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Implementation of the TPACK model to strengthen the digital competencies of teachers in an educational institution

Implementación del modelo TPACK para fortalecer las competencias digitales de los docentes de una institución educativa

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Abstract

This applied study, with a quantitative approach and quasi-experimental design, aimed to demonstrate the effect of the TPACK model on the continuous improvement of the digital competencies of teachers at an educational center in Daule, Ecuador, during the year 2024, based on Sustainable Development Goal (SDG) number 4, which aims to promote inclusive and quality education. The sample consisted of 70 teachers, distributed equally between a control group (CG) and an experimental group (EG). A validated questionnaire was used to assess digital competence levels in the pre- and post-intervention stages. Initial results showed average levels of digital competence in both groups, with no significant differences (p = 0.475). after the implementation of the program based on the TPACK model, the group that received the intervention (EG) showed statistically significant progress (p = 0.000), with 91.43 % of teachers reaching a high level of digital competence and eliminating the lowest level, unlike the control group, which showed insignificant variations. It is concluded that the TPACK model is an effective strategy for transforming and strengthening teachers' digital competencies, promoting more inclusive, relevant, and innovative teaching.

Keywords: TPACK model, digital teaching skills, inclusive education.

Resumen

El presente estudio aplicado, de enfoque cuantitativo y diseño cuasi experimental, tuvo como objetivo demostrar el efecto del modelo TPACK en mejora continua de las competencias digitales de los maestros de un centro educativo de Daule, Ecuador, durante el año 2024, con base en el objetivo de desarrollo sostenible (ODS) número 4, dirigido a promover una educación inclusiva y de calidad. La muestra estuvo conformada por 70 docentes, distribuidos equitativamente en un grupo de control (GC) y otro experimental (GE), se utilizó un cuestionario validado para evaluar los niveles de competencia digital en las etapas pre y post intervención. Los resultados iniciales mostraron niveles medios de competencia digital en los dos grupos, sin diferencias significativas (p = 0,475); tras la implementación del programa basado en el modelo TPACK, el grupo que recibió la intervención (GE) evidenció un avance estadísticamente significativo (p = 0,000), alcanzando el 91,43 % de docentes en el nivel alto de competencia digital y eliminando el nivel más bajo, a diferencia con el grupo control que evidenció variaciones pocos significativas. Se concluye que el modelo TPACK es una estrategia efectiva para transformar y fortalecer las competencias digitales en los maestros, impulsando una enseñanza más inclusiva, pertinente e innovadora.

Palabras clave: Modelo TPACK, competencias digitales docentes, educación inclusiva.

Introduction

Digital competencies (DC) represent an essential set of skills necessary for the effective and safe use of technology, both in personal and professional contexts. In today's educational landscape, their significance is undeniable, as they encompass everything from basic technological tool management to more complex aspects such as information management, online security, and digital content creation.

However, despite their relevance, educators face multiple challenges in fully developing these competencies. Among these challenges are inadequate initial training, lack of continuous professional development, resistance to change, and limitations in technological infrastructure. In this regard, UNESCO (2022)

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emphasizes that the effective integration of Information and Communication Technologies (ICT) significantly promotes the development of digital competencies in teaching, which directly contributes to achieving Sustainable Development Goal (SDG) number 4, aimed at ensuring inclusive, equitable, and quality education.

Within this framework, the present study conceptualizes "digital competencies" as the dependent variable, organized into three key dimensions: (1) instrumental competencies, which include mastery of basic tools such as office software and digital platforms; (2) didactic competencies, associated with the integration of ICT in planning, teaching, and assessment processes; and (3) communicative competencies, related to interaction and collaboration in virtual environments (Huamán, 2021; Quintana, 2000; Adell, 2019).

In response to the need to strengthen these competencies, the Technological, Pedagogical, and Content Knowledge (TPACK) model proposed by Mishra and Koehler (2006) emerges as an integrative proposal to enhance teaching practices, as it facilitates the coordinated incorporation of pedagogical, technological, and disciplinary knowledge. This model promotes innovative educational practices, collaborative work, versatile assessment strategies, and a comprehensive improvement of learning outcomes.

