Revista de Psicodidáctica 26 (2021) 53–61

Revista de Psicodidáctica

www.elsevier.es/psicod

Original

Digital pedagogy and cooperative learning: Effect on the technological pedagogical content knowledge and academic achievement of pre-service teachers☆

Lourdes Meroño[a,*], Antonio Calderón[b], and José L. Arias-Estero[a]

[a] *Faculty of Sport, UCAM Catholic University of Murcia, Spain*
[b] *Department of Physical Education and Sport Sciences, University of Limerick, Ireland*

A R T I C L E I N F O

Article history:
Received 20 June 2020
Accepted 21 October 2020
Available online 7 December 2020

Keywords:
Digital competence
Teaching/learning strategies
Technology training
Structural equation modeling

A B S T R A C T

Given the growing role of digital technology and its relevance in the national curriculum, the design and enactment of aligned pedagogies is a challenge for the community of teacher education. This research aims to explore: (a) whether Technological Pedagogical Content Knowledge (TPACK) model and cooperative learning (CL) facilitate preservice teachers' perception of TPACK and academic achievement; and (b) whether there is a relationship between preservice teachers' perception of TPACK and their academic achievement. A quasi-experimental pretest–posttest design with three groups ($n = 293$) was performed for 15 weeks. One group has experienced a pedagogical approach based on TPACK and small-group work. A second group experienced a pedagogical approach based on TPACK and CL. A control group experienced a teacher-centered pedagogical approach and individual assignments. Main findings show that the two experimental groups improved their perception of TPACK and their academic achievement. However, statistically significant improvements were found favoring the group that experienced TPACK and CL. The prediction model also showed that TPACK predicted the academic achievement of pre-service teachers who also experienced TPACK and CL. In summary, digital pedagogies based on TPACK and CL improve pre-service teachers' TPACK and academic achievement. The use of these pedagogies could influence the development of the digital competence of future teachers. Increasing the digital competence of future teachers is indeed a crucial aspect, given the current social and pedagogical scenario.

Pedagogía digital y aprendizaje cooperativo: Efecto sobre los conocimientos tecnológicosy pedagógicos del contenido y el rendimiento académico en formación inicial docente

Palabras clave:
Competencia digital
Estrategias de enseñanza/aprendizaje
Formación digital
Modelo de ecuaciones estructurales

R E S U M E N

Ante el creciente rol de la tecnología digital y su importancia en los currículos educativos, el diseño y la aplicación de metodologías adaptadas es un desafío para la comunidad educativa. Esta investigación persigue conocer: (a) si una metodología basada en el modelo Technological Pedagogical Content Knowledge (TPACK) y el aprendizaje cooperativo (AC) favorece la mejora de la percepción de los conocimientos TPACK y el rendimiento académico de alumnado universitario; y (b) si hay relación entre la percepción de los conocimientos TPACK y el rendimiento académico. El diseño es cuasi-experimental de medidas pretest-postest con tres grupos de clase ($n = 293$) durante 15 semanas. Un grupo ha experimentado una metodología basada en el modelo TPACK y tareas grupales. Un segundo grupo ha desarrollado una metodología basada en el modelo TPACK y AC. Un grupo control ha seguido una metodología centrada en el docente y tareas individuales. Los resultados muestran que los dos grupos experimentales mejoran la percepción de los conocimientos TPACK y el rendimiento académico. Sin embargo, se hallan mejoras estadísticamente significativas a favor del grupo que sigue ambos modelos. El modelo de predicción

PII of original article:S1136-1034(20)30038-1.

☆ Please cite this article as: Meroño L, Calderón A, Arias-Estero JL. Pedagogía digital y aprendizaje cooperativo: Efecto sobre los conocimientos tecnológicos y pedagógicos del contenido y el rendimiento académico en formación inicial docente. Rev Psicodidáct. 2021;26:53–61.

* Corresponding author.

muestra que la percepción de los conocimientos TPACK predice el rendimiento académico del grupo que desarrolla tareas TPACK cooperativas. Por tanto, pedagogías digitales basadas en los modelos TPACK y AC mejoran los conocimientos TPACK y el rendimiento académico de estudiantes en formación inicial docente. Su uso puede favorecer además, el desarrollo de la competencia digital de los futuros docentes. Aspecto determinante en el escenario pedagógico y social actual.

Introduction

In higher education, digital technology approaches to teaching and learning based on cooperative methodologies are becoming increasingly frequent (Calderón et al., 2020; Tlhoaele et al., 2016). Such approaches, in turn, demand training in digital competence to meet the needs of the educational community according to the requirements of the curriculum (Cubeles & Riu, 2018; Gawrisch et al., 2019; Henderson et al., 2015). In today's pedagogical and social scenario, the European Space for Higher Education is even more aware of the challenge of rethinking digital pedagogy to boost the quality of teaching (Caena & Redecker, 2019). According to Mishra and Koehler (2006) and Cherner and Smith (2017), quality in 21st-century teaching requires developing an understanding of the complex relationships between technology, content, and pedagogy, and using this understanding to acquire digital competence. For this purpose, the Technological Pedagogical Content Knowledge (TPACK; Koehler & Mishra, 2008) model was created.

