Contemporary Educational Technology, 2023, **15**(3), ep439
ISSN: 1309-517X (Online)

OPEN ACCESS **Research Article**

TPACK model as a framework for in-service teacher training

Ana María Ortiz Colón [1]
0000-0003-0440-6107

Tomás Izquierdo Rus [2*]
0000-0003-0686-2747

Javier Rodríguez Moreno [1]
0000-0002-5890-3654

Miriam Agreda Montoro [1]
0000-0002-0940-6504

[1] Department of Pedagogy, University of Jaen, Jaen, SPAIN
[2] Department of Methods Research and Diagnosis in Education, University of Murcia, Murcia, SPAIN
[*] Corresponding author: tomasizq@um.es

Citation: Ortiz Colón, A. M., Izquierdo Rus, T., Rodríguez Moreno, J., & Agreda Montoro, M. (2023). TPACK model as a framework for in-service teacher training. *Contemporary Educational Technology, 15*(3), ep439. https://doi.org/10.30935/cedtech/13279

ARTICLE INFO

Received: 22 Oct 2022
Accepted: 7 Apr 2023

ABSTRACT

Research has proven that TPACK model can significantly contribute to teachers' training in their educational work, along with the training context, as well as to contribute to their initial training. The objective of this research is to analyze the level of teaching competence that teachers have according to TPACK model, as well as the variables that influence the technological implementation in the classroom. For the data analysis, we used a validated questionnaire composed by 47 items divided into the seven dimensions of TPACK model. We performed a stratified sampling by conglomerates in various stages, using public schools as a sampling unit. The sample is formed by 825 teachers. This is a descriptive and non-experimental investigation, where we performed a multivariate analysis of variance (MANOVA) test between the dimensions of the diagnosis scale and the socio-demographic variables. The most significant results have been the differences found regarding the educational stage and the age of the participants. It should be noted that the organization of the two stages, although based in the same principles and with common elements for the transition from one to another, is different. The study presents some adapted and focused training proposals in order to alleviate the training weaknesses of in-service teachers from TPACK model.

Keywords: TPACK, teacher training, primary education, child education, educational technology, lifelong learning

INTRODUCTION

For a long time, the use of technology in the educational field ceased to be a simple choice and, instead, became a reality. When including the digital competence as a key competence of the educational system, this requires adapting to the new educational challenges and to adjust to educational politics (Aguaded et al., 2015; Ortega & Gómez, 2019; Tirado et al., 2016).

In this line, many studies have been published on the incorporation and use of information and communication technologies (ICTs) in educational centers, as the creation of classrooms with technological resources requires a very specific structure (Fernández et al., 2018), but it does not mean a complete integration of technology unless there are teachers with a high digital competence (Hernández-Selles et al., 2023). To this end, it is necessary that teachers improve their digital competence and integrate ICTs in the teaching practice (Hannaway, 2019; Njiku, 2022).

Copyright © 2023 by authors; licensee CEDTECH by Bastas. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/).

In the current educational context, teachers are transforming the educational process through ICTs (Fathelrahman, 2019; Zhang et al., 2019) making a great effort and going beyond the use of simple instrumental skills (Cabero & Barroso, 2016; Cabero & Gimeno, 2019). In fact, the use of such technologies is transforming the management and implementation of teaching activities (Kwon et al., 2019; Shah & Cheng, 2019; Zhu et al., 2019). Therefore, it is necessary that teachers in service are able to value their training on ICTs according to TPACK model, in order to use technology in a pedagogical and effective way, as TPACK model facilitates the integration of digital media and tools in the teaching-learning process (Vaerenewyck et al., 2017).

The training of teachers is the aspect that makes the use of technology more difficult (Brinkley, 2020; Gómez et al., 2019); this is why teachers with effective instruction and literacy skills have a greater training level. This way, Chai et al. (2019) draw the attention on the training that the teachers received during their pre-service period, which becomes decisive for the ulterior use of ICTs during their teaching practice. In addition, if we analyze the training of teachers in service who develop the use of ICTs, it has a positive effect in TPACK levels. Some of the obstacles that appear before the integration are the skills and the knowledge of teachers regarding the use of technology (Paidican & Arredondo, 2022; Yildiz, 2019), as well as the instrumental nature of the teaching action, which is exclusively focused on the instrumental manipulation of technologies (Cabero & Gimeno, 2019). Under this conception, TPACK model was born (Mishra & Koehler, 2006), which is the combination of disciplinary and pedagogical knowledge that teachers should have, including ICTs as an additional element.

TPACK model revolves around three basic components that, in turn, generate four intersections between them, along with the training context, for the appropriate inclusion of ICTs in the classroom (Habibi et al., 2022; Senol, 2020; Tseng et al., 2016, 2019). TPACK model is a solid diagnostic framework for the digital teaching competence that teachers have according to the results of research carried out in this regard. Thus, the three areas of TPACK model, if properly integrated, will result in an improvement in teacher quality. There are many studies developed on this topic, which obtains favorable results in the application of TPACK model both in the training of teachers in service and in the initial training of teachers (García Aretio, 2020; Izgi-Onbasili et al., 2022).

In the beginning, the investigations developed were of generalist nature on the use of ICTs, finding differences between the different levels of knowledge (Castillejos et al., 2014; Max et al., 2022). In this line, stand out the studies developed on the initial training of teachers (Kadioglu et al., 2023; Valtonen et al., 2018) and on different educational levels and disciplinary contexts (Hsu et al., 2017). Yang et al. (2019) carried out a study with teachers in service in levels K-12 taking TPACK as a reference.