Theoretically, the TPACK model comprises three main dimensions: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK), whose intersection enables educators to make informed decisions for planning, designing, and implementing effective learning experiences. This comprehensive approach is complemented by subdimensions such as Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK), which reinforce the coherence between what is taught, how it is taught, and the tools employed (Mishra & Koehler, 2006; Cabero et al., 2017).

The relevance of this proposal is underscored by international data revealing a concerning digital divide. The OCDE (2020) reports that in countries like Peru, Ecuador, Chile, and Mexico, 39% of educators possess digital competencies below level 1, while only 13% reach advanced levels. In the European Union, according to the European Commission (2023), only 26% of adults have advanced digital competencies, which directly impacts their employability. This scenario highlights the urgent need for continuous training to ensure updated and equitable education.

In Latin America, UNESCO (2021) emphasizes the necessity of strengthening digital citizenship, employability, and equitable access to technology. Similarly, the UN (ONU, 2022) underscores the importance of content, capacity, and connectivity as key elements for enhancing digital learning. Such recommendations are applicable to local contexts like the Unidad Educativa Particular Olmedo in Daule, Ecuador, where limitations in the use of devices such as projectors, digital boards, or laptops, along with a preference for traditional methodologies and difficulty in relating disciplinary knowledge to technological tools, have been identified. This situation has led to student demotivation and inadequate preparation for labor market challenges.

Research background reinforces this need. Paidicán and Arredondo (2023) highlight low research output on TPACK in Ibero-America and stress the need to apply the model in interdisciplinary contexts. Iskandar et al. (2021) demonstrated that a brief program can significantly enhance knowledge of TPACK and teachers' emotional quotient. Similarly, studies conducted in Namibia (Nepembe & Cimuja, 2023), Brazil (Silva et al., 2021), and Mexico (Centeno, 2021) agree on the importance of continuous training to improve technological integration in classrooms. In Ecuador, studies by Lema (2021), Torres (2021), and Rodríguez (2021) have validated the effectiveness of the TPACK model in strengthening constructivism and pedagogical innovation.

From a theoretical perspective, the study is grounded in theory of connectivism (Siemens, 2004), which posits learning as the construction of digital networks centered on student autonomy, and the multimedia learning theory (Mayer, 2005), which emphasizes the value of combining text, image, and sound to enhance understanding. Both approaches find a point of articulation in the TPACK model, which allows for the coherent alignment of content, pedagogy, and technology.

The relevance of the study is justified across three dimensions. First, on a practical level, it enables educators to acquire skills to incorporate technological resources that enhance teaching, foster interactive classes, and address current educational needs. Second, from a methodological perspective, the research provides a theoretical framework applicable to future training interventions in various contexts. Finally, from a social standpoint, it contributes to closing gaps in digital literacy that affect educators' professional performance.

Given this reality, the implementation of the TPACK model is positioned as a pertinent strategy to overcome the limitations faced by teaching staff and transform educational practice. Within this framework, the main research question is: What is the effect of the TPACK model on the digital competencies of educators at an educational institution in Daule during 2024?

Based on this, the general objective of the research is to demonstrate the effect of the TPACK model on the digital competencies of educators at an educational institution in Daule, Ecuador, in 2024. Additionally, three specific objectives are proposed: (1) to determine the effect of the TPACK model on instrumental digital

competencies, (2) on didactic digital competencies, and (3) on communicative digital competencies. From this, the hypothesis is formulated: the application of the TPACK model is effective in strengthening the digital competencies of educators at an educational institution in Daule.

Methodology

The present study is grounded in a quantitative approach, aiming to obtain reliable, measurable, and quantifiable information regarding the percentages of improvement or decline in digital competencies (DC) among the educators who participated in the research sample. According to Hernández et al. (2018), the quantitative method relies on the collection and analysis of quantifiable data, with the purpose of testing a hypothesis and understanding the relationship that may exist between two or more variables.

