Fernández-Hernández et al., 2022, p. 39).

Internal consistency validity

The estimation of the internal consistency reliability of the items of the measuring instrument was calculated using Cronbach's alpha coefficient (α) and McDonald's omega method (ω); the justification for incorporating the latter method resided in its usefulness to "try to mitigate the inadequate use of Cronbach's alpha when its statistical assumptions are not met" (Frías-Navarro & Pascual-Soler, 2022, p. 5). Firstly, the reliability indicator was calculated for the entire scale and, secondly, for each of the proposed factors or constructs. The coefficients returned indicate their adequacy and proximity to those obtained in factor distributions that, from differential structural scales, are based on the TPACK theoretical model (Table 2).

Table 2

Internal consistency coefficients of instruments and/or instrumental adaptations based on the TPACK model

Scale		TK		CK		PK		PCK		TCK		TPK		TPACK	
α		α		α		α		α		α		α		α	
.98[a]		.81		.82		.76		.82		.88		.81		.79	
.96[b]		.83-.94		.83-.94		.83-.94		.83-.94		.83-.94		.83-.94		.83-.94	
.95[c]		.61		.78		.87		.81		-		.86		.92	
.85[d]		-		-		-		-		-		-		-	
-[e]		.88		.86		.97		.94		.84		.84		.93	
-[f]		.86		.86		.86		.86		.84		.82		.83	
.95[g]		-		-		-		-		-		-		-	
-[h]		.90		.88		.95		.78		.83		.91		.89	
-[i]		.82		≈.81		.84		.85		.80		.86		.92	
ω	α	ω	α	ω	α	ω	α	ω	α	ω	α	ω	α	ω	α
.93	.93*	.80	.80	.77	.77	.84	.84	.80	.76	.78	.76	.83	.82	.61	.61

Note.[a] = Fernández-Chávez et al. (2022);[b] = Joldanova et al. (2022);[c] = Diamah et al. (2022);[d] = Widyasari et al. (2022);[e] = Ibrohim et al. (2022);[f] = Jiménez and Cabero (2021);[g] = Ortiz-Colón et al. (2020);[h] = Cabero (2014);[i] = Schmidt-Crawford et al. (2009); * Ortega-Sánchez (2023).

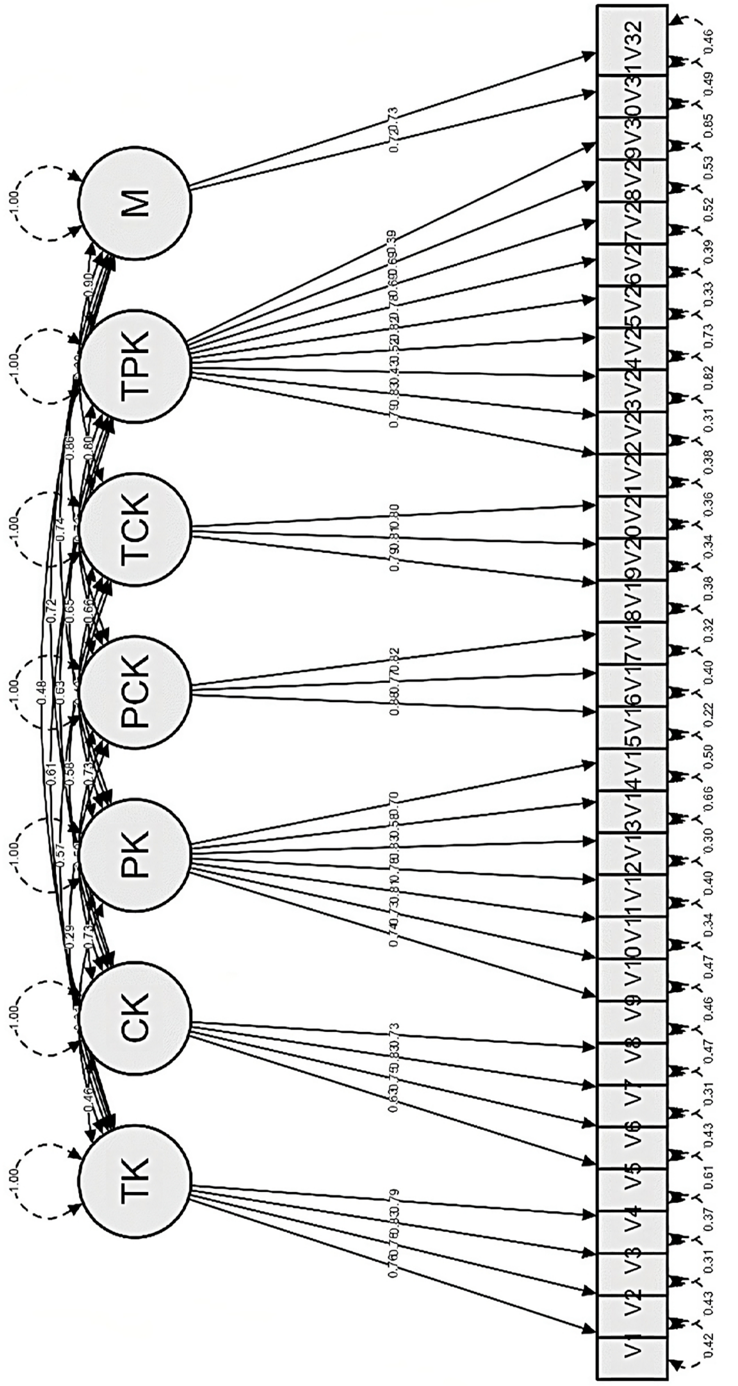
Construct validity

In order to verify and accept the questionnaire and its factorial structure, the necessary analyses were carried out to assess its instrumental usefulness in the measurement of the competences associated with the TPACK model. Thus, based on the scientific literature and applied instruments related to self-efficacy in the theoretical and procedural dimensions of the model, we tested 7 hypotheses on latent variables (constructs), defined on the basis of 32 observed variables or indicators. Previous Exploratory Factor Analysis (EFA) guided the numerical and factorial distribution and the choice of the number of indicators for each latent variable.

Our purpose was to identify the relationship between these indicators and their constructs (factors), and between the constructs themselves, based on the resulting measures of goodness of fit. To this end, and within the framework of structural equation analysis using covariance structures, we conducted a Confirmatory Factor Analysis (CFA). The estimation method employed, consistent with the sample size, was maximum likelihood estimation, for which a sample size of around 200 observations is recommended (Bentler, 1989).

