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PRESENTACIÓN

Innoeduca. International Journal of Technology and Educational Innovation es una publicación científica que nace auspiciada por el Grupo de investigación Innoeduca (grupo consolidado de la Junta de Andalucía - SEJ-533) de la Universidad de Málaga (España). Innoeduca es un grupo interdisciplinar de docentes e investigadores (pedagogos, matemáticos, informáticos, diseñadores gráficos…) de distintos niveles educativos, que desarrollan productos, investigaciones y formación en el campo de la Innovación y la Tecnología Educativa. Desde sus inicios, el grupo ha desarrollado una labor investigadora permanente y ha tenido como prioridades el contacto y la colaboración con otros investigadores y centros nacionales e internacionales.

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Difundir contenidos de calidad entre la comunidad científica es la finalidad de este proyecto. Por ello, se admitirán artículos escritos en inglés, español o portugués.

Esperamos que este número resulte interés al lector dada la relevancia de las investigaciones publicadas.

Julio Ruiz-Palmero
Director de Innoeduca. International Journal of Technology and Educational Innovation

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ÍNDICE

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Students' Perspectives on the Educational Benefits of ChatGPT: A Quantitative Exploration

Perspectivas de los estudiantes sobre los beneficios educativos de ChatGPT: una exploración cuantitativa

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Davinder Kaur
ORCID: 0000-0002-2909-6806
Symbiosis Law School, Pune, India
Symbiosis International (Deemed University), Pune, India
davinder.kaur@symlaw.ac.in

Vartika Kapoor
ORCID: 0000-0002-6611-5025
Symbiosis Centre for Management Studies, Noida, India
Symbiosis International (Deemed University), Pune, India
vartika3105@gmail.com

ABSTRACT

The objective of this study is to quantitatively analyse the benefits and incentives of using ChatGPT from students' perspectives. An initial pool of items encompassing various benefits of ChatGPT for students, has been generated on the basis of extant literature. To validate the benefits quantitatively, primary data has been collected using structured questionnaires from 515 students studying in higher educational institutions (HEIs) of Delhi – National Capital Region (NCR), India. Exploratory factor analysis (EFA) was performed to uncover the underlying structure of perceived benefits of using ChatGPT. Further, confirmatory factor analysis (CFA) was employed to confirm the factor structure and ensure the reliability and validity of the identified categories of benefits. The findings indicate six key categories, namely "Learning Support", "Content Generation", "Knowledge Acquisition", "Personalized Learning", "Academic Writing", and "Efficiency". Each category reflects different aspects of how ChatGPT enhances the educational experience for students. The study aims to tools in education by providing empirical evidence on the specific benefits of ChatGPT. Practically, the study provides valuable insights for educators, academic institutions, and policymakers on how to effectively integrate ChatGPT and similar AI tools into the curriculum.

KEYWORDS Artificial Intelligence, ChatGPT, Benefits, Confirmatory Factor Analysis, Exploratory Factor Analysis, Students

RESUMEN

El objetivo de este estudio es analizar cuantitativamente los beneficios e incentivos del uso de ChatGPT desde la perspectiva de los estudiantes. Se generó un conjunto inicial de preguntas que abarcan diversos beneficios de ChatGPT para los estudiantes, basándose en la literatura existente. Para validar cuantitativamente los beneficios, se recopilaron datos

primarios mediante cuestionarios estructurados de 515 estudiantes de instituciones de educación superior (IES) de Delhi, Región de la Capital Nacional (NCR), India. Se realizó un análisis factorial exploratorio (AFE) para descubrir la estructura subyacente de los beneficios percibidos del uso de ChatGPT. Además, se empleó un análisis factorial confirmatorio (AFC) para confirmar la estructura factorial y garantizar la fiabilidad y validez de las categorías de beneficios identificadas. Los hallazgos indican seis categorías clave: "Apoyo al aprendizaje", "Generación de contenido", "Adquisición de conocimientos", "Aprendizaje personalizado", "Redacción académica" y "Eficiencia". Cada categoría refleja diferentes aspectos de cómo ChatGPT mejora la experiencia educativa de los estudiantes. El estudio proporciona evidencias empíricas sobre los beneficios específicos de ChatGPT. En la práctica, facilita información valiosa para educadores, instituciones académicas y legisladores sobre cómo integrar eficazmente ChatGPT y herramientas de IA similares en el currículo.