In this study, we intend to examine the application of TPACK model in early childhood education and primary education, and, to that end, it is necessary to establish beforehand the self-perceptions that teachers in these educational stages have regarding the knowledge stated in TPACK model. The general objective of the study is to analyze of knowledge that teachers have according to TPACK model, considering the variables: educational stage; location province; and age of teachers. Those self-perceptions will serve as a guide to answer the following questions:

1. Is it possible to identify any differences in the training of teachers in-service regarding the different types of knowledge according to TPACK model?
2. Are there any differences in the training of teachers in-service on ICTs in early childhood education and primary education regarding TPACK model?
3. Are there any differences in the profile of early childhood education and primary education teachers in-service in the dimensions of TPACK model?

MATERIALS AND METHODS

For the data gathering, a questionnaire method has been used, with an instrument designed by Schmidt et al. (2012), adapted and translated by Cabero (2014), having received the permission to use the instrument for the diagnosis of TPACK model. This is a non-experimental investigation of descriptive nature. The population is composed by teachers at the public schools of early childhood education and primary education of the Region of Andalusia (Spain), with n=49,495. We carried out a stratified sampling by conglomerates, using public schools as a sampling unit (1,751 schools of early childhood education and primary education). The strata were defined according to age, educational stage and geographic area, where teachers carry out their teaching practice. The sample is composed by 825 teachers in service.

The data were analyzed using SPSS statistical program (v. 24 for Mac). We performed an analysis to collect the main statistical measures; and, in order to determine the existence of statistically significant differences between the self-perception of teachers regarding their training from TPACK model, it has been made a multivariate analysis of variance (MANOVA) based on the general linear model and considering the variables of age, province and educational stage. Kolmorogov-Smirnov and Levene contrast tests were used to verify the assumptions of normality and homoscedasticity.

Instrument

Questionnaire is composed by 47 items, divided in the seven dimensions, where TPACK model lays.

1. Technological knowledge (TK) with seven items.
2. Content knowledge (CK) with 12 items, divided between CK in science (CK-S: three items), CK in reading and writing (CK-RW: three items), CK in mathematics (CK-Mat: three items), and CK in social sciences (CK-Soc: three items).
3. Pedagogical knowledge (PK: seven items).
4. Pedagogical content knowledge (PCK: seven items).
5. Technological content knowledge (TCK: four items).
6. Technological pedagogical knowledge (TPK: five items).
7. Technological pedagogical content knowledge (TPACK: eight items).

The reliability of the questionnaire, obtained on the basis of the calculation of Cronbach's alpha, is .955, which indicates a strong internal consistency. Regarding the dimensions, the following values were obtained: CK=.884; PK=.90; PCK=.822; TCK=.883; TPK=.844, and TPACK=.916.

Participants

The sample comprises 825 teachers of early childhood education and primary education from public schools. According to gender, 57.8% of the sample are women and the 42.2% are men. Most of the teachers are in the age range of 50-59 years old (33.9%), followed by teachers between 40-49 years old (31%), and a 26.7% who have between 31 and 39 years old. Teachers aged 60 and older, represent the 3.3% and those with 30 or under, represent a 5.1%. Regarding educational stage, where they develop their professional practice, teachers of primary education represent a 62.1%, and teachers of early childhood education a 37.9%.

RESULTS

It can be observed how the perception of the teachers regarding PK is the most positive one of the seven dimensions ($\bar{x}_{PK} = 4.11, \mathrm{SD} = .481$). In addition, the positive constant remains regarding TPK ($\bar{x}_{TPK} = 3.85, \mathrm{SD} = .581$), where the value close to four indicates a perception relatively positive of teachers regarding the technology potential within the educational context. Nevertheless, this does not indicate a successful development of the educational work of the teachers in service through TPACK model, as shown by the low scores in some of the dimensions, like TK ($\bar{x}_{TK} = 3.44, \mathrm{SD} = .746$), something that draws special attention, since it follows that people interact with technology in multiple contexts and yet teachers perceive that their TK is not as extensive as it should be (**Table 1**).

Regarding TK dimension, teachers perceive that the opportunities to work with different technologies were not many ($\bar{x} = 3.18$). Teachers also state that they do not know much about the variety of technologies that exist today ($\bar{x} = 3.28$), which can be due to the subject's disciplinary content itself. In fact, in TCK dimension it can be observed how the knowledge on technologies focused to understand and develop reading and writing content is much higher in mathematics or social sciences ($\bar{x}_{TCK-RW} = 3.70 \geq \bar{x}_{TCK-Soc} = 3.46 \geq \bar{x}_{TCK-Mat} = 3.42$). Regarding TPK dimension, teachers perceive themselves positively to adapt the use of the technology to teaching activities ($\bar{x} = 4.01$), but trend changes when that use refers to teaching lessons ($\bar{x} = 3.64$).