Hu and Bentler (1999) recommended that the model be fitted by paying attention to the RMSEA (Root Mean Square Error of Approximation) and SRMR (Standardised Root Mean Square Residual) indices, whose recommended values are < .08, and the CFI (Comparative Fit Index), whose optimal values are > .95 (Jöreskog & Sörbom, 1993; Schumacker & Lomax, 2015) (Figure 2) (Figure 2).

Figure 2
Confirmatory factor analysis. Path diagram of the final model



Note: M = TPACK integrated dimensional model.

Both the parsimony fit measure ($\chi =^{2}_{(443)}$ 868, $p < .001$, χ^2 /df = 1.95 [< 5]) and the overall absolute and comparative fits achieved can be considered satisfactory (Table 3).

Table 3

Absolute fit (RMSEA and SRMR) and comparative fit (CFI and TLI)

				RMSEA 90% CI	
CFI	TLI	SRMR	RMSEA	Lower	Upper
0.987	0.985	0.065	0.058	0.052	0.064

Discriminant validity

Empirical evidence of the existence of discriminant validity was obtained by applying the confidence interval test of the correlations (Anderson & Gerbing, 1988) between the seven factors that make up the theoretical model of Mishra and Koehler (2008). According to the correlation matrix ($p < .001$) and the confidence intervals obtained (Table 4) and, considering that none of them contains 1 at 95% confidence, the discriminant validity of the scale can be confirmed (Henseler et al., 2015).

Convergent validity

Finally, the convergent validity of each latent construct is analysed on the basis of the Average Variance Extracted (AVE) (Lévi & Varela, 2006). The coefficients returned show that the heptafactorial structure of the model presents sufficient evidence of convergent validity (TK [4 items]: AVE = 0.689; CK [4 items]: AVE = 0.648; PK [7 items]: AVE = 0.648; PCK [3 items]: AVE = 0.633; TCK [3 items]: AVE = 0.371; TPK [9 items]: AVE = 0.614); TPACK [2 items]: AVE = 0.547). It can be stated that more than 50% of the variance of each construct is due to its indicators and, therefore, its suitability for the empirical explanation of the latent constructs can be concluded.

Table 4

TPACK model factor correlations and confidence intervals

R		TK	CK	PK	PCK	TCK	TPK	TPACK
TK	*r*	—						
	P	—						
	Upper 95% CI	—						
	Lower 95% CI	—						
CK	*r*	.353	—					
	P	< .001	—					
	Upper 95% CI	0.447	—					
	Lower 95% CI	0.250	—					
PK	*r*	.253	.597	—				
	P	< .001	< .001	—				
	Upper 95% CI	0.356	0.665	—				
	Lower 95% CI	0.144	0.519	—				
PCK	*r*	.216	.451	.592	—			
	P	< .001	< .001	< .001	—			
	Upper 95% CI	0.321	0.537	0.661	—			
	Lower 95% CI	0.105	0.356	0.514	—			
TCK	*r*	.432	.439	.404	.545	—		
	P	< .001	< .001	< .001	< .001	—		
	Upper 95% CI	0.520	0.526	0.494	0.620	—		
	Lower 95% CI	0.335	0.343	0.305	0.460	—		
TPK	*r*	.492	.495	.546	.564	.645	—	
	P	< .001	< .001	< .001	< .001	< .001	—	
	Upper 95% CI	0.573	0.576	0.620	0.636	0.706	—	
	Lower 95% CI	0.402	0.405	0.462	0.482	0.573	—	
TPACK	*r*	.329	.479	.521	.611	.630	.676	—
	P	< .001	< .001	< .001	< .001	< .001	< .001	—
	Upper 95% CI	0.426	0.561	0.599	0.678	0.694	0.733	—
	Lower 95% CI	0.225	0.387	0.434	0.535	0.556	0.609	—

Note. *R*. Factorial relationship.

Factor invariance analysis

Considering the lack of studies in Spanish teacher training contexts that have evaluated the stability of the structure of the measurement instruments based on the TPACK model among different subgroups, we analyse the factorial invariance of the TPACK-ES scale. With this analysis, we hope to verify the independence of its measurement properties from the characteristics of the groups being compared, to obtain empirical evidence of its stability, to check the absence of bias in the measurement and, therefore, to guarantee the validity of the results.

In order to find out what extent measurement invariance existed, we performed a multi-group structural equation modelling (SEM), based on the grouping variables gender and educational level. In this modelling, we included the mean structure for the three proposed models: Model 1 (configurational invariance), Model 2 (metric invariance) and Model 3 (scalar or strong invariance) (Rens van de Schoot & Hox, 2012).

The results returned (Table 5 and Table 6) indicate that the factor model can be applied to all comparison groups and that the factor loadings are equal across groups (p > .05). This circumstance makes possible the statistical comparison of structural relationships between latent variables between groups. It is also evident that the intercepts of the items are equal in the groups of interest (p > .05), which proves the usability of the scale for intergroup comparison of means. Given that the factor structure, factor loadings and intercepts can be considered invariant, the instrument meets the equivalence criteria (Abalo et al., 2006).

Table 5
Model fits. Grouping variable: gender

				Reference contrast			Contrast of differences		
	AIC	BIC	n	χ^2	gl	p	$\Delta\chi^2$	Δgl	p
Model 1	19780.409	20649.423	303	1547.724	886	< .001			
Model 2	19871.729	20555.056	303	1739.044	936	< .001	191.320	50	.382
Model 3	19868.885	20433.372	303	1800.200	968	< .001	61.156	32	.269

Table 6
Model fits. Grouping variable: educational level

				Reference contrast			Contrast of differences		
	AIC	BIC	*n*	χ^2	gl	*p*	$\Delta\chi^2$	Δgl	*p*
Model 1	19545.691	21283.718	303	2984.251	1772	< .001			
Model 2	19626.079	20992.733	303	3264.639	1872	< .001	280.388	100	.458
Model 3	19684.297	20694.433	303	3514.857	1968	< .001	250.218	96	.327

Design and procedure

The present research belongs to the non-experimental cross-sectional studies (Ato et al., 2013). The instrument was administered to the participant sample in a single 30-minute session during the second semester of the 2021-2022 academic year, with prior communication of the purpose of the study and the confidentiality with which the data would be treated. Likewise, their consent was requested to use the responses obtained.

The study was conducted in accordance with the guidelines of the Declaration of Helsinki (Declaration of the World Medical Association), guaranteeing the ethical-philosophical commitment and unwavering respect for human dignity, privacy, physical and moral integrity, as well as the protection of personal data in the processing o f the survey and throughout the research. Privacy regulations were complied with, taking into account the personal data protection code (Organic Law 3/2018), anonymity and informed consent. The study was also reviewed and approved by the Bioethics Committee of the university responsible for the research (IR 15/2018).