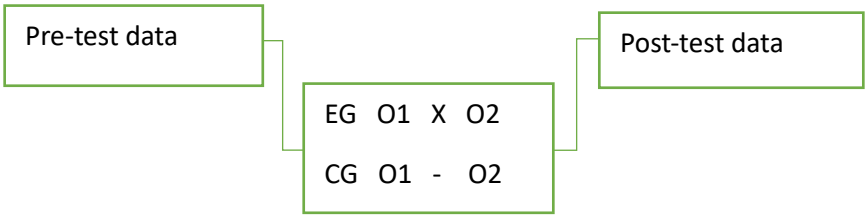
In terms of classification, it is applied research, as its purpose was to investigate the causal relationship of digital competencies among educators. It focused on examining how the dimensions of the TPACK model could affect the development of these skills. Research of this nature is essential, as it continuously contributes to knowledge, with the expectation that its conclusions will be applicable in other contexts. In this sense, the study dedicated itself to observing and understanding reality, without the immediate intention of attempting to alter it (Ñaupas et al., 2016).

The design is experimental, as it sought to investigate and validate the influence of the independent variable (TPACK) on the dependent variable (DC). It is quasi-experimental in nature, since it assessed the impact of the implementation of the TPACK model on digital competencies by evaluating educators at an educational center in Daule in 2024, before and after the teacher training program. Quasi-experimental studies represent a valid alternative to experimental designs and, although they do not involve random assignment of participants, they are relevant for studying effects (Shadish et al., 2002).

This study employs a longitudinal approach, which involved observing the research subjects at multiple points in time. In this research, the educators at the educational center were assessed using an initial test, followed by the execution of the training program, and subsequently, a post-test was conducted to determine the program's effect on the educators. According to Hernández et al. (2018), the longitudinal approach allows for the collection of information at various moments over time, facilitating the observation of changes and trends in the analyzed variables, as well as establishing their relationships.

The scope of this research is explanatory, as it attempted to demonstrate the effect of the TPACK model on the digital competencies of educators at an educational institution in Daule. Data collection for the pre-test was scheduled during the third quarter of the 2024-2025 academic year; based on the obtained data, a training program was designed to strengthen the digital competencies of the teachers at Unidad Educativa Olmedo. The design is represented through the following scheme:

Figure 1
Research design



Where:

- EG corresponds to the experimental group
- CG corresponds to the control group
- X represents the TPACK model training program
- O_1 denotes the pre-test
- O_2 denotes the post-test

The population consisted of 70 educators from an educational institution in Daule, Ecuador, who participated as a sample for the study. The sample was intentionally selected, distributed evenly: 35 educators formed the experimental group and 35 the control group. Both groups participated in the measurement process and were evaluated before and after the intervention.

A questionnaire based on the Likert scale was used as the instrument, with an evaluative rating from 1 to 5. In this scale, "Never" has a value of 1; "Almost never," 2; "Sometimes," 3; "Almost always," 4; and "Always," 5, with 10 questions for each dimension. The instrument was validated by five experts and applied in the pre- and post-intervention phases to measure the levels of digital competencies in the established dimensions. Additionally, Cronbach's alpha coefficient was applied, yielding a result of 0.95, which is considered excellent. This questionnaire collected data related to the instrumental, didactic, and communicative dimensions of educators' digital competencies. It allowed for the establishment of a baseline and the progress made after the implementation of the training program based on the TPACK model.

To conduct the statistical analysis of the results, SPSS software was utilized. The Shapiro-Wilk normality test was applied to determine the distribution of the data, followed by the independent samples t-test to compare the results between both groups. Furthermore, descriptive statistics were applied to obtain frequencies, percentages, and means, in order to characterize the levels of digital competencies before and after the intervention. This procedure allowed for the evaluation of whether the differences between the experimental group and the control group were statistically significant, thus verifying the impact of the TPACK model on educators' digital competencies.