Table 1. Means & standard deviations (SDs) of most representative items of technological dimensions of TPACK model*

Dimension	Items	Mean	SD	SEM
TK	I have had enough opportunities to work with different technologies	3.18	1.044	.042
	I know many different technologies	3.28	1.037	.039
	I often play and test with technology	3.44	1.037	.042
	I assimilate technological knowledge easily	4.00	.789	.025
TCK	I know technologies that I can use to understand and elaborate mathematical content	3.42	.863	.035
	I know technologies that I can use to understand & elaborated reading & writing content	3.70	.811	.033
	I know technologies that I can use to understand & elaborated reading & writing content	3.46	.813	.033
TPK	I know how to select technologies that improve teaching approaches for lessons	3.64	.797	.032
	I can adapt the use of technologies to different teaching activities	3.94	.734	.030
	I assume critical thinking about how to use technology in the classroom	3.97	.648	.026
	My training as a teacher has made me reflect more carefully on how technology can influence the teaching approaches, I use in the classroom	4.01	.737	.030
TPACK	I can guide & help others coordinate use of technology & teaching approach in school	3.43	.955	.039
	I can use in my classroom teaching materials that combine content, technologies and teaching approaches that I have learned about	3.88	.684	.028
	I know how to select technologies to use in the classroom that improve the content I teach, the way I teach it and what the students learn	3.80	.721	.029
	I can adapt the use of technologies to different teaching activities	4.01	.727	.030

Note. *For choice of most representative items, criterion of selecting those with a value greater than 3 has been followed

Table 2. Multivariate analysis of intersection*age, intersection*province, & intersection*educational stage

Multivariate analysis	F	p	η_p^2	1-β
Intersection*age (λ Wilks'=.945; p-value=.195; η_p^2=.014; & 1-β=.912)				
Technological knowledge (TK)	1.565	.182	.010	.485
Content knowledge (CK)	2.978	.039*	.020	.800
Pedagogical knowledge (PK)	.931	.446	.006	.297
Pedagogical content knowledge (PCK)	1.925	.105	.013	.582
Technological content knowledge (TCK)	.480	.750	.003	.165
Technological pedagogical knowledge (TPK)	.912	.456	.006	.291
Technological pedagogical content knowledge (TPACK)	.822	.512	.005	.264
Technological knowledge (TK)	1.565	.182	.010	.485
Intersection*province (λ Wilks'=.899; p-value=.079; η_p^2=.015; & 1-β=.965)				
Technological knowledge (TK)	2.003	.056	.023	.783
Content knowledge (CK)	1.671	.113	.019	.691
Pedagogical knowledge (PK)	1.449	.183	.017	.616
Pedagogical content knowledge (PCK)	.924	.488	.011	.403
Technological content knowledge (TCK)	1.602	.132	.018	.669
Technological pedagogical knowledge (TPK)	2.129	.051	.024	.789
Technological pedagogical content knowledge (TPACK)	2.008	.052	.023	.784
Technological knowledge (TK)	2.003	.056	.023	.783
Intersection*education stage (λ Wilks'=.841; p-value=.004*; η_p^2=.61*; & 1-β=1.000)				
Technological knowledge (TK)	8.381	.004*	.610**	1.000
Content knowledge (CK)	2.477	.116	.000	.824
Pedagogical knowledge (PK)	.099	.753	.000	.762
Pedagogical content knowledge (PCK)	.250	.617	.000	.690
Technological content knowledge (TCK)	3.152	.014*	.021	.821
Technological pedagogical knowledge (TPK)	2.637	105	.004	.368
Technological pedagogical content knowledge (TPACK)	8.481	.002*	.030	.978
Technological knowledge (TK)	8.381	.004*	.610**	1.000

Note. *p≤.05 & **Medium effect size (η_p^2=.060-.139).

Multivariate Analysis

MANOVA allows to select two or more dependent variables simultaneously assuming the correlation between variables and if these are significant, avoiding type I errors. MANOVA test is more potent when the samples are relatively extensive. Therefore, meeting the necessary principles to perform parametric tests and with a sample extensive enough, the multivariate analysis of variance has been used with the variables of age, province and educational stage (Table 2).

Table 3. Inter-subject effect tests, univariate F, & significance of teachers' self-perception of CK

Dimension	Items	F	p	η_p^2	1-β
CK	I have enough knowledge about mathematics (CK-Mat)	2.875	.022*	.020	.780
	I have different methods & strategies to develop my knowledge about mathematics (CK-Mat)	2.813	.025*	.020	.770
	I know how to apply a scientific way of thinking (CK-S)	2.836	.050*	.015	.765
	I know how to apply a literary way of thinking (CK-RW)	2.596	.035*	.017	.731

Note. Only the most statistically significant differences are shown: *p≤.05

Table 4. Post-hoc test for multiple comparisons (Tukey's test)

Items	Age (I)	Age (J)	Mean	MD (I-J)	p
I have enough knowledge about mathematics	≥ 60 ($\bar{x} = 4.10$)	≤ 30	3.45	.65	.008*
		31-39	3.56	.54	.007*
		40-49	3.74	.36	.070
		50-59	3.70	.40	.045*
I have different methods & strategies to develop my knowledge about mathematics	≥ 60 ($\bar{x} = 4.00$)	≤ 30	3.32	.68	.004*
		31-39	3.50	.51	.009*
		40-49	3.64	.36	.064
		50-59	3.60	.40	.040
I know how to apply a scientific way of thinking)	≥ 60 ($\bar{x} = 4.05$)	≤ 30	3.64	.40	.060
		31-39	3.55	.50	.005*
		40-49	3.62	.43	.014*
		50-59	3.70	.36	.040*
I know how to apply a literary way of thinking	≤ 30 ($\bar{x} = 4.03$)	31-39	3.70	-.33	.025*
		40-49	3.69	.24	.021*
		50-59	3.86	.17	.250
		≥ 60	3.80	.23	.286

Note. MD: Mean differences; Statistically significant differences are shown; & *p≤.05

The multivariate test will be performed with every one of the items of this dimension, as well as post-hoc tests like Tukey's, adjusting the confidence interval between the means with Bonferroni, in order to know such inter-group differences. The most significant results appeared in the intersection with the educational stage variable. To delve into these differences, being a dichotomic variable, we followed the same procedure, comparing the main effects with Bonferroni.