Data analysis

After applying the Kolmogorov-Smirnov hypothesis test and testing the absence of the expected normality in the variables and factors that make up the construct, their skewness and kurtosis values were calculated. Since the skewness results for each variable were below 2 (S = 0.260 - 1.898, SE = 0.140 - 0.141) and the kurtosis results were below 7 (K = 0.020 - 2.433, SE = 0.279 - 0.281), it can be considered that the distribution is close to normal (Curran et al., 1996). Likewise, for the fulfilment of this assumption in the application of parametric statistics, this tendency to normality was identified in each study variable and comparison group (*gender*) (S = -0.984 _ -1.456, SE = 0.169 - 0.245; K = 0.942 - 1.012, SE = 0.377 - 0.485), and in each scale factor and comparison group (*gender*) (*S* = -0.725-0.230, *SE* = 0.169 - 0.246; *K* = 0.634 - 1.003, *SE* = 0.377 - 0.488). Having identified the absence of equality of variances (homoscedasticity) in 6 of the 32 items of the scale and in its fifth factor (TCK), the Welch's test, Student's t-test for independent samples, was applied.

Once the assumption of homoscedasticity and descriptive normality (skewness and kurtosis) (*S* = -0.23 __ -0.712, *SE* = 0.140; *K* = 0.159 - 0.918, *SE* = 0.279 - 0.280) in the group distributions of the *study* variable was verified, we sought to test the existence of statistically significant differences according to this variable, identify the predictor variables and evaluate the joint effect or interaction of the categorical variables *gender* and *level of study* on the TPACK dimensional model. For this purpose, single-factor ANOVAs, 2x4 factorial ANOVAs and Bonferroni *post-hoc* analyses were carried out to determine the specific differential levels and their potential effects. Finally, the analyses are completed with effect sizes and the calculation of statistical power.

Checking for the absence of multivariate *outliers* was done by calculating the Mahalanobis distance. The results returned report *p-values* greater than .001 (*p* = .21 - .90) for all scale factors. Consequently, given the absence of missing cases and/or outliers, the application of value imputation techniques was not necessary. Furthermore, in order to identify possible neglected responses, we proceeded to study the individual reliability of the items (Huang & Wang, 2021) using the *Partial Least Squares* Analysis Method (PLS-SEM). The results obtained show that the items that make up the scale are reliable, as the loadings of their coefficients have values above 0.7 (0.832 - 0.912). Therefore, the presence of random responses, inattentive or with a possible insufficient effort to respond (IER [*Insufficient Effort Responding*] or CR [*Careless Responding*] is not identified, a circumstance that has motivated the non-application of bias controls.

For data processing, the statistical packages SPSS v.25, JASP 0.16.4.0, G*Power v.3.1.9.7. and SmartPLS v. 3.3 were used.

RESULTS

The group results report statistically higher mean levels in men in variables related to the TK [*Technological Knowledge*] dimension (ability to solve technical problems with technologies, ability to learn technology and update new technologies), CK [*Content Knowledge*] (sufficiency in content knowledge), PK [*Pedagogical Knowledge*] (familiarity with common misconceptions in students), TCK [*Technological Content Knowledge*] (technological training for teaching) and, fundamentally, with the TPK [*Technological Pedagogical Knowledge*] dimension (selection of technologies for learning, selection of technological resources for teaching, selection of technologies for teaching and learning, leadership in teaching support for the use of technologies and diverse methodologies, and representation of the usefulness of technologies in the teaching task). When the hypothesis reverses its premises (Group 1 [Men] < Group 2 [Women]), however, no statistically significant increases in value are evident in any variable or factor.

Consequently, a higher self-perceived male dominance of technological knowledge and competence (M♂ = 3.83-4.03, *SD* = 0.71-0.95; M♀ = 3.51-3.74, *SD* = 0.84-0.93), and of knowledge about teaching and learning processes with technology (M♂ = 3.77-4.37, *SD* = 0.68-0.93; M♀ = 3.50-4.18, *SD* = 0.66-0.83) can be identified. However, these results record small to moderate effect sizes (*d* = 0.214-0.457) and low statistical power validity indices (1-β = .459-.723). The mean values are close to 4, confirming an optimal degree of identification with the formulated competence statements. These levels find dimensional correspondence, consistently, with the TK factor (M♂ = 3.99, *SD* = 0.65; M♀ = 3.70, *SD* = 0.67, *d* = 0.439, 1-β = .673) and the TPK factor (M♂ = 3.96, *SD* = 0.52; M♀ = 3.83, *SD* = 0.48, *d* = 0.259, 1-β = .492) (Table 7) (Table 7).

Table 7

Comparison of values by variables and factors according to gender (male > female)

	♂ (*n* = 97)	♀ (*n* = 206)	*t*	df	*p*	1-β	*d*
	M (SD)	M (SD)					
TK (V1)*	4.03 (0.78)	3.64 (0.87)	3.808	208.922	< .001	.723	0.457
TK (V2)*	4.03 (0.71)	3.74 (0.84)	3.099	219.766	.001	.459	0.370
TK (V3)	3.83 (0.95)	3.51 (0.93)	2.806	301	.003	.527	0.349
F1_TK	3.99 (0.65)	3.70 (0.67)	3.473	301	< .001	.673	0.439
CK (V5)	3.81 (0.83)	3.60 (0.83)	1.991	300	.024	.489	0.240
PK (V14)	3.66 (0.82)	3.41 (0.80)	2.415	301	.008	.494	0.296
TCK (V19)*	3.85 (0.96)	3.66 (0.78)	1.696	156.405	.046	.529	0.217
TPK (V22)	3.89 (0.68)	3.73 (0.75)	1.839	299	.033	.528	0.235
TPK (V23)	4.04 (0.70)	3.86 (0.66)	2.127	300	.017	.501	0.262
TPK (V27)	3.95 (0.78)	3.80 (0.69)	1.734	298	.042	.505	0.214
TPK (V29)	3.77 (0.93)	3.50 (0.83)	2.548	299	.006	.480	0.304
TPK (V30)	4.37 (0.76)	4.18 (0.75)	1.964	298	.025	.481	0.236

	♂ (*n* = 97)	♀ (*n* = 206)	*t*	df	*p*	1-β	*d*
	M (SD)	M (SD)					
F6_TPK	3.96 (0.52)	3.83 (0.48)	2.140	301	.017	.492	0.259

Note. The one-tailed alternative hypothesis specifies that the male group is larger than the female group. *Welch's test.