Finally, in terms of ethical standards, both national and international criteria were considered, focusing on ensuring the comfort of participants and the quality of results. Principles such as obtaining voluntary consent, respecting participants' rights and dignity, allowing withdrawal at any time, maintaining data confidentiality through coding and electronic safeguarding, and ensuring transparency in the communication of results were applied. Additionally, concrete benefits, such as strengthening educators' digital competencies, were offered, and a rigorous approach was ensured to guarantee the reliability and validity of the data, all while respecting the well-being and equity of those involved.

Results and discussion

The results of the study demonstrate the positive effect of implementing the TPACK model on strengthening educators' digital competencies (DC). In the pre-test phase, both the control group (CG) and the experimental group (EG) exhibited similar conditions regarding their levels of digital competency. The majority of educators in both groups were situated at the medium level, with 54.29% in the CG and 68.57% in the EG. In the low level, the CG showed 20% compared to 11.43% in the EG, while at the high level, the CG had 25.71% and the EG had 20%, indicating a slight advantage for the EG at the medium level but also a greater initial concentration at the low level.

Table 1

Levels of digital competencies in educators (pre-test and post-test)

Level	Pre-test CG	Pre-test EG	Post-test CG	Post-test EG
Low	20,00 %	11,43 %	11,43 %	0,00 %
Medium	54,29 %	68,57 %	62,86 %	8,57 %
High	25,71 %	20,00 %	25,71 %	91,43 %
Total	100%	100%	100%	100%

Note. CG = Control Group, EG = Experimental Group. Source: Own elaboration based on León (2024).

After the intervention with the training program based on the TPACK model, the results of the post-test revealed significant changes. In the EG, no educator remained at the low level, 91.43% reached the high level, and only 8.57% remained at the medium level. In contrast, the CG still had 11.43% at the low level, 62.86% at the medium level, and only 25.71% at the high level, maintaining the same results as initially. The difference was confirmed through inferential analysis using the Student's t-test, which showed a statistically significant difference in the post-test ($M_{EG} = 4.260$; $M_{CG} = 3.114$; $p = 0.000$), thereby validating the hypothesis regarding the impact of the TPACK model on the development of educators' digital competencies.

Table 2

Comparison of means pre-test and post-test in digital competencies (Student's t-test)

Moment	Group	Mean	SD	p-value
Pre-test	EG	3,057	0,363	0,335

	CG	3,100	0,320	
Post-test	EG	4,260	0,263	0,000*
	CG	3,114	0,329	

Note. *p < 0.05 (significant difference). SD = Standard Deviation. Source: Own elaboration based on León (2024).

In the instrumental dimension, the pre-test showed that 8.57% of educators in the CG were at the low level, 51.43% at the medium level, and 40% at the high level. In contrast, the EG had 2.86% at the low level, 71.43% at the medium level, and 25.71% at the high level. Following the intervention, the EG showed substantial improvement: no educator remained at the low level, 11.43% stayed at the medium level, and 88.57% reached the high level. The CG, however, recorded only a slight change: 2.86% at the low level, 51.43% at the medium level, and 45.71% at the high level.

Table 3
Results by dimension: Instrumental digital competency

Level	Pre-test CG	Pre-test EG	Post-test CG	Post-test EG
Low	8,57 %	2,86 %	2,86 %	0,00 %
Medium	51,43 %	71,43 %	51,43 %	11,43 %
High	40,00 %	25,71 %	45,71 %	88,57 %
Total	100%	100%	100%	100%

Regarding the didactic dimension, initial data indicated that 22.86% of educators in the CG were at the low level, 51.43% at the medium level, and 25.71% at the high level. In the EG, these figures were 14.29%, 48.57%, and 37.14%, respectively, suggesting a slightly more favorable initial profile. After the intervention, 94.29% of the EG reached the high level, none remained at the low level, and only 5.71% stayed at the medium level. In contrast, the CG maintained 14.29% at the low level, 57.14% at the medium level, and only 28.57% at the high level.