*Multivariate results of intersection*age*

Inter-subject effect tests (**Table 3**) show statistically significant differences between the age variable and four of the twelve items of CK dimension, two of them belong to CK-Mat dimension ($F_{2.875}$, p=.022; $F_{2.813}$, p=.025); and other two are part of the sub-dimensions CK-S and CK-RW. After verifying the dependency ratio between variables, the results of the inter-group multiple comparisons are shown through Tukey's post-hoc test (**Table 3**).

Regarding the results of the inter-group multiple comparisons (**Table 4**), we observe how in the three first items analyzed, teachers over 60 years old claim to have a more positive self-perception about having enough knowledge on mathematics ($\bar{x} = 4.10$), as well as having a diversity of methods and strategies to develop their knowledge about mathematics ($\bar{x} = 4.00$) and knowing how to apply a scientific way of thinking ($\bar{x} = 4.05$). Regarding the first item, the differences between teachers over 60 and under 30 stand out with more than half a point in the mean difference (p=.008), much like it happens with teachers between 31 and 39 years old (p=.007), the difference of means with the age group of 50 to 59 years old is lower, but there are inter-group differences as well (p=.045).

In the second item, the perception about having multiple methods and strategies to develop knowledge on mathematics, teachers over 60 only show differences with younger age groups, finding the greater mean difference with teachers under 30, reaching almost 0.7 points (p=.004), surpassing the half a point with the age group of 31 to 39 years old (p=.009).

Regarding the third item, it is noteworthy that teachers with 60 years old or more do not present differences with teachers younger than 30, but they do with the rest of the age groups, being the higher mean difference with teachers from 31 to 39 and 40 to 49 years old ($p_{31\text{-}39}$=.005; $p_{40\text{-}49}$=.014). Lastly, regarding the

Table 5. Inter-subject effect tests, univariate F, & significance of teachers' self-perception of TK

Dimension	Items	F	p	η_p^2	1-β
TK	I usually play or test with technology	10.539	.001*	.020	.900
	I know a lot of different technologies	9.639	.002*	.016	.873
	I have all the technical knowledge that I need to use the technology	6.228	.013*	.010	.803
TCK	I know technologies that I can use to understand & elaborate content about sciences	7.523	.006*	.015	.882
	I know technologies that I can use to understand & elaborate content about social studies	5.321	.021*	.010	.802
TPACK	I can guide and help others to coordinate the use of technologies and teaching approaches in my center	4.500	.034*	.010	.800

Note. Only the most statistically significant differences are shown: *p≤.05

knowledge on how to apply a literary way of thinking, teachers under 30 are the ones with a greater confidence in themselves and with a positive self-perception ($\bar{x} = 4.03$), presenting differences with teachers from 31 to 39 (p=.025), and from 40 to 49 years old (p=.021).

These results indicate that the experience is important regarding CK and its evolution from the teaching practice. Everything seems to indicate that as more experience is gained in the classroom, and therefore over the years, teachers are more decisive when applying multiple methods and strategies to teach the content of the subject.

Multivariate results of the intersection*educational stage

Table 5 shows the inter-subject test between the educational stage variable and the items referring to TK, TCK, and TPACK dimensions, establishing a dependency ratio with them. With respect to TK dimension, there are statistical differences regarding the frequency of the experience with technologies ($F_{10.539}$, p=.001), the knowledge on the multiplicity of existent technology ($F_{9.639}$, p=.002) and having enough knowledge at a theoretical level to use the technology ($F_{6.228}$, p= .013). If we pay attention to TCK dimension, where the content of the disciplines and the technology already intervenes, it can be observed that the differences in the self-perception of teachers, according to the stages, happen when referring to sciences ($F_{7.523}$, p=.006) and social sciences ($F_{5.321}$, p=.021), and both items are about the comprehension and elaboration of contents for the subjects.

Table 6 shows the results obtained according to the pairing comparison test with Bonferroni correction for the educational stage variable. In the items belonging to the TK dimensions, we can observe that the incidence among the differences of the means is much higher compared with the rest. Primary education teachers are the ones who experiment more with technology, and they also claim to have more knowledge on this. Regarding the knowledge on different technologies the previous trend is followed, being early childhood education teachers those who seem to have a lesser knowledge.

Early childhood education teachers have a more positive perception regarding TCK dimension, regarding the knowledge they have on the proper technologies for the comprehension and elaboration about sciences ($\bar{x} = 3.41$); in the rest of the items the scores are lower. Focusing on primary education teachers, in TPCK dimension, they stand out regarding the knowledge on technologies that they can use for the comprehension of contents about sciences ($\bar{x} = 3.60$) and social sciences ($\bar{x} = 3.52$).

It should be noted that the organization of the two stages, although based in the same principles and with common elements for the transition from one to another, is different. Early childhood education is structured around areas for the development of abilities, while primary education is organized in areas addressed to the acquisition of competences, therefore, training is constructed around subjects that are transversely related. On the contrary, in the early childhood education stage the work is done in a global manner.