The TPACK model is based on three elements that support the development of digital competence: technological knowledge (TK, knowledge of technological capabilities and applications that can be integrated into the content); pedagogical knowledge (PK, knowledge about teaching/learning/evaluation strategies); content knowledge (CK, knowledge of the module matter to be imparted). These three kinds of knowledge, in turn, interrelate with each other and give rise to: pedagogical content knowledge (PCK, pedagogical knowledge that helps students to acquire the skills of the module); technological content knowledge (TCK, knowledge about the contents of the module matter using technological tools); technological pedagogical knowledge (TPK, knowledge of how technology can be used to acquire new knowledge about the contents of the module); and technological pedagogical and content knowledge (TPACK, knowledge about how to use the most appropriate technology in a pedagogical framework adapted to the specific teaching situation; Krause & Lynch, 2018). According to some studies (Pamuk et al., 2015) the first-level knowledge (TK, PK, and CK) could predict the development of the second-level knowledge (PCK, TCK, and TPK).

Under the European Digital Competence Framework for Educators, the duty to help students become digitally competent requires educators to develop their digital competence (Redecker, 2017). For this reason, most research focused on this model has sought to diagnose teachers' mastery of TPACK (Hofer & Grandgenett, 2012). In general, the literature's discourse favors the development of TPACK to meet the needs of the current teaching (Cabero & Barroso, 2016; Porras-Hernández & Salinas-Amescua, 2013). Besides, the results suggest that TPACK is not static but may differ as a function of internal and/or external context variables (Krauskopf et al., 2018). Taking into account the above, age, sex, and teaching experience are highly influential in TPACK configuration (Erdogan & Sahin, 2010; Tokmak et al., 2013), as well as the variables educational stage, teacher training, and module matter, which are highly related to TPACK perception (Chai et al., 2013; Swallow & Olofson, 2017). Among the external variables, the perception of self-efficacy has a high predictive relationship with the perception of TPACK (Abbitt, 2011; Akturk & Ozturk, 2019).

However, there is little guidance on how to develop the practice of teaching and/or training programs based on TPACK (Hofer & Grandgenett, 2012; Voogt et al., 2013). In this sense, Yeh et al. (2015) and Ay et al. (2015) have rethought the TPACK model from a hands-on approach that includes in its design student characteristics, module content, curriculum design, practical teaching, and evaluations. As a result, a current challenge is to activate TPACK through pedagogical approaches that integrate all the elements into its design. In this line, Chai et al. (2019) designed an intervention in preservice teacher training focused on two TPACK tasks. The first task was a collaborative design to make a creative product after choosing a topic. The second task was to create an individual design to examine the module in more depth. Pareto and Willermark (2019) advocate a constructive design intervention based on the development of real teaching proposals, including the planning, implementation, and evaluation of learning tasks related to the development of TPACK. Oakley (2020) also developed an intervention in preservice teacher training based on TPACK through the creation of digital teaching resources. The results show that the process of creating digital stories and using them in professional practice is useful for developing one's TPACK. To adapt the curriculum design to the characteristics and needs of context, Gawrisch et al. (2019) proposed a conceptual framework based on the perspective of socialization. These authors recommend reflection, observation, and tutor-led application to discover the true value of technology in teaching. However, to this day, it is necessary to delve deeper into this model to clarify numerous unknowns that revolve around its conceptual complexity (Rosenberg & Koehler, 2015). For example, the pedagogical approaches that facilitate its integration (Oakley, 2020) should be analyzed, and/or the degree to which the perception of TPACK corresponds to a real measure based on academic achievement should be confirmed, among others (Drummond & Sweeney, 2017; Scherer et al., 2017).

In this sense, one of the pedagogical approaches that provide the most benefits to current teaching in higher education is cooperative learning (CL; Cecchini et al., 2020). CL is a pedagogical model based on social constructivism that enhances learning through five elements: (1) positive interdependence, (2) promotive (face-to-face) interaction, (3) individual accountability, (4) interpersonal and small-group skills, and (5) group processing to improve the group's future effectiveness (Johnson et al., 2014). This pedagogical approach places affective learning as a central aim of its teaching to help students learn to value their own contributions and those of others, to be more self-sufficient, to adapt peer-to-peer teaching to their own needs and to those of others (Baloche & Brody, 2017). Currently, it is a key methodology for the development of students' curricular competencies and can be enactment in any module, course, and educational level (Palomares-Montero & Chisvert-Tarazona, 2016).