Table 4
Results by dimension: Didactic digital competency

Level	Pre-test CG	Pre-test EG	Post-test CG	Post-test EG
Low	22,86 %	14,29 %	14,29 %	0,00 %
Medium	51,43 %	48,57 %	57,14 %	5,71 %
High	25,71 %	37,14 %	28,57 %	94,29 %
Total	100%	100%	100%	100%

The communicative dimension also showed notable improvements in the EG. In the pre-test, 42.86% of the EG were at the low level, 40% at the medium level, and only 17.14% at the high level, indicating an urgent need for improvement. After the intervention, 85.71% of the educators reached the high level, with only 11.43% remaining at the medium level and just 2.86% at the low level. In contrast, the CG showed little variation: 34.29% at the low level, 51.43% at the medium level, and 14.29% at the high level.

Table 5
Results by dimension: Communicative digital competency

Level	Pre-test CG	Pre-test EG	Post-test CG	Post-test EG
Low	34,29 %	42,86 %	31,43 %	2,86 %
Medium	51,43 %	40,00 %	54,29 %	11,43 %
High	14,29 %	17,14 %	14,29 %	85,71 %
Total	100%	100%	100%	100%

The Shapiro-Wilk normality test applied to the measurements in both groups confirmed that the data had an appropriate distribution for parametric tests. The means of the pre-test in the communicative dimension were similar: 2.780 for the CG and 2.746 for the EG. However, in the post-test, the EG achieved a mean of 4.257

compared to 2.740 for the CG, with a standard deviation of 0.3910, indicating greater homogeneity among participants in the experimental group.

Table 6
Results by dimension: Communicative digital competency

Level	Statistic	DF	Sig.
Pre_CG	0.962	35	0.270
Pre_EG	0.974	35	0.557
Post_CG	0.966	35	0.350
Post_EG	0.973	35	0.519

In summary, the results of this study demonstrate that the implementation of the TPACK model had a significant impact on strengthening educators' digital competencies, particularly in the instrumental, didactic, and communicative dimensions. The findings support the theory of Mishra and Koehler (2006), who proposed that the effective integration of technology in education requires a balanced combination of pedagogical, disciplinary, and technological knowledge.

In comparison to previous studies, our results align with those of Iskandar et al. (2021), who found that educators trained in the TPACK model exhibited greater mastery of digital tools. However, this study provides more robust evidence by utilizing a quasi-experimental design with a control group, overcoming the limitations of research based solely on self-reports (Paidicán & Arredondo, 2023).

The most notable advancement was observed in the instrumental dimension, where 88.57% of educators in the experimental group reached a high level of competency. This suggests that TPACK not only enhances technical skills but also fosters their pedagogical application, as noted by Cabero et al. (2017). Moreover, the improvement in the communicative dimension (from 2.746 to 4.257) is particularly relevant in today's educational context, where digital interaction is essential (Oliva & Mata, 2022).

One limitation of the study is that it did not evaluate the long-term impact. Future research could analyze the sustainability of these competencies or their application in rural contexts. Nonetheless, the results support the implementation of TPACK as an effective strategy to reduce the digital divide among educators, contributing to Sustainable Development Goal 4 (SDG 4) on quality education.

Proposal
Implementation of the TPACK model in rural educational institutions.

1. **Rationale**

The introduction of technology in the teaching-learning process in rural schools addresses challenges observed in developing countries like Ecuador. These obstacles include a lack of infrastructure, poor connectivity, and insufficient training of educators in technological skills. In this context, the TPACK model (Technological Pedagogical Content Knowledge), developed by Mishra and Koehler (2006), offers a combined perspective in terms of technological, pedagogical, and content knowledge, encouraging educators to develop and plan teaching strategies with educational technologies.