DISCUSSION

The general results of the study show a positive trend regarding PK, PCK, and TPK dimensions, but, on the contrary, the dimension in which teachers seems to have the least mastery is that of TK. Teachers consider themselves self-effective regarding the mastery of content, both on the specific content of the disciplines they teach, or on PK for the development of the teaching-learning process. These results partially match with the

Table 6. Pairing comparison test with Bonferroni correction

Dimension	Items	Stage (I)	Mean	Stage (J)	Mean	MD (I-J)	p
TK	I usually play or test with technology	ECE	3.27	PE	3.41	-.280	.001
	I know a lot of different technologies	ECE	3.13	PE	3.37	-.245	.002
	I have all technical knowledge that I need to use technology	ECE	3.33	PE	3.53	-.197	.013
TCK	I know technologies that I can use to understand and elaborate content about sciences	ECE	3.41	PE	3.60	-.191	.006
	I know technologies that I can use to understand and elaborate content about social studies	ECE	3.36	PE	3.52	-.156	.021
TPACK	I can guide and help others to coordinate the use of technologies and teaching approaches in my center	ECE	3.32	PE	3.50	-.18	.034

Note. ECE: Early childhood education; MD: Mean differences; PE: Primary education; & Only most statistically significant differences are shown: *p≤.05

ones obtained by Chen and Jang (2018) and Nilsson (2022), in their studies, concluded that teachers in service have a higher self-perception regarding TPK and CK dimensions, being the self-efficacy lower in TK and TPACK dimensions.

In a different vein, teachers perceive that their basic training allows to value and reflect on how the technology affects the teaching approaches and how to integrate it in the classroom (TPK), this dimension could be determining to know how teachers make decisions regarding the use of technology in the classroom (Sofyan et al., 2023; Yeh et al., 2017). In this sense, Taimalu and Luik (2019) and Tondeur et al. (2016) relate this fact with a constructivist pedagogical perspective, where the teachers who had this approach were the ones who obtained positive results regarding TPK dimension. Also, variables like motivation and confidence also affect CK and TCK dimensions in particular (Kong et al., 2020).

In addition, after the multivariate analysis, it was proved that, in general, the age of teachers does not seem to have any influence on TPACK model, and those results were partially similar to those of other studies (Silva & Morrás, 2019; Yang et al., 2019**)**. However, after observing the univariate results it was proved that there was in fact a relation between this variable and CK dimension, where senior teachers presented a higher confidence regarding the mastery of the content in mathematics and sciences (Backfish et al., 2020), defend the idea that this is because, historically, the disciplines that were rooted in sciences and mathematics had a clearer connection with technology (Kulaksiz & Karaca, 2022). However, younger teachers present a better knowledge on CK-RW dimension. In this respect, Alabbasi (2018) developed research, which confirmed that the storytelling, mediated by technology, allowed to increase the efficacy of teachers in this sub-dimension specifically, but also in the rest of dimensions.

Lastly, regarding the incidence of the educational stage, where teachers develop their teaching practice, it is observed a relation with TK, TCK, and TPACK dimensions, where primary education in-service teachers achieve better results, especially regarding TK, and so they tend to have a higher confidence. It must be considered that primary education teachers organize their teaching practice by disciplinary areas, while early childhood education teachers organize it in a more global way for the development of abilities, therefore, Primary education teachers need to generate a greater integration between the content knowledge and the technology (TCK) (Jung et al., 2019; Kong et al., 2022).

New investigations advocate for the inclusion of another dimension in TPACK model, in order to address the requests of the knowledge society (Kali et al., 2019; Lai et al., 2022) advocate for a re-conceptualization of the model, integrating the space/context as a dimension, promote the AI teaching competence (Celik, 2023; Sun et al., 2022) and incorporating student participation as a key element in the pedagogical development of teachers (Karlsson & Nilsson, 2023; Zhou et al., 2023).

CONCLUSIONS

This study analyzed the self-perception of early childhood education and primary education teachers in service regarding their technological training from the model's point of view. This kind of studies are fewer in number than the ones developed with teachers under training. The results allow us to explore the reality of the educational practice of teachers on a daily basis, as well as detecting the weak points in their training through TPACK model. Then the main findings, based on research questions addressed are summarized.

1. Is it possible to identify any differences in the training of teachers regarding the different types of knowledge according to TPACK model?

In a previous analysis, it has been observed that the dimension of TPACK model, where teachers are perceived with a higher level of competence has been that related to PK. Therefore, teachers claim to be more trained in the set of pedagogical and didactic knowledge, the core of their training process. Similarly, this trend remains, albeit with a slightly lower score, compared to TPK dimension.

However, if we move to the dimensions including knowledge and use of technology at a higher level, the perception of teachers begins to decline. That is the case of TK dimension, where the lowest scores are obtained. It must be borne in mind that the evolution of technology does not stop; it grows exponentially and there is a great diversity of tools and resources, so it is complicated to be able to access all the available technology. It is significant that teachers perceive that they have not had significant opportunities to work with different technologies, as well as to have extensive knowledge about them. However, they do perceive an ease in acquiring knowledge about them.

2. Are there any differences in the training of teachers on ICTs in early childhood education and primary education regarding TPACK model?

These differences have been found in TK, TCK, and TPACK dimensions. Significantly, primary education teachers have carried out a high degree of experimentation with technology, possess greater technical knowledge about it, and seem to know more about its diversity. On the one hand, early childhood education is structured under the imprint of a global training focused on the development of student capacities, where knowledge is organized in three main areas, such as autonomy, knowledge of oneself and of the environment, and language. On the other hand, primary education focuses on a structure based on competency education, where knowledge is structured in various areas that are normally integrated into subjects with their own entity.

3. Are there any differences in the profile of early childhood education and primary education teachers in-service in the dimensions of TPACK model?