Previous research has analyzed the effect of interventions in pre-service teachers based on the design and creation of cooperative digital support tasks (e.g., infographics, blogs, etc.), and their subsequent dissemination in the learning community (e.g., via Twitter and/or Instagram, among others; Balakrishnan, 2014; Hortigüela-Alcalá et al., 2019). The results have shown the benefits of a constructive learning approach together with cooperative pedagogical approaches in university students (Snowball & McKenna, 2017). There have also been benefits in the classroom climate that, in turn, can generate greater intrinsic motivation and academic achievement, with choice and novelty being two pedagogical principles that drive these results (Calderón et al., 2020). However, students and teachers are the ones who demand training in digital competence to meet the needs of current teaching (Scrabis-Fletcher et al., 2016).

In short, although the TPACK model and CL are a trend in current literature, no interventions have been made that integrate the two models into their design. Therefore, the aims of this research are to determine: (a) whether a pedagogical approach based on the TPACK model and CL promotes the improvement of the perception of TPACK and academic achievement of university students; and (b) whether there is a relationship between the perception of TPACK and academic achievement. The first hypothesis is that the pedagogical approach based on the TPACK model and CL would achieve higher values of perception of TPACK and academic achievement than the pedagogical approach used by the university students of the other two groups. The second hypothesis is that the perception of TPACK and academic achievement would be related to each other, and the perception of TPACK could predict academic achievement outcomes.

Method

Design

The study follows a quasi-experimental design with two experimental groups and a control group, using pretest–posttest measures to collect data on TPACK, and only posttest for academic achievement. Experimental group 1 (EG1) followed a pedagogical approach based on the TPACK model and small-group work. Experimental group 2 (EG2) followed a pedagogical approach based on the TPACK model and CL. The control group (CG) followed a teacher-centered pedagogical approach and individual tasks.

Participants

The participants in this study were 293 preservice teachers (235 men and 58 women, M_{age} = 20.93, SD = 3.98). EG1 includes 85 students (69 men and 16 women, M_{age} = 20.81, SD = 3.19), EG2 is made up of 126 students (95 men and 31 women, M_{age} = 21.35, SD = 4.18), and the CG comprises 82 students (71 men and 11 women, M_{age} = 20.63, SD = 4.59). The module leader has three years of experience in teacher education and is the same one for all three groups. To promote consistency in the intervention, all sessions follow a structure that has the same purposes, teaching strategies, and assessment strategies.

Instruments

TPACK Perception. We used the validated Spanish version of the TPACK Questionnaire (Cabero et al., 2015), initially created by Schmidt et al. (2009), made up of 47 items that assess the perception of knowledge contemplated by the TPACK model: PK (7 items), TK (7 items), CK (12 items), PCK (4 items), TCK (4 items), TPK (5 items), and TPACK (8 items). Items were rated on a 5-point Likert-type scale, ranging from 1 (*Strongly disagree*) to 5 (*Strongly agree*).

Academic achievement. The academic achievement of the three groups was measured through the grades of the ordinary records of the module. These grades were obtained from: (a) the achievement of a partial test during the intervention; (b) a final test after the intervention; and (c) an applied work. The written tests consisted of multi-choice questions and short-answer questions. The applied work included performing academic tasks, which were collective for both the experimental groups and individual for the CG, and aligned with the results of learning the module. The academic achievement scale ranges from Failed (0–4.9) to Outstanding (9.0–10.0).

Table 1
Description of TPACK (from Abbitt, 2011)

Knowledge	Description
CK	Knowledge about the contents of the module.
PK	Knowledge of teaching/learning/evaluation strategies.
TK	Knowledge of technological tools that can be integrated into the content.
PCK	Pedagogical knowledge that helps students to acquire certain skills or content.
TCK	Knowledge about the contents of the matter using technological tools.
TPK	Knowledge of how technology can be used to acquire new knowledge about the contents of the module.
TPACK	Knowledge of how to use the most appropriate technology in a pedagogical framework adapted to the specific teaching situation.

Procedure

This study was carried out in the module of Sport Pedagogy during the second semester of the first year of the Bachelor Degree in Physical Activity and Sport Sciences at the UCAM Catholic University of Murcia (Spain) during the academic courses 2017–18 and 2018–19. The study was approved by the ethics committee of this university, consistent with the Helsinki Declaration agreement. Besides, all participants were informed in writing of the characteristics of the study and voluntarily signed the corresponding consent form.