There are no significant factorial interactions between gender and education in any of the domains of the TPAK model [TK ($F_{(3, 295)}$ = .602, p = .614), CK ($F_{(3, 295)}$ = .602, p = .227), PK ($F_{(3, 295)}$ = .786, p = .503), PCK ($F_{(3, 293)}$ = .773, p = .510), TCK ($F_{(3, 293)}$ = 1.179, p = .318), TPK ($F_{(3, 295)}$ = .334, p = .801) and TPACK ($F_{(3, 293)}$ = .457, p = .712).

Although no statistically significant differences are identified as a function of educational background in the TK and CK dimensions ($F_{(3, 295)}$ = .745, p = .526; $F_{(3, 295)}$ = 1.462, p = .225), the remaining factors report their existence with moderate effect sizes (f = 0.263-0.351), except for the TPK domain with a small effect size (f = 0.175). Considering the values returned by statistical power (*1*-β = .762-.985) [greater than .80], the differences identified can be generalised to the population from which the data are drawn, except for the TPK domain with reduced statistical power (*1*-β = .617) (Table 8).

Table 8

Comparison of factor values as a function of educational level

	♂ (*n* = 97)	♀ (*n* = 206)	*F*	df	*p*	1-β	*f*
	M (SD)	M (SD)					
PK[a]	3.93 (0.55)	3.78 (0.62)	10.039	3	< .001**[a]	.853	0.282
PK[b]	4.13 (0.46)	3.90 (0.46)					
PK[c]	3.85 (0.40)	3.80 (0.41)					
PK[d]	3.45 (0.62)	3.50 (0.54)					
PCK[a]	3.81 (0.52)	3.61 (0.67)	13.070	3	<.001**[b] / *[a]	.985	0.351
PCK[b]	3.65 (0.78)	3.75 (0.52)					
PCK[c]	3.45 (0.60)	3.34 (0.65)					
PCK[d]	3.04 (0.86)	3.05 (0.74)					
TCK[a]	3.87 (0.87)	3.47 (0.73)	7.870	3	< .001**[c]/ *[b]	.762	0.263
TCK[b]	3.45 (0.79)	3.50 (0.61)					
TCK[c]	3.21 (0.88)	3.05 (0.75)					
TCK[d]	3.23 (0.80)	3.08 (0.71)					

	♂ (*n* = 97)	♀ (*n* = 206)	*F*	df	*p*	1-β	*f*
	M (SD)	M (SD)					
TPK[a]	4.08 (0.56)	3.88 (0.45)	4.077	3	.024*[c]	.617	0.175
TPK[b]	4.03 (0.53)	3.88 (0.47)					
TPK[c]	3.80 (0.46)	3.76 (0.52)					
TPK[d]	3.82 (0.43)	3.62 (0.48)					
TPACK[a]	3.82 (0.73)	3.79 (0.68)	10.858	3	< .001**[d/] *[d]	.947	0.318
TPACK[b]	3.84 (0.85)	3.80 (0.66)					
TPACK[c]	3.38 (0.62)	3.53 (0.65)					
TPACK[d]	3.28 (0.68)	3.10 (0.72)					

[a] = second year of Bachelor's degree;[b] = third year of Bachelor's degree;[c] = fourth year of Bachelor's degree;[d] = Master's degree.

** $p^a < 0.01$ between second year Bachelor and Master (*M* = 3.83-3.48, *SD* = 0.60-0.58), third year Bachelor and Master (*M* = 3.96-3.48, *SD* = 0.47-0.58), and fourth year Bachelor and Master (*M* = 3.81-3.48, *SD* = 0.41-0.58).

[a] p*< 0.05 between the second and fourth year of the Bachelor's degree (*M* = 3.67-3.37, *SD* = 0.64-0.63). ** $p^b <$ 0.01 between third and fourth year undergraduate (*M* = 3.72-3.37, *SD* = 0.59-0.63), second year undergraduate and Master's (*M* = 3.67-3.04, *SD* = 0.64-0.79), and third year undergraduate and Master's (*M* = 3.72-3.04, *SD* = 0.59-0.79).

[c] p**< 0.01 between the second and fourth year of the Bachelor's degree (*M* = 3.59-3.10, *SD* = 0.79-0.79), and between the second year of the Bachelor's degree and the Master's degree (*M* = 3.59-3.15, *SD* = 0.79-0.77). * $p^b <$ 0.05 between the third and fourth year of the Bachelor's degree (*M* = 3.49-3.10, *SD* = 0.66-0.79).

* $p^c < 0.05$ between second and fourth year undergraduate (*M* = 3.94-3.77, *SD* = 0.49-0.50), second year undergraduate and Master (*M* = 3.94-3.72, *SD* = 0.49-0.46), and third year undergraduate and Master (*M* = 3.92-3.72, *SD* = 0.49-0.46).

[d] p*< 0.05 between the second and fourth year of Bachelor's degree (*M* = 3.80-3.49, *SD* = 0.69-0.64), and the third and fourth year of Bachelor's degree (*M* = 3.81-3.49, *SD* = 0.71-0.64). ** $p^d < 0.01$ between the second year of Bachelor and Master (*M* = 3.80-3.19, *SD* = 0.69-0.70), and the third year of Bachelor and Master (*M* = 3.81-3.19, *SD* = 0.71-0.70).

DISCUSSION AND CONCLUSIONS

The results of the validity, reliability and stability of the TPACK-ES scale were satisfactory, a circumstance that will allow its application in other Spanish teacher training contexts with similar characteristics. According to the results obtained, statistically significant differences are identified according to the gender of the future teachers, in the domains related to technological experimentation (TK), in the understanding of how teaching-learning can improve when certain technologies are used (TPK), and in other structuring variables of the TPACK model. These results are consistent with those obtained by Ortiz-Colón et al. (2020) for the first dimension (TK) in in-service primary school teachers in Andalusia (Spain) (*n* = 607), with those returned by Koh et al. (2010) in trainee teachers in both dimensions and with those obtained by Cetin-Berber and Erdem (2015) in the first dimension, and distinctive with respect to those provided by Leal and Rojas (2020) for Colombian trainee teachers (*n* = 274), which conclude the absence of significant differences according to the gender declared by the participants.