Regarding whether the sociodemographic variables have an influence on the dimensions of TPACK model in teachers, no relationship of dependency has been found with respect to the province, where all the teachers carry out their professional work, so there is a similarity in all the geographical areas of the region. However, age seems to be an influential variable in teachers' knowledge based on TPACK model. It is regarding CK dimension, where the clear influence of the age variable is seen, as teachers who are 60 years old or older are those who have a greater knowledge of mathematics, as well as the ability to use various methods and strategies for the development of their mathematical knowledge. Something similar occurs with the ability to apply scientific modes of thought. It may be argued that the experience becomes a component of great importance and in constant evolution from the teaching practice. These results indicate that, as more experience is achieved in classrooms and, therefore, there is an increase in age, teachers increase their ability to solve problems, as well as their creativity in applying different strategies and methods in the classroom, all aimed at teaching content in their classes.

Main Contributions

This study is part of a larger investigation developed through a research project that aims to determine the degree of digital competence of teachers in public schools in the region, using TPACK model as a frame of reference. The main contributions provided by this investigation refer to the differences established regarding the educational stage, where teachers are ascribed, as well as their age, which enables the educational administration to develop training proposals focused and adapted to alleviate the weaknesses of teachers.

Concluding, the study presents certain limitations to be considered. Firstly, the investigation was carried out only with teachers in service of the region of Andalusia, so they might not be generalizable to other regions or countries, due to the particular characteristics of this one. On the other hand, our analysis is based on an instrument that evaluates the self-perception of teachers, so there might be biases in the answers regarding the real technological integration from TPACK model. Adopting qualitative methodologies, like interviews and discussion groups in future works, the results of this study could be strengthened.

Author contributions: AMOC: project administration; **AMOC & JRM:** conceptualization & investigation; **TIR & MAM:** software & data analysis; **JRM & MAM:** methodology. All authors approved the final version of the article.

Funding: This article has received support from the IEG research project entitled "Digital competence in primary education students in the province of Jaén" (2019/5904) and from the Innovation and teaching improvement project of the University of Jaén entitled "Creation of an educational learning community on project-based learning mediated by ICT" (PIMED28 201921).

Ethics declaration: The authors declared that this research has been carried out in accordance with a good code of ethics. The research instrument was aimed at persons of legal age. All participants gave their voluntary consent to be a part of the investigation. Informed consents were obtained from the participants. Authors declared that they informed the participants that their anonymity and confidentiality would be guaranteed, and that the data obtained would be used for scientific purposes, in addition to the promised absence of any variables that could lead to the identification of the participant.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the corresponding author on request.

REFERENCES

Aguaded, I., Tirado, R., & Hernando, A. (2015). Media competence in adult citizens in Andalusia, Spain. *Information, Communication & Society, 18*, 659-679. https://doi.org/10.1080/1369118X.2014.985244

Alabbasi, D. (2018). The design and application of a digital storytelling process model to enhance teachers' understanding of TPACK and foster positive attitudes toward teaching with technologies. *International Journal of Technology Enhanced Learning, 10*, 309-328. https://doi.org/10.1504/IJTEL.2018.095142

Backfish, I., Lachner, A., Hische, C., & Scheiter, K. (2020). Professional knowledge or motivation? Investigating the role of teachers' expertise on the quality of technology enhanced lessons plans. *Learning and Instruction, 64*, 101300. https://doi.org/10.1016/j.learninstruc.2019.101300

Brinkley, K. E. (2020). The effects of training on instructor beliefs about and attitudes toward online teaching. *American Journal of Distance Education, 34*, 19-35. https://doi.org/10.1080/08923647.2020.1692553

Cabero, J. (2014). *La formación del profesorado en TIC: Modelo TPACK. Conocimiento tecnológico pedagógico y de contenido* [*ICT teacher training: TPACK model. Pedagogical and content technological knowledge*]. Secretariado de Recursos Audiovisuales y Nuevas Tecnologías [Secretariat of Audiovisual Resources and New Technologies].

Cabero, J., & Barroso, J. (2016). ICT teacher training: A view of TPACK model/Formación del profesorado en TIC: Una visión del modelo TPACK. *Cultura y Educación* [*Culture and Education*]*, 28*, 633-663. https://doi.org/10.1080/11356405.2016.1203526

Cabero, J., & Gimeno, A. M. (2019). Information and communication technologies and initial teacher training. Digital models and competences. *Profesorado-Revista de Currículum y Formación del Profesorado* [*Faculty-Curriculum and Teacher Training Magazine*]*, 23*, 247-268. https://doi.org/10.30827/profesorado.v23i3.9421

Castillejos, B., Arturo, C., & Lagunes, A. (2014). El enfoque del conocimiento tecnológico pedagógico del contenido (TPACK): Revisión del modelo [The technological pedagogical content knowledge (TPACK) approach: Model review]. In *Los modelos tecno-educativos, revolucionando el aprendizaje del siglo XXI* [*Techno-educational models, revolutionizing 21st century learning*].

Celik, I. (2023). Towards Intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. *Computers in Human Behavior, 138*, 107468. https://doi.org/10.1016/j.chb.2022.107468

Chai, C. S., Koh, J. H. L., & Teo, Y. H. (2019). Enhancing and modeling teachers' design beliefs and efficacy of technological pedagogical content knowledge for 21st century quality learning. *Journal of Educational Computing Research, 57*, 360-384. https://doi.org/10.1177/0735633117752453

Chen, Y. H., & Jang, S. J. (2019). Exploring the relationship between self-regulation and TPACK of Taiwanese secondary in-service teachers. *Journal of Educational Computing Research, 57*, 978-1002. https://doi.org/10.1177/0735633118769442

Fathelrahman, A. (2019). Using reflection to improve distance learning course delivery: A case study of teaching a management information systems course. *Open Learning: The Journal of Open, Distance and E-Learning, 34*, 176-186. https://doi.org/10.1080/02680513.2018.1508338