The intervention was carried out for 30 sessions, two per week, and this was the teaching load of the module. Both the EG1 and EG2 interventions followed a pedagogical approach based on TPACK (Table 1). The tasks designed for the two experimental groups, following the TPACK model, presented a constructivist orientation adapted to the specific teaching situation (Pareto & Willermark, 2019). Also, in EG2, the TPACK tasks were designed according to Johnson et al. (2014) CL premises (positive interdependence, promoting face-to-face interaction, individual accountability, interpersonal and small groups skills and group processing; Figure 1). For this purpose, group assignments were designed with common goals that could be achieved if, and only if, all participants contributed to their development. The assessment was carried out through self-assessment and peer-assessment processes, considering the rubrics designed for this purpose (Johnson et al., 2008). The CG followed a teacher-led pedagogical approach based on direct instruction. The tasks designed for the CG were based on students' autonomous study and individual work, using the support materials available to students in the University virtual learning environment (Figure 1).

Data analysis

The internal consistency of the TPACK perception instrument was tested using the Composite Reliability Index (CRI), the average variance extracted (AVE), Cronbach's alpha index, and McDonald's omega coefficient, and its dimensionality was measured with the Kaiser-Meyer-Olkin (KMO) sample adequacy measure and Bartlett's sphericity test. The normality of the data was examined with the Kolmogorov-Smirnov test. To achieve the first purpose, two types of analyses were performed. First, we analyzed possible differences in the perception of TPACK in the three groups using 3x2 (3 groups × 2 measures: pretest–posttest) MANOVA, and Bonferroni's post hoc test. Second, possible differences in the average academic achievement of the three groups were studied using ANOVA. To achieve the second aim, the predictive relationships