They are also consistent with Ibrohim et al.'s study (2022) of Indonesian science teachers' perceptions of the TPACK model (*n* = 1,357). Their research identified significant differences according to the gender and educational level of the participants. Concurrent with the results of the present study, higher overall levels of men's TPACK competence perception were observed. These same results are in line with the findings of the meta-analysis by Yanpar Yelken et al. (2019) and the study by Beri and Sharma (2019), which identified significant differences between the types of knowledge of the TPACK model as a function of gender. In the context of these differences, in the present research, technological knowledge (TK) and technological pedagogical knowledge (TPK) have small to moderate (TK) effect sizes that are larger in favour of males.

As for content knowledge, technological content knowledge and pedagogical knowledge, where differences are identified in some of their variables (CK-V5, TCK-V19 and PK-V14), the analysis of Yanpar Yelken et al. (2019) observes full factorial differences; however, partially concurrently with the present research, small effect sizes in favour of men are recorded in all three domains. In line with the research of Gebhardt et al. (2019) and in the context of this research, it can be stated that men express a higher level of digital competence confidence and thus in the use of ICT and its application in learning than women. This digital gender gap seems to contrast with other recent studies in the field of teacher education (Pozas & Letzel, 2021).

In relation to the influence of educational level on perceptions of TPACK self-efficacy, significant differences are found in 5 (PK, PCK, TCK, TPK and TPACK) of the 7 dimensions of the model, with mean scores close to 4 in favour of men in practically all the educational stages. However, no increase in these scores is identified as a function of the future teacher's educational progress. These results are consistent with those of Lee and Lee (2020) and Ibrohim et al. (2022), who identified the influence of educational level on in-service teachers' perception of TPACK; however, they differ in their descriptive trends, as higher scores were observed in teachers with a Master's degree in all domains. The results are in line with the findings of Long et al. (2020), who found significant differences according to the educational level of Chinese primary school teachers (*n* = 159), except for the TK and TPK dimensions, where males had higher scores than females. Similarly, these levels of perceived self-efficacy of prospective teachers contrast with those obtained in other geographical areas, as evidenced by the research results of Al-Abdullatif (2019) for Saudi teacher trainees and Wang et al. (2020) for Chinese prospective teachers.

Contextual factors such as learning styles, cultural, socio-economic (Ali & Hawk, 2022) and identity characteristics, or the influence of teachers' emotions (Huang et al., 2022) need to be considered in the articulation and design of teaching-learning activities based on the TPACK model. Consequently, it is necessary to diagnose and fill in the gaps in the development and innovation of this model in order to ensure its effective implementation. In this regard, we agree with Napitupulu and Sebayang (2022) in identifying the limitations in moving towards heutagogical and cyber-agogical learning designs related to TPACK-based learning, conditioned, among other factors, by the lack of access to studies on the impact of the model on learning and sufficient infrastructure support for its proper development.

The results show the influence of contextual factors on the processes of technology integration and on the assessment of perceived self-efficacy in digital competences by prospective teachers. Context, which includes factors linked to personal identity (gender) and prior education (Morgan et al., 2022), is indeed a complex and interrelated multi-layered structure. In this sense, the TPACK model is not reduced to a set of integrated knowledge and competences, but is also context-oriented, which in turn impacts on the aims of the model itself (Kulaksız & Karaca, 2022). Thus, the existence of a gender digital divide continues to be identified and, consequently, the need for more specific training in digital competence for teachers (Gisbert-Cervera et al., 2022), which considers the incorporation of contextual components in the design, implementation and evaluation of the TPACK model in teacher education.

Limitations

Despite the type of sampling, design (case study) and, therefore, the limited sample size, the results of the present research may be useful for the implementation of teacher training programmes on the operational and effective implementation of the TPACK model. In addition, the drawbacks of administering the instrument as a self-report should be considered, especially in relation to the potential biases produced by social desirability and assent (De las Cuevas & González de Rivera, 1992). In this line, future work should triangulate the results obtained in this research with the application of techniques such as *on-site* observation, semi-structured and in-depth interviews, and the focus group, in order to understand the conceptions, teaching actions and didactic positions of trainee teachers on the integration of educational technology in their teacher training plans.

Finally, the cross-sectional design of this research suggests the need for further longitudinal studies (Lachner et al., 2021) capable of analysing, through different temporal measures, possible changes in the perception of future teachers' competence self-efficacy after the design, implementation and evaluation of specific teacher training programmes based on the TPACK model.

FUNDING

This research has been funded by the research project *La naturaleza de I-STEM (NoSTEM) para la formación ciudadana* (PID2020-118010RB-I00) [State Agency for Research - Ministry of Science and Innovation].

REFERENCES

Abalo, J., Lévy, J. P., Rial, A., & Varela, J. (2006). Invarianza factorial con muestras múltiples. En J. P. Lévy, & J. Varela (Coords.), *Modelización con estructuras de covarianzas en ciencias sociales: Temas esenciales, avanzados y aportaciones especiales* (pp. 259-278). Netbiblo.

Aktaş, I., & Özmen, H. (2020). Investigating the impact of TPACK development course on pre-service science teachers' performances. *Asia Pacific Education Review, 21*(4), 667-682. https://doi.org/10.1007/s12564-020-09653-x

Al-Abdullatif, A. M. (2019). Auditing the TPACK confidence of pre-service teachers: The case of Saudi Arabia. *Education and Information Technologies*, *24*, 3393–3413. https://doi.org/10.1007/s10639-019-09924-0

Ali, S., & Hawk, N. (2022). Examining teachers' perceptions of TPACK in culturally diverse classroom. En T. Bastiaens (Ed.), *Proceedings of EdMedia + Innovate Learning* (pp. 218-221). Association for the Advancement of Computing in Education (AACE). https://cutt.ly/f88q33z

Alpaslan, M. M., Ulubey, Ö., & Ata, R. (2021). Adaptation of Technological Pedagogical Content Knowledge Scale into Turkish culture within the scope of

21st century skills. *Psycho-Educational Research Reviews*, *10*(1), 77–91. https://cutt.ly/m88q6Sz

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*(3), 411-423. https://doi.org/10.1037/0033-2909.103.3.411

Anderson, S. E., & Kyzar, K. B. (2022). Between school and home: TPACK-in-practice in elementary special education contexts. *Computers in the Schools*, *39*(4), 323–341. https://doi.org/10.1080/07380569.2022.2086738

Assis, M. dos S. de, & Vieira-Santos, J. (2021). Conhecimento tecnológico e pedagógico do conteúdo (TPACK) na construção do saber docente virtual: Uma revisão sistemática. *Acta Scientiarum. Education*, *43*(1), Artículo e51998. https://doi.org/10.4025/actascieduc.v43i1.51998

Ato, M., López-García, J. J., & Benavente, A. (2013). Un sistema de clasificación de los diseños de investigación en psicología. *Anales de Psicología*, *29*(3), 1038–1059. https://doi.org/10.6018/analesps.29.3.178511

Bentler, P. M. (1989). *EQS structural equations program manual*. BMDP Statistical Software.