Incorporating the TPACK model in rural schools will improve educators' digital competencies, adapting technology to the specificities of each community and promoting quality, inclusive, and equitable education, in line with SDG 4 of the 2030 Agenda. This suggestion responds to the urgent need to reduce the digital divide and foster more innovative and contextualized teaching in rural areas.

2. **Objectives:**

General Objective

To operationalize the TPACK framework in rural schools to improve educators' digital competencies and teaching-learning practices through the contextualized application of technologies.

Specific Objectives:

1. To diagnose the technological pedagogical content knowledge of rural educators.
2. To develop and implement a training program based on the TPACK model for educators.

3. To support and evaluate didactic strategies with ICT implemented in the classroom.

3. Methodology

The proposal is framed within action research, to be developed as a quasi-experimental study with a mixed approach (qualitative and quantitative) and longitudinal design, in four phases:

- **Phase 1: Initial diagnosis**. Application of surveys and interviews to educators to identify the level of TPACK competencies and the technological readiness of the institution.
- **Phase 2: Educator training**. Design and execution of in-person and virtual workshops focused on the three dimensions of the TPACK model, emphasizing its applicability in rural contexts.
- **Phase 3: Implementation in the classroom**. Development and use of didactic sequences mediated by ICT, integrating disciplinary content, pedagogy, and technology.
- **Phase 4: Review and feedback**. Evaluation of teaching practices using observation rubrics, digital portfolios, and follow-up interviews.

4. Activity Schedule:

Activity	Month 1	Month 2	Month 3	Month 4	Month 5
Assessment of competencies and environment	X				
Design of training plan	X	X			
Implementation of TPACK workshops		X	X		
Transfer of strategies to the classroom		X	X	X	X
Evaluation and follow-up				X	X
Defense and dissemination				X	

5. Estimated Budget

Category	Estimated Cost
Textbooks and printed guides	300
Compensation for facilitators (2 people)	1200
Transportation to rural areas	400
Connectivity for virtual meetings	250
Evaluation and summary	100
Total Estimated	**2250**

Note: The figures may vary depending on the number of receiving institutions and the local context.

Conclusions

Based on the results obtained, it is concluded that the application of the TPACK model had a significant impact on strengthening the digital competencies (DC) of educators at an educational institution in Daule during 2024, as 91.43% of participants in the experimental group (EG) reached the highest level of competency. The comparative analysis between the control group (CG) and the EG demonstrates that, although both groups started with similar levels in the pre-test, in the post-test, the EG achieved a significantly higher average, validating the research hypothesis (H1).

In the instrumental dimension, the results suggest that the intervention based on the TPACK model led to notable improvements in the mastery of technological tools by the EG. The difference in post-test means between both groups, along with a smaller standard deviation in the EG, indicates not only an increase in the level of technical knowledge but also greater homogeneity in participant performance. This finding highlights the effectiveness of the TPACK model in strengthening the basic competencies required for the use of technological resources, which are essential in current teaching practices.

Regarding the didactic dimension, the results confirm that the TPACK model supports the effective integration of technology in the processes of planning, implementation, and assessment of teaching. Both the level of competency achieved and the coherence of the results were superior in the EG compared to the CG. This indicates that educators not only acquired technical skills but also developed solid pedagogical criteria to apply these tools in real educational contexts in a relevant and reflective manner.

In the communicative dimension, a significant improvement was also observed among educators in the EG, who enhanced their use of digital tools aimed at interaction and collaboration in virtual environments following the intervention. The difference in means, as well as the reduction in standard deviation, reflect an effective transformation in the use of digital media, which favors more efficient communication and enriched collaborative work both within the classroom and beyond.

Overall, these findings support the effectiveness of the TPACK model as a formative strategy for the comprehensive development of educators' digital competencies, aligning with the quality, equity, and inclusion objectives proposed by SDG 4 of the 2030 Agenda. The implementation of this model also represents a viable alternative to reduce the digital divide in the education system, particularly in contexts with technological and methodological limitations.

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