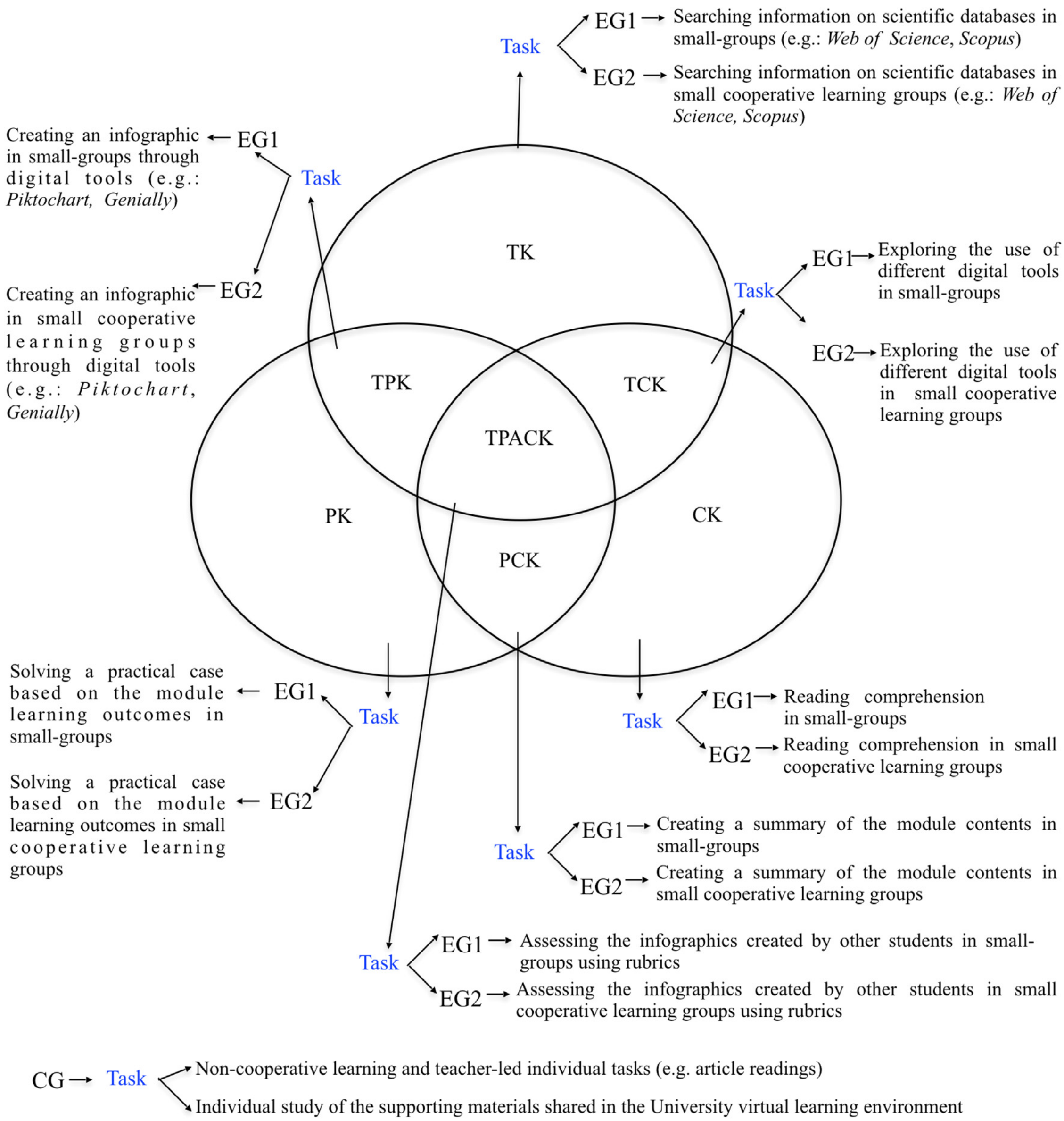

Figure 1. Examples of the EG1, EG2 and CG tasks (authors' elaboration).

between TPACK and the students' academic achievement were analyzed individually for each group through structural equation modeling (SEM), following the methodological proposal of Kline (2015). In the first step (measurement model), the bidirectional associations between the different variables were inspected with confirmatory factorial analysis. In the second step, the predictive effect of the perception of TPACK on students' academic achievement was examined. To perform this multivariate analysis through SEM, the maximum likelihood method was applied with the start procedure, with 5000 iterations, given the violation of the assumption of multivariate normality (Mardia coefficient = 213.11, $p < .001$; Kline, 2015). Normality and linearity statistics were calculated using skewness and kurtosis values, which are appropriate if the value of χ^2/df is less than 5, the incremental indices (Comparative Fit Index: CFI; Normed Fit Index: NFI; Tucker-Lewis index: TLI) are equal to or greater than .95, the root mean square error of approximation (RMSEA) indices are less than .08, and the standardized root mean square residual (SRMR) indexes are close to zero (Bentler, 1990; Byrne, 2001).

The level of significance was $p < .005$. Prior to the SEM analysis, a preliminary analysis using bivariate correlations was performed to study the possible relationship between the dependent variables in each group. Statistical analysis was performed with the IBM SPSS v22 (IBM, 2013) and AMOS v22 (Arbuckle, 2013) statistical packages.

Results

The internal consistency of the instrument obtained with Cronbach alpha was .92. The indices for each of the subscales of the TPACK model were high (TK = .89, CK = .91, PK = .90, PCK = .85, TCK = .85, TPK = .87, TPACK = .86). The reliability of the instrument was confirmed: FC = .92 and VME = .53. The CRIs (TK = .75, CK = .81, PK = .77, PCK = .83, TCK = .79, TPK = .85, TPACK = .82) and VME (TK = .63, CK = .65, PK = .63, PCK = .61, TCK = .63, TPK = .65, TPACK = .60) were also suitable for each of the TPACK subscales. The dimensionality, KMO = .90, and Bartlett's sphericity ($p < .001$) were also confirmed. MANOVA results revealed statistically signif-

Table 2
Descriptive statistics and intergroup analysis of each dependent variable in pretest and posttest

Variables	Pretest			Posttest			*F*	*d*	*p*	η^2
	EG1 *M(SD)*	EG2 *M(SD)*	CG *M(SD)*	EG1 *M(SD)*	EG2 *M(SD)*	CG *M(SD)*				
CK	2.31(*.30*)	2.40(*.43*)	2.38(*.43*)	3.96(*.45*)	4.01(*.46*)	3.80(*.38*)	2.82	0.19	.061	.01
PK	2.97(*.28*)	3.03(*.23*)	3.02(*.61*)	4.00(*.47*)$^{+}$	4.16(*.52*)^{*x}	3.19(*.49*)	3.91	0.25	.027*	.02
TK	2.86(*.57*)	3.07(*.59*)	3.02(*.24*)	4.02(*.33*)$^{+}$	4.10(*.37*)^{*x}	3.03(*.58*)	38.73	0.18	.000*	.21
PCK	2.93(*.39*)	3.14(*.31*)	3.13(*.30*)	3.99(*.49*)$^{+}$	4.20(*.62*)^{*x}	3.80(*.63*)	10.22	0.34	.014*	.06
TCK	2.85(*.42*)	3.16(*.52*)	3.14(*.54*)	3.93(*.25*)$^{+}$	3.98(*.26*)^{*x}	3.16(*.52*)	32.93	0.12	.000*	.18
TPK	2.94(*.35*)	3.18(*.33*)	3.16(*.31*)	2.96(*.34*)$^{+}$	4.46(*.54*)^{*x}	3.21(*.29*)	205.51	0.18	.000*	.58
TPACK	3.07(*.32*)	3.10(*.33*)	3.09(*.34*)	3.10(*.31*)$^{+}$	4.37(*.59*)^{*x}	3.10(*.34*)	126.72	0.21	.000*	.46
Academic achievement	–	–	–	5.42(*1.83*)	7.23(*1.44*)^{*x}	5.65(*1.98*)	35.04	0.98	.000*	.19