Beri, N., & Sharma, L. (2019). A study on technological and content knowledge among teacher-educators in Punjab region. *International Journal of Engineering and Advanced Technology, 8*(5), 1306-1312. https://doi.org/10.35940/ijeat.E1186.0585C19

Cabero, J. (2014). *La formación del profesorado en TIC: modelo TPACK*. Plubidisa.

Cabero, J., & Martínez, A. (2019). Las TIC y la formación inicial de los docentes. Modelos y competencias digitales. *Profesorado. Revista de Currículum y Formación del Profesorado, 23*(3), 247-268. https://doi.org/10.30827/profesorado.v23i3.9421

Castéra, J., Marre, C. C., Yok, M. C. K., Sherab, K., Impedovo, M. A., Sarapuu, T., Delserieys Pedregosa, A., Khatoon Malik, S., & Armand, H. (2020). Self-reported TPACK of teacher educators across six countries in Asia and Europe. *Education and Information Technologies*, *25*(4), 3003–3019. https://doi.org/10.1007/s10639-020-10106-6

Cetin-Berber, D., & Erdem, A. R. (2015). An investigation of Turkish pre-service teachers' technological, pedagogical and content knowledge. *Computers, 4*(3), 234-250. https://doi.org/10.3390/computers4030234

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2016). A review of the quantitative measures of technological pedagogical content knowledge (TPACK). En M. C. Herring, M. J. Koehler, & P. Mishra (Eds.), *Handbook of technological pedagogical content knowledge (TPACK) for educators* (pp. 87-106). Routledge. https://doi.org/10.4324/9781315771328

Chen, Y., & Cao, L. (2022). Promoting maker-centred instruction through virtual professional development activities for K-12 teachers in low-income rural areas. *British Journal of Educational Technology*, *53*(4), 1025-1048. https://doi.org/10.1111/bjet.13183

Cheng, S. L., & Xie, K. (2018). The relations among teacher value beliefs, personal characteristics, and TPACK in intervention and non-intervention settings. *Teaching and Teacher Education*, *74*, 98–113. https://doi.org/10.1016/j.tate.2018.04.014

Ciriza-Mendívil, C., Lacambra, A., & Hernández de la Cruz, J. (2022). Technological pedagogical content knowledge: Implementation of a didactic proposal for preservice history teachers. *Frontiers in Education*, *7*, Artículo 852801. https://doi.org/10.3389/feduc.2022.852801

Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological Methods, 1*(1), 16–29. https://doi.org/10.1037/1082-989X.1.1.16

De las Cuevas, C., & González de Rivera, J. L. (1992). Autoinformes y respuestas sesgadas. *Anales de Psiquiatría*, *8*(9), 362–366.

Diamah, A., Rahmawati, Y., Paristiowati, M., Fitriani, E., Irwanto, I., Dobson, S., & Sevilla, D. (2022). Evaluating the effectiveness of TPACK-based training program in enhancing pre-service teachers' perceptions of TPACK. *Frontiers in Education*, *7*, 1-27. https://doi.org/10.3389/feduc.2022.897447

Fernández-Chávez, C., Domínguez-Ramírez, P., & Salcedo-Lagos, P. (2022). Validación de aplicación del modelo TPACK, asociado a las habilidades conciencia fonológica y conocimiento de letras para educadoras de parvularios. *Revista Electrónica Educare*, *26*(3), 1-20. https://doi.org/10.15359/ree.26-3.8

Fernández-Hernández, J. L., Herranz-Hernández, P., & Segovia-Torres, L. (2022). Validación cruzada sobre una misma muestra: una práctica sin fundamento. *R.E.M.A. Revista Electrónica de Metodología Aplicada*, *24*(1), 38-40. https://doi.org/10.17811/rema.24.1.2022.38-40

Frías-Navarro, D., & Pascual-Soler, M. (2022). *Lectura crítica y recomendaciones para redactar el informe de investigación*. Palmero Ediciones. https://doi.org/10.17605/osf.io/kngtp

Gebhardt, E., Thomson, S., Ainley, J., & Hillman, K. (2019). *Gender differences in computer and information literacy. An In-depth analysis of data from ICILS*. Springer. https://doi.org/10.1007/978-3-030-26203-7_1

Gisbert-Cervera, M., Usart, M., & Lázaro-Cantabrana, J. L. (2022). Training pre-service teachers to enhanced digital education. *European Journal of Teacher Education*, *45*(4), 532–547. https://doi.org/10.1080/02619768.2022.2098713

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal* *of Academy of Marketing Science*, *43(1)*, 115-135. https://doi.org/10.1007/s11747-014-0403-8

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1-55. http://dx.doi.org/10.1080/10705519909540118

Huang, J. L., & Wang, Z. (2021). Careless responding and insufficient effort responding. *Oxford Research Encyclopedia of Business and Management*. https://doi.org/10.1093/acrefore/9780190224851.013.303

Huang, K., Chen, Y., & Jang, S. (2020). TPACK in special education schools for SVI: A comparative study between Taiwanese and Chinese in-service teachers. *International Journal of Disability, Development and Education*, *69*(2), 435-450. https://doi.org/10.1080/1034912x.2020.1717450

Huang, X., Huang, L., & Lajoie, S. P. (2022). Exploring teachers' emotional experience in a TPACK development task. *Educational Technology Research and Development*, *70*(4), 1283–1303. https://doi.org/10.1007/s11423-022-10135-7

Ibrohim, I., Purwaningsih, E., Munzil, M., Hidayanto, E., Sudrajat, A., Saefi, M., & Hassan, Z. (2022). Possible links between Indonesian science teacher's TPACK perception and demographic factors: Self-reported survey. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(9), Artículo em2146. https://doi.org/10.29333/ejmste/12282

Ismaeel, D. A., & Al Mulhim, E. N. (2022). E-teaching internships and TPACK during the Covid-19 Crisis: The case of Saudi pre-service teachers. *International Journal of Instruction*, *15*(4), 147-166. https://doi.org/10.29333/iji.2022.1549a

Janssen, N., Knoef, M., & Lazonder, W. (2019) Technological and pedagogical support for pre-service teachers' lesson planning*. Technology, Pedagogy and Education, 28*(1), 115-128. https://doi.org/10.1080/1475939X.2019.1569554

Jiménez, M. J., & Cabero, J. (2021). Los conocimientos tecnológicos, pedagógicos y de contenidos del profesorado universitario andaluz sobre las TIC. Análisis desde el modelo TPACK. *Innoeduca. International Journal of Technology and Educational Innovation*, *7*(1), 4-18. https://doi.org/10.24310/innoeduca.2021.v7i1.11940

Joldanova, D., Tleuzhanova, G., Kitibayeva, A., Smanova, G., & Mirza, N. (2022). Formation of TPACK and acmeological competency of future teachers in foreign language education. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 10*(4), 935-954. https://doi.org/10.46328/ijemst.2717

Jöreskog, K. G., & Sörbom, D. (1993). *LISREL 8: Structural equation modeling with the SIMPLIS command language*. Lawrence Erlbaum Associates Publishers.