Fernández, F. J., Fernández, M. J., & Rodríguez, J. M. (2018). The integration process and pedagogical use of ICTs in Madrid schools. *Educación XX1* [*Education XX1*]*, 21*, 395-416. https://doi.org/10.5944/educXX1.17907

García Aretio, L. (2020). Teacher knowledge and skills in digital and distance education. A reflection for training. *Revista Iberoamericana de Educación a Distancia* [*Ibero-American Journal of Distance Education*]*, 23*, 9-30. https://doi.org/10.5944/ried.23.2.26540

Gómez, I. M., Ruiz, M., & Ortega, D. (2019). Digital literacy of teachers in training: Moving from ICTs (information and communication technologies) to LKTs (learning and knowledge technologies). *Education Sciences, 9*, 1-10. https://doi.org/10.3390/edusci9040274

Habibi, A., Razak, R. A., Yusop, F. D., Muhaimin, M., Asrial, A., Mukminin, A., & Jamila, A. (2022). Exploring the factors affecting pre-service science teachers' actual use of technology during teaching practice. *South African Journal of Education, 42*(1), 1-11. https://doi.org/10.15700/saje.v42n1a1955

Hannaway, D. (2019). Mind the gaps: Professions perspectives of technology-based teaching and learning in the foundation phase. *South African Journal of Childhood Education, 9*, 1-10. https://doi.org/10.4102/sajce.v9i1.674

Hernández-Selles, N., Muñoz-Carril, P. C., & González-Sanmamed, M. (2023). Higher education teacher's roles in collaborative learning processes in virtual environments. *Revista Iberoamericana de Educación a Distancia* [*Ibero-American Journal of Distance Education*]*, 26*(1), 39-58. https://doi.org/10.5944/ried.26.1.34031

Hsu, C. Y., Tsai, M. J., Chang, Y. H., & Liang, J. C. (2017). Surveying in-service teachers' beliefs about game-based learning and perceptions of technological pedagogical and content knowledge of games. *Journal of Educational Technology & Society, 20,* 134-143.

Izgi-Onbasili, U., Avsar-Tuncay, A., Sezginsoy-Seker, B., & Kiray, S. A. (2022). An examination of preservice teachers' experiences in creating a scientific digital story in the context of their self confidence in technological pedagogical content knowledge. *Journal of Baltic Science Education, 21*(2), 207-223. https://doi.org/10.33225/jbse/22.21.207

Jung, Y. J., Cho, K., & Shing, W. S. (2019). Revisiting critical factors on teachers' technology integration: The differences between elementary and secondary teachers. *Asia Pacific Journal of Education, 39*, 548-561. https://doi.org/10.1080/02188791.2019.1620683

Kadioglu, C., Cetin, A., Acar, B., & Kucuk, S. (2023). Predicting preservice science teachers' TPACK through ICT usage. *Education and Information Technologies*. https://doi.org/10.1007/s10639-023-11657-0

Kali, Y., Sagy, O., Benichou, M., Atias, O., & Levin, R. (2019). Teaching expertise reconsidered: The technology, pedagogy, content and space (TPeCS) knowledge framework. *British Journal of Educational Technology, 50*, 2162-2177. https://doi.org/10.1111/bjet.12847

Karlsson, G., & Nilsson, P. (2023). Capturing student teachers' TPACK by using T-CoRe and video-annotation as self-reflective tools for flexible learning in teacher education. *Technology, Pedagogy and Education, 32*(2), 223-237. https://doi.org/10.1080/1475939X.2023.2170455

Koehler, M., Shin, T. S., & Mishra, P. (2012). How do we measure TPACK: Let me count the ways. In R. Ronau, R. Rakes, & M. Niess (Eds.), *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 16-31). IGI Global. https://doi.org/10.4018/978-1-60960-750-0.ch002

Kong, S. C., Lai, M., & Li, Y. (2023). Scaling up a teacher development program for sustainable computational thinking education: TPACK surveys, concept tests and primary school visits. *Computers & Education, 194*, 104707. https://doi.org/10.1016/j.compedu.2022.104707

Kong, S. C., Lai, M., & Sun, D. (2020). Teacher development in computational thinking: Design and learning outcomes of programming concepts, practices and pedagogy. *Computers & Education, 151,* 1-19. https://doi.org/10.1016/j.compedu.2020.103872

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

Kwon, K., Park, S. J., Shin, S., & Chang, C. Y. (2019). Effects of different types of instructor comments in online discussions. *Distance Education, 40*, 226-242. https://doi.org/10.1080/01587919.2019.1602469

Lai, C., Wang, Q., & Huang, X. (2022). The differential interplay of TPACK, teacher beliefs, school culture and professional development with the nature of in-service EFL teachers' technology adoption. *British Journal of Educational Technology, 53*(5), 1389-1411. https://doi.org/10.1111/bjet.13200

Max, A. L., Lukas, S., & Weitzel, H. (2022). The relationship between self-assessment and performance in learning TPACK: Are self-assessments a good way to support preservice teachers' learning? *Journal of Computer Assisted Learning, 38*(4), 1160-1172. https://doi.org/10.1111/jcal.12674

Mishra, P., & Koehler, J. (2006). Technological pedagogical content knowledge: A new framework for teacher knowledge. *Teachers College Record, 108*, 1017-1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Nilsson, P. (2022). From PCK to TPACK-supporting student teachers' reflections and use of digital technologies in science teaching. *Research in Science & Technological Education*. https://doi.org/10.1080/02635143.2022.2131759