Note. *M*: Mean; *SD*: standard deviation. *Significant differences between EG1 and EG2 ($p < .005$); ^{x}Significant differences between EG2 and CG ($p < .005$); +Significant differences between EG1 and GC ($p < .005$); *d*: Effect size (small < .50; moderate: .50–.79; large ≥.80).

icant differences in the three groups in the entire TPACK except for CK and academic achievement. Specifically, EG2 scored higher both in TPACK and academic achievement (Table 2). That is, the results showed that both experimental groups improved their perception of TPACK and academic achievement. However, the participants who received training with both models (EG2) achieved higher values of perception of TPACK and academic achievement.

As shown in Table 3, the results of the correlation-based preliminary analysis showed high and statistically significant differences in EG1 between PCK and CK (p = .000, Table 3). EG2 results showed a high correlation between PCK and CK (p = .000), and between PCK and PK (p = .000); as well as between TPK and PK (p = .004), between TPK and PCK (p = .004), and between TPK and TPACK (p = .000). In contrast, in the CG, no statistically significant correlations were found between the types of knowledge of TPACK, so there was no prediction model for this group. Concerning academic achievement, only correlations between the perception of TPACK and academic achievement of the EG2 students were found (p = .002, Table 3).

According to the normality rules proposed by Curran et al. (1996), the items fulfill normality, because the skewness values were below 2, and the kurtosis values were below 7. The fit indices of the SEM based on the perception of the EG1 students were not adequate, $\chi^2(20, N = 85) = 61.05$, $p = .830$, $\chi^2/df = 1.88$, CFI = .79, GFI = .76, AGFI = .77, RMSEA = .09. That is, there was no prediction of the types of knowledge of the TPACK model for this group. However, the SEM based on the EG2 students' perception confirmed the adequacy of the fit indices: $\chi^2(20, N = 126) = 105.10$, $p = .320$, $\chi^2/df = 3.29$, CFI = .93, GFI = .91, AGFI = .93, RMSEA = .05. According to the EG2 students' perception, the first-level knowledge (TK, PK and CK) predicts the acquisition of the second-level knowledge (PCK, TCK and TPK), and these, in turn in, predict TPACK and academic achievement (Figure 2).

Discussion

This research aimed to determine: (a) whether a pedagogical approach based on the TPACK model and CL promotes preservice teachers' improvement of their perception of TPACK and academic achievement; and (b) whether there is a relationship between the perception of TPACK and academic achievement. The results confirm the two study hypotheses. The benefits of digital pedagogy, using the TPACK model, are reflected in the perception of TPACK and academic achievement both in EG1 and EG2. However, participants who received training in both models (EG2) achieved higher values of perception of TPACK and academic achievement. It was also found that the perception of TPACK predicted the academic achievement of the EG2 students. In short, the higher scores of the students who received the TPACK and CL model (EG2) confirm the benefits of CL for the development of TPACK.

Based on the first purpose of the study, the benefits of TPACK digital pedagogy experienced by the EG1 are consistent with those of recent studies advocating the effectiveness of this model to integrate new technologies into training processes (Kale et al., 2020; Oakley, 2020). This may be due to the characteristics of the TPACK model, which provides practice opportunities that link CK, TK, and PK together as elements that support the development of digital competence (Baran et al., 2019). Another possible explanation may be the learning approach of the TPACK model, which creates a solid foundation of pedagogy and curriculum content, connected to the application of digital technology during teacher training (Kale, 2017; Kale & Akcaoglu, 2017). In a similar line, Oakley (2020) finds that the TPACK model helps preservice teachers to integrate technology as a training tool. In this sense, Pareto and Willermark (2019) emphasize the importance of designing TPACK tasks on site, that

Table 3
Correlation coefficients between the dependent variables in EG1, EG2, and CG

Variables	EG1							EG2							CG						
	CK	PK	TK	PCK	TCK	TPK	TPACK	CK	PK	TK	PCK	TCK	TPK	TPACK	CK	PK	TK	PCK	TCK	TPK	TPACK
CK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PK	.80	-	-	-	-	-	-	.76	-	-	-	-	-	-	.51	-	-	-	-	-	-
TK	.83	.28	-	-	-	-	-	.71	.39	-	-	-	-	-	.06	.06	-	-	-	-	-
PCK	.00*	.20	.06	-	-	-	-	.00*	.00*	.23	-	-	-	-	.34	.06	.10	-	-	-	-
TCK	.97	.72	.32	.99	-	-	-	.44	.69	.38	.49	-	-	-	.37	.07	.77	.42	-	-	-
TPK	.47	.40	.76	.77	.30	-	-	.56	.04*	.11	.04*	.21	-	-	.97	.64	.31	.47	.83	-	-
TPACK	.07	.75	.11	.08	.45	.78	-	.16	.34	.92	.11	.61	.00*	-	.17	.51	.59	.71	.49	.63	-
Academic achievement	.58	.90	.11	.27	.92	.46	.58	.98	.90	.95	.84	.66	.38	.02*	.39	.98	.63	.36	.32	.54	.85