Kadioglu-Akbulut, C., Cetin-Dindar, A., Kucuk, S., & Acar-Sesen, B. (2020). Development and validation of the ICT-TPACK-science scale. *Journal of Science*

Education and Technology, 29(3), 355-368. https://doi.org/10.1007/s10956-020-09821-z

Kartal, B., & Çınar, C. (2022). Preservice mathematics teachers' TPACK development when they are teaching polygons with geogebra. *International Journal of Mathematical Education in Science and Technology*, 1-33. https://doi.org/10.1080/0020739x.2022.2052197

Koh, J. H. L., Chai, C. S., & Tsai, C. C. (2010). Examining the technological pedagogical content knowledge of Singapore pre-service teachers with a large-scale survey. *Journal of Computer Assisted Learning*, *26*(6), 563-573. https://doi.org/10.1111/j.1365-2729.2010.00372.x

Kulaksız, T., & Karaca, F. (2022). Elaboration of science teachers' technology-based lesson practices in terms of contextual factors influencing TPACK. *Research in Science & Technological Education*, 1-21. https://doi.org/10.1080/02635143.2022.2083598

Lachner, A., Fabian, A., Franke, U., Preiß, J., Jacob, L., Führer, C., Küchler, U., Paravicini, W., Randler, C., & Thomas, P. (2021). Fostering pre-service teachers' technological pedagogical content knowledge (TPACK): A quasi-experimental Field Study. *Computers & Education*, *174*, 104304. https://doi.org/10.1016/j.compedu.2021.104304

Leal, L., & Rojas, J. (2020). Percepciones de autoeficacia y conocimientos TPACK en profesores en formación. *Diversitas*, *16*(2). https://doi.org/10.15332/22563067.6295

Lee, S. W., & Lee, E. A. (2020). Teacher qualification matters: The association between cumulative teacher qualification and students' educational attainment. *International Journal of Educational Development, 77,* Artículo 102208. https://doi.org/10.1016/j.ijedudev.2020.102218

Lévy, J. P., & Varela, J. (2006). *Modelización con estructuras de covarianzas en ciencias sociales: Temas esenciales, avanzados y aportaciones especiales*. Netbiblo.

Liu, B. (2022). *Exploring secondary mathematics teachers' TPACK development and student-centred Beliefs* [Ponencia de congreso]. Proceedings of the 2022 8th International Conference on Humanities and Social Science Research (ICHSSR 2022), Congqing, China. https://doi.org/10.2991/assehr.k.220504.057

Long, T., Zhao, G., Li, X., Zhao, R., Xie, K., & Duan, Y. (2020). Exploring Chinese in-service primary teachers' Technological Pedagogical Content Knowledge (TPACK) for the use of thinking tools. *Asia Pacific Journal of Education*, *42*(2), 350-370. https://doi.org/10.1080/02188791.2020.1812514

Manokore, V., & Kuntz, J. (2022). TPACK tried and tested: Experiences of post-secondary educators during COVID-19 pandemic. *International Journal for the Scholarship of Teaching and Learning*, *16*(2), 1-13. https://doi.org/10.20429/ijsotl.2022.160214

Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. *Journal of Digital Learning in Teacher Education, 35*(2), 76-78. https://doi.org/10.1080/21532974.2019.1588611

Mishra, P., & Koehler, M. J. (2008). *Introducing technological pedagogical content knowledge*. [Ponencia de congreso]. Annual Meeting of the American Educational Research Association, Nueva York.

Morgan, A., Sibson, R., & Jackson, D. (2022). Digital demand and digital deficit: Conceptualising digital literacy and gauging proficiency among higher education students. *Journal of Higher Education Policy and Management*, *44*(3), 258–275. https://doi.org/10.1080/1360080x.2022.2030275

Napitupulu, E., & Sebayang, N. (2022). TPACK learning model design needs analysis for 21st century skills. *Journal of Positive School Psychology*, *6*(6), 9278-9284. https://cutt.ly/s85N45I

Nazari, N., Nafissi, Z., Estaji, M., Marandi, S. S., & Wang, S. (2019). Evaluating novice and experienced EFL teachers' perceived TPACK for their professional development. *Cogent Education, 6*(1), Artículo 1632010. https://doi.org/10.1080/2331186X.2019.1632010

Oda, K., Herman, T., & Hasan, A. (2020). Properties and impacts of TPACK-based GIS professional development for in-service teachers. *International Research in Geographical and Environmental Education, 29*(1), 40–54. https://doi.org/10.1080/10382046.2019.1657675

Ortega-Sánchez, D., & Gómez-Trigueros, I. M. (2020). MOOCs and NOOCs in the training of future geography and history teachers: A comparative cross-sectional study based on the TPACK model. *IEEE Access*, *8*, 4035–4042. https://doi.org/10.1109/access.2019.2963314

Ortiz-Colón, A., Ágreda Montoro, M., & Rodríguez Moreno, J. (2020). Autopercepción del profesorado de educación primaria en servicio desde el modelo TPACK. *Revista Electrónica Interuniversitaria de Formación del Profesorado*, *23*(2), 53-65. https://doi.org/10.6018/reifop.415641

Otzen, T., & Manterola, C. (2017). Técnicas de muestreo sobre una población a estudio. *International Journal of Morphology*, *35*(1), 227–232. https://doi.org/10.4067/s0717-95022017000100037

Pozas, M., & Letzel, V. (2021). "Do you think you Have what it takes?" – Exploring predictors of pre-service teachers' prospective ICT use. *Technology, Knowledge and Learning*. https://doi.org/10.1007/s10758-021-09551-0

Rens van de Schoot, P. l., & Hox, J. (2012). A checklist for testing measurement invariance. *European Journal of Developmental Psychology*, *9*(4), 486-492. https://doi.org/10.1080/17405629.2012.686740