Njiku, J. (2022). Attitude and technological pedagogical and content knowledge: The reciprocal predictors? *Journal of Research on Technology in Education*. https://doi.org/10.1080/15391523.2022.2089409

Ortega, D., & Gómez, I.M. (2019). Didactics of historical-cultural heritage QR codes and TPACK model: An analytic revision of three classroom experiences in Spanish higher education contexts. *Education Sciences, 9*, 117. https://doi.org/10.3390/educsci9020117

Paidican, M. A., & Arredondo, P. A. (2022). The technological-pedagogical knowledge for in-service teachers in primary education: A systematic literature review. *Contemporary Educational Technology, 14*(3), 370. https://doi.org/10.30935/cedtech/11813

Schmidt, D., Baran, E., Thompson, A., Mishra, P., Koehler, M., & Shin, T. (2012). Technological pedagogical content knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers*. Journal of Research on Technology in Education, 42,* 123-149. https://doi.org/10.1080/15391523.2009.10782544

Senol, S. (2020). Modelling the relations between Turkish chemistry teachers' sense of efficacy and technological pedagogical content knowledge in context. *Interactive Learning Environments, 30*(7), 1215-1228. https://doi.org/10.1080/10494820.2020.1712430

Shah, M., & Cheng, M. (2019). Exploring factors impacting student engagement in open access courses. *Open Learning: The Journal of Open, Distance and E-Learning, 34*, 187-202. https://doi.org/10.1080/02680513.2018.1508337

Silva, H., & Morrás, A. (2019). Conocimiento tecnológico didáctico y del contenido de profesores Chilenos [Technological didactic and content knowledge of Chilean teachers]. *Campus Virtuales* [*Virtual Campus*]*, 8*, 121-138.

Sofyan, S., Habibi, A., Sofwan, M., Yaakob, M. F. M., Alqahtani, T. M., Jamila, A., & Wijaya, T. T. (2023). TPACK-UotI: The validation of an assessment instrument for elementary school teachers. *Humanities and Social Sciences Communications, 10*(1), 1-7. https://doi.org/10.1057/s41599-023-01533-0

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,* 28(2), 1-25. https://doi.org/10.1007/s10639-022-11256-5

Taimalu, M., & Luik, P. (2019). The impact of beliefs and knowledge on the integration of technology among teacher educators: A path analysis. *Teaching and Teacher Education, 79*, 101-110. https://doi.org/10.1016/j.tate.2018.12.012

Tirado, R., Hernando, A., & Aguaded, I. (2016). The capacity of elderly citizens to access digital media in Andalusia (Spain). *Information, Communication & Society, 19*, 1427-1444. https://doi.org/10.1080/1369118X.2015.1111401

Tondeur, J., Van Braak, J., Ertmer, P. A., & Ottenbreit, A. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development, 65*, 555-575. https://doi.org/10.1007/s11423-016-9481-2

Tseng, J. J., Cheng, Y. S., & Yeh, H. N. (2019). How pre-service English teachers enact TPACK in the context of web-conferencing teaching: A design thinking approach. *Computers & Education, 128*, 171-182. https://doi.org/10.1016/j.compedu.2018.09.022

Tseng, J. J., Lien, Y. J., & Chen, H. J. (2016). Using a teacher support group to develop teacher knowledge of Mandarin teaching via web conferencing technology. *Computer Assisted Language Learning, 29*(1), 127-147. https://doi.org/10.1080/09588221.2014.903978

Vaerenewyck, L. M., Shinas, V. H., & Steckel, B. (2017). Sarah's story: One teacher's enactment of TPACK + in a history classroom. *Literacy Research and Instruction, 56*, 158-175. https://doi.org/10.1080/19388071.2016.1269267

Valtonen, T., Kukkonen, J., Kontkanen, S., Mäkitalo, K., & Sointu, E. (2018). Differences in pre-service teachers' knowledge and readiness to use ICT in education. *Journal of Computer Assisted Learning, 34*, 174-182. https://doi.org/10.1111/jcal.12225

Yang, J., Wang, Q., Wang, J., Huang, M., & Ma, Y. (2019). A study of K-12 teachers' TPACK on the technology acceptance of e-schoolbag. *Interactive Learning Environments, 29*(7), 1062-1075. https://doi.org/10.1080/10494820.2019.1627560

Yeh, Y. F., Hsu, Y. S., Wu, H. K., & Chien, S. P. (2017). Exploring the structure of TPACK with video-embedded and discipline-focused assessments. *Computers & Education, 104*, 49-64, https://doi.org/10.1016/j.compedu.10.006

Yildiz, H. (2019). Examining the acceptance and use of online social networks by preservice teachers within the context of unified theory of acceptance and use of technology model. *Journal of Computing in Higher Education, 31*, 173-209. https://doi.org/10.1007/s12528-018-9200-6

Zhang, J., Lou, X., Zhang, H., & Zhang, J. (2019). Modeling collective attention in online and flexible learning environments. *Distance Education, 40*, 278-301. https://doi.org/10.1080/01587919.2019.1600368

Zhou, C., Wu, D., Li, Y., Yang, H. H., Man, S., & Chen, M. (2022). The role of student engagement in promoting teachers' continuous learning of TPACK: Based on a stimulus-organism-response framework and an integrative model of behavior prediction. *Education and Information Technologies, 28,* 1-21. https://doi.org/10.1007/s10639-022-11237-8

Zhu, M., Herring, S., & Bonk, C.J. (2019). Exploring presence in online learning through three forms of computer-mediated discourse analysis. *Distance Education, 40*(2), 205-225. https://doi.org/10.1080/01587919.2019.1600365