Note. *Significance level for $p < .005$. CK: content knowledge, PCK: pedagogical content knowledge, PK: pedagogical knowledge, TCK: technological content knowledge, TK: technological knowledge, TPACK: technological, pedagogical, and content knowledge, TPK: technological pedagogical knowledge.

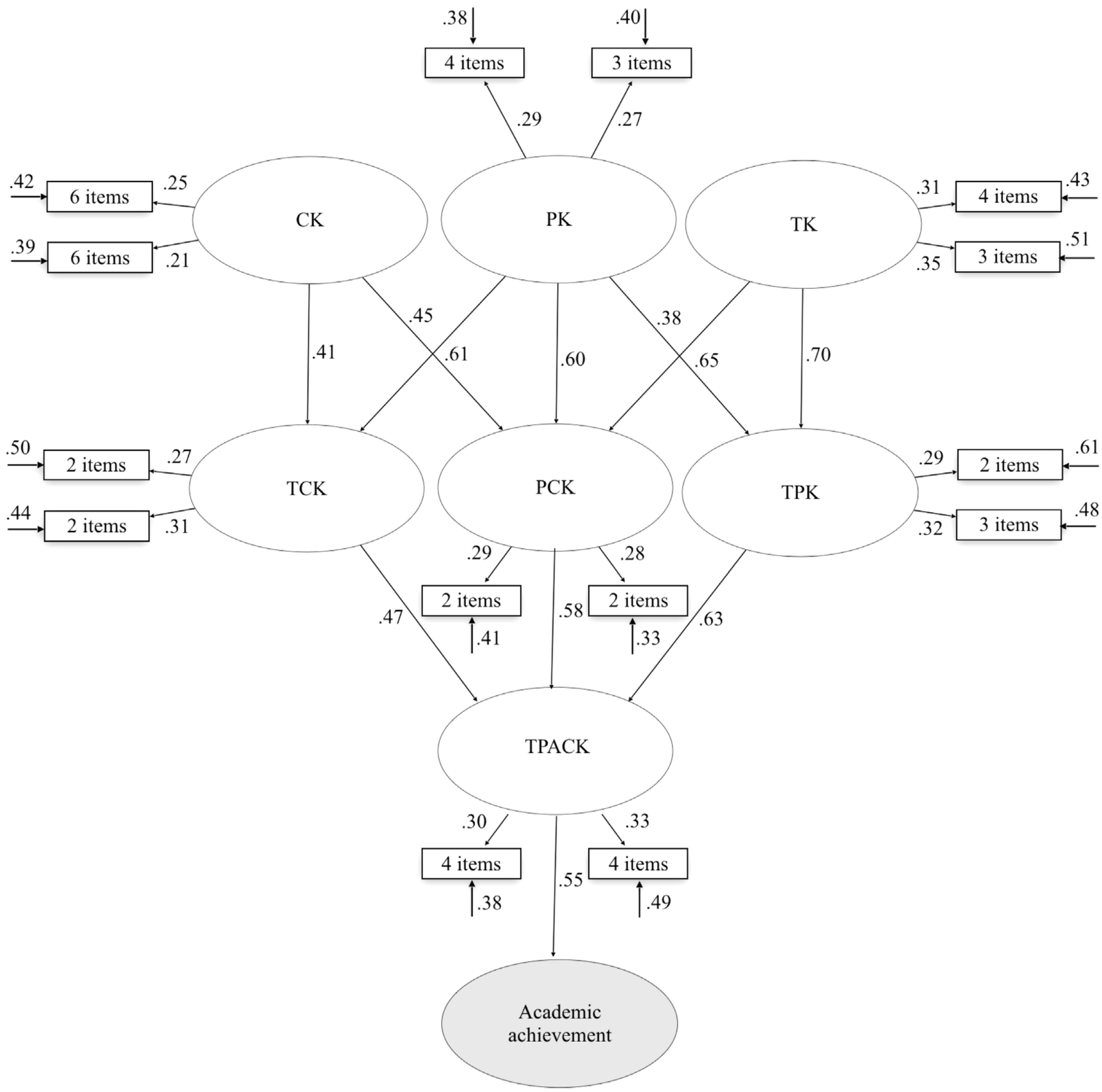

Figure 2. SEM according to the perception of TPACK and the academic achievement of EG2 (authors' elaboration).