Roussinos, D., & Jimoyiannis, A. (2019). Examining primary education teachers' perceptions of TPACK and the related educational context factors. *Journal of Research on Technology in Education*, *51*(4), 377-397. https://doi.org/10.1080/15391523.2019.1666323

Schmidt-Crawford, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 123-149. https://doi.org/10.1080/15391523.2009.10782544

Schmidt-Crawford, M., Brianza, E., & Petko, D. (2020). Developing a short assessment instrument for technological pedagogical content knowledge (TPACK.xs) and comparing the factor structure of an integrative and a transformative model. *Computers and Education, 157*, Article 103967. https://doi.org/10.1016/j.compedu.2020.103967

Schmidt-Crawford, M., Brianza, E., & Petko, D. (2021). Self-reported technological pedagogical content knowledge (TPACK) of pre-service teachers in relation to digital technology use in lesson plans. *Computers in Human Behavior, 115*, Article 106586. https://doi.org/10.1016/j.chb.2020.106586

Schumacker, R. E., & Lomax, R. G. (2015). *A beginner's guide to structural equation modeling*. Routledge. https://doi.org/10.4324/9781315749105

Sun, J., Ma, H., Zeng, Y., Han, D., & Jin, Y. (2022). Promoting the AI teaching competency of K-12 computer science teachers: A TPACK-based professional development approach. *Education and Information Technologies*. https://doi.org/10.1007/s10639-022-11256-5

Tan, J. S. H., & Chen, W. (2022). Spiral model of collaborative lesson design: A model to develop TPACK and TEL design competency in pre-service teachers. En A. Weinberger, W. Chen, D. Hernandez-Leo, & B. Chen (Eds.), *Proceedings of the 15th Computer-Supported Collaborative Learning: CSCL 2022* (pp. 91-98). International Society of the Learning Sciences.

Tondeur, J., Scherer, R., Siddiq, F., & Baran, E. (2019). Enhancing pre-service teachers' technological pedagogical content knowledge (TPACK): A mixed-method study. *Educational Technology Research and Development*, *68*(1), 319-343. https://doi.org/10.1007/s11423-019-09692-1

Wang, Y., Gu, X., & Liu, S. (2020). The investigation and analysis of pre-service teachers toward TPACK competencies. *Open Journal of Social Sciences*, *8*(12), 327-339. https://doi.org/10.4236/jss.2020.812027

Widyasari, F., Masykuri, M., Mahardiani, L., Saputro, S., & Yamtinah, S. (2022). Measuring the effect of subject-specific pedagogy on TPACK through Flipped learning in e-learning classroom. *International Journal of Instruction*, *15*(3), 1007-1030. https://doi.org/10.29333/iji.2022.15354a

Yanpar Yelken, T., Ergen, B., & Kanadli, S. (2019). A meta-analysis of research on technological pedagogical content knowledge by gender. *Contemporary Educational Technology*, *10*(4), 358-380. https://doi.org/10.30935/cet.634182

APPENDIX

TK (Technological Knowledge)

1. I know how to solve my own technical problems with technologies.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

2. I am able to learn to use any programme or technological tool easily.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

3. I keep up to date with new technologies.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

4. I have the technical skills I need to use technology in different contexts (personal, educational, administrative, etc.).

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

CK (Content Knowledge)

5. I have sufficient knowledge of the content I am going to teach in my future work as a teacher.

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither agree nor disagree
   - ☐ Agreed.
   - ☐ I fully agree

6. I consider that I have sufficient resources to search for, process, organise and understand the disciplinary content that I will teach in my future work as a teacher.

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither agree nor disagree
   - ☐ Agreed.
   - ☐ I fully agree

7. I have a variety of methods and strategies to improve my understanding of the content of the subjects I have to teach in my future work as a teacher.

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither agree nor disagree
   - ☐ Agreed.
   - ☐ I fully agree

8. I am able to reflect on the curriculum for the level of education I will be teaching as well as any other experienced colleague.

   - ☐ Strongly disagree
   - ☐ Disagree
   - ☐ Neither agree nor disagree
   - ☐ Agreed.
   - ☐ I fully agree

PK (Pedagogical Knowledge)

9. I know how to assess student learning in a classroom.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

10. I can adapt my teaching according to the needs of the learners in order to make them understand the content I want to teach them.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

11. I consider that I am able to adapt my teaching methodology to the diversity of a classroom.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

12. I am able to carry out an assessment of classroom learning in multiple ways.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

13. I am able to use a wide range of teaching methodologies and strategies in a classroom.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

14. I am familiar with the common misconceptions of learners.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

15. I know how to organise and maintain classroom management.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

PCK (Pedagogical Content Knowledge)

16. I am able to select effective teaching methodologies and strategies to guide student learning in the content areas I will teach as a future teacher.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

17. The training I have received has enabled me to help students to solve real-world problems related to the contents I will teach as a future teacher.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

18. The training I have received has enabled me to select appropriate assessment tools to assess students' learning performance.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

TCK (Technology Content Knowledge)

19. I am trained in those technologies that I can use in the classroom to make understandable those contents and procedures that I will teach to my future students.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

20. The training received has enabled me to use specific software tools for teaching.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

21. The training I have received and the courses I have participated in have taught me which technologies I can apply to the teaching of disciplinary content.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

TPK (Technological Pedagogical Knowledge)

22. I can choose technologies that enhance the focus and understanding of a lesson or content for learners.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

23. I am able to select those technological resources that will facilitate my task as a teacher to work on a specific topic or content in the classroom.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

24. My training as a teacher has led me to think more deeply about how technology can influence the processes and teaching methodologies I will use in my future classes.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

25. I reflect critically on how to use technology in my future work as a teacher.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

26. I am able to adapt the use of the technologies I am learning in my teacher training to different teaching activities.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

27. I am able to select technologies to use in my future work as a teacher, which improve learning and the way content is transmitted and taught to students.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

28. I am able to use classroom strategies that combine different content, technologies and methodologies, which I have learnt in my teacher training.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

29. I can provide leadership to help other colleagues coordinate good use of technologies combined with diverse classroom methodologies.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

30. I consider that technologies help teachers in their regular task in the classroom to teach contents and procedures.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

TPACK (Technological Pedagogy and Content Knowledge)

31. I am able to prepare teaching materials that appropriately combine content, technologies and diverse classroom methodologies or strategies.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree

32. The training I have received has enabled me to correctly combine the contents, technologies and methodologies to achieve the knowledge of a specific subject.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Neither agree nor disagree
- ☐ Agreed.
- ☐ I fully agree