is, adapted to each specific teaching situation and context. These findings show the importance of the TPACK model with a practical orientation (Yeh et al., 2015) and give us an idea of its value as a pedagogical approach to take into account in the design of new curriculum and curricula, in line with the needs of the current context (Ay et al., 2015). The results support, as Gawrisch et al. (2019) suggest, the positive effect of designing constructivist orientation tasks based on the TPACK model to generate new learnings (e.g., Pareto & Willermark, 2019). The design of a pedagogical approach based on the TPACK model and CL may be the reason for the results of this study, showing the EG2 group's higher scores in the TK, PK, PCK, TCK, TPK, TPACK, and in academic achievement. This may be due to the elements that mediated the effectiveness of CL (Johnson et al., 2014). The results also confirm the potential of CL in teacher education and higher education (Cecchini et al., 2020), considering affective learning and empathy as implicit elements in the teaching of this pedagogical model based on social constructivism (Baloche & Brody, 2017). Specifically, the following elements were identified. First, positive interdependence in perceiving that the students need from each other (Chai et al., 2019). Second, promoting face-to-face interaction by fostering social and affective relationships (Kale et al., 2020). Third, each member's responsibility, as it is necessary for group success (Cecchini et al., 2020). Fourth, interpersonal skills and working in small groups for the development of TPACK (Swanson et al., 2019). Fifth, group processing by reflecting on the usefulness and feasibility of using digital tools or other tools according to the purpose of the academic activity (Mouza et al., 2014). Sixth, immediate feedback through evaluation rubrics, allowing students to reflect on their learning, express their ideas, understand the ideas of others, and try to unite them (Johnson & Johnson, 2005). In this sense, Chai et al. (2019) improved the perception of TPACK through an intervention based on the elaboration of digital-supported individual and collaborative tasks that seek to fulfill the requirements of educational curriculums. These findings, in turn, highlight the value of considering social and emotional factors for the development of digital competence through the TPACK model. In this sense, CL is shown to be a pedagogical approach ally of the TPACK model and can promote the development of digital empathy, which, according to Selwyn (2020) is indeed necessary in the current scenario and especially in the post-pandemic scenario. However, CK was the only variable that showed no statistically significant differences between the three groups. Similar results were found by Angeli and Valanides (2009). In the study, they reported a small influence of the research methodology on this knowledge. That is, the students learn the content regardless of the pedagogical approach enacted.

Based on the second purpose, findings show the high relationship between the perception of TPACK and the academic achievement of the EG2 students. These findings are empirically supported by studies showing the positive effect of CL on student learning and achievement (Slavin, 2014). Cecchini et al. (2020) recently corroborated the benefits of CL in higher education. In their research, they also note the effectiveness of CL if highly structured tasks that integrate its elements are designed.

There are two main findings in the results of the EG2 students in the prediction model of this study. First, the perception of first-level knowledge (TK, PK, and CK) predicts the perception of second-level knowledge (PCK, TCK, and TPK). These predictive relationships corroborate the impact of TK, PK, and CK on PCK, TCK, and TPK (Pamuk et al., 2015), and they show the positive influence of CL on their development. Second, the perception of TPACK predicts students' academic achievement. These results show that the perception of TPACK, like other variables such as the perception of self-efficacy, is an influential factor in students' academic achievement (Akturk & Ozturk, 2019). These findings reaffirm the benefits of CL in higher education (Cecchini et al., 2020), and they enhance its value as a mediating element of TPACK and preservice teaching students' academic achievement.

In today's pedagogical and social landscape, the development of pedagogical approaches that contribute to the development of the digital competence of future teachers is now more necessary than ever before. This study shows that the combination of the TPACK and CL pedagogical models improves future teachers' development of digital competence and academic achievement. On a practical level, the characteristics of CL were shown to enhance the benefits of the TPACK model linked to the understanding of the complex relationships between technology, content, and pedagogy, all of which help to improve university students' digital competence. At the scientific level, this study contributes to the pedagogical literature about preservice teaching students and, in general, to higher education on how to develop teaching practice and/or training programs based on TPACK and to analyze which pedagogical approaches can facilitate its integration. However, the results should be interpreted with caution due to the complexity of the teaching and learning processes and their measurement in an educational context (Meroño et al., 2019), as well as the possible influence of the teacher on academic achievement. These aspects show the main limitation of this study (along with the use of a natural sample), which could be reduced, for example, through the use of mixed-method designs such as those proposed by Johnson and Onwuegbuzie (2004).

Future research could use such designs to contribute to the analysis and discussion of the enactment of the TPACK model, as well as to contrast these results with other pedagogical approaches. It would also be interesting to contrast these findings with other studies based on the TPACK model focused for instance on student characteristics, module content, and/or curriculum design, among others.

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