PALABRAS CLAVE inteligencia artificial, ChatGPT, beneficios, análisis factorial confirmatorio, análisis factorial exploratorio, estudiantes

1. INTRODUCTION

1.1. Emergence of ChatGPT in higher education

Artificial Intelligence (AI) stands as one of the most transformative technological advancements impacting the education sector. Within the realm of AI, Natural Language Processing (NLP) has facilitated the development of chatbots powered by Large Language Models (LLMs), enabling them to comprehend and generate human-like responses (Albadarin et al., 2024). These AI-driven chatbots have the potential to enrich student learning by offering self-directed study recommendations and personalized guidance (Shoufan, 2023). Among them, Chat Generative Pre-Trained Transformer (ChatGPT), launched by OpenAI in late 2022, has emerged as a particularly influential tool in educational contexts (Onyekwere & Enamul, 2025; Vázquez-Cano et al., 2023). ChatGPT has gained considerable popularity among students because of its capabilities in providing human-like assistance in idea generation and writing samples (Dai et al., 2023); producing well-structured, informative and contextually appropriate responses (Farhi et al., 2023; Rudolph et al., 2023; Singh et.al., 2025); offering advice on the structural aspects of a text (Imran & Almusharraf, 2023); and efficiently performing the tasks related to natural language processing such as translation, guided writing, summarizing, and so on (King, 2023; Kohnke et al., 2023). Because of the impressive abilities of ChatGPT, scholars believe that ChatGPT will become an integral part of writing, as computers and calculators have become essential parts of science and mathematics (McMurtrie, 2023). Hence, some researchers recommend that students should be involved with ChatGPT in order to facilitate learning, rather than prohibiting its usage (Sharples, 2022).

1.2. Existing research on educational benefits of ChatGPT

Highlighting the learning opportunities provided by ChatGPT for all levels of education, Kasneci et al. (2023) opine that ChatGPT can not only develop reading, writing, thinking, and problem-solving skills in students, but can also empower learners with disabilities. Further, some studies have also highlighted the strengths of ChatGPT in knowledge management in higher education. For example, Farrokhnia et al. (2023) argued

that ChatGPT serves as a natural language model by generating plausible answers and providing personalized responses in real-time. Similarly, Lee (2023) opined that ChatGPT serves as a virtual teaching assistant by providing detailed and relevant information to students. Rasul et al. (2023) highlighted the benefits of using ChatGPT in higher education which include personalized feedback, facilitating adaptive learning, supporting research and data analysis, helping in automated administrative services and developing innovative assessments (Padilla-Hernández et.al., 2019). Scholars have also indicated that ChatGPT helps in fostering students' performance, engagement and motivation (Albadarin et al., 2024). Furthermore, Firat (2023) investigated the implications of ChatGPT by qualitatively analyzing the perceptions of students using thematic content analysis. The author concluded that ChatGPT enhances learning experiences of students by providing personalized instructions. Mahapatra (2024) indicated that ChatGPT has a positive impact on academic writing skills of a student by using the mixed-methods intervention study. Shoufan (2023) qualitatively analyzed the perceptions of students and concluded that they perceive ChatGPT to be interesting, motivating, and helpful for their studies. Based on the university students' perspectives, Jo (2024) concluded that knowledge acquisition, knowledge application, personalization and novelty value contribute towards the benefits of using ChatGPT. Ngo (2023) conducted a quantitative survey among university students and identified several benefits of ChatGPT, including time efficiency, access to information across various domains, personalized tutoring, and assistance in idea generation for writing tasks.

1.3. Rationale for quantitative Exploration of ChatGPT's Educational Benefits

To gain a comprehensive understanding of the learning benefits of ChatGPT, this study adopts a quantitative approach to explore students' perspectives. Although both qualitative and quantitative approaches provide important insights, a quantitative lens helps in systematic measurement and validation of the perceived benefits of ChatGPT to the students. Further, analysing students' perspective is crucial for designing user friendly educational technologies that align with their needs and preferences (Chiu & Churchill, 2016; Ngo, 2023; Veletsianos & Moe, 2017). The initial studies have offered valuable insights into students' perceptions of ChatGPT (Godsk & Elving, 2024; Hojeij et al., 2024; Ngo, 2023; Shoufan, 2023; Zhang & Tur, 2024), and there is a growing body of literature that highlights the need to systematically investigate the educational benefits and challenges associated with these technologies (Baidoo-Anu & Owusu Ansah, 2023; Kasneci et al., 2023; Rudolph et al., 2023). However, most of the existing studies are qualitative in nature, that rely on thematic analyses, open-ended responses, or simple rating items (Ilić et.al, 2024; Wang & Fan, 2025). Also, several recent studies have developed scales or survey items to assess specific aspects of students' experiences with ChatGPT —such as its perceived usefulness, academic support (Farhi et.al., 2023; Jo, 2024; Mohapatra, 2024; Ngo, 2023; Shoufan, 2023), but there remains a lack of a comprehensive, validated instrument that captures the full range of educational benefits perceived by students across multiple dimensions (Hoffmann et.al., 2024). Recent researches have also emphasized the importance of understanding the student engagement with AI for purposes such as content creation, academic writing support, and personalized learning (Cotton et al., 2023; Dwivedi et al., 2023). Quantitative studies can complement qualitative inquiries by measuring the extent and perceived effectiveness of AI-assisted learning tools across diverse educational dimensions.

Therefore, the present study attempts to quantitatively analyze the perceived benefits of using ChatGPT among students. As ChatGPT continues to evolve and become more integrated in various aspects

of education (Van Dis et al., 2023), the present study is imperative to maximize its benefits. To uncover the underlying structure of perceived benefits of using ChatGPT, the study employs exploratory factor analysis (EFA). Further, confirmatory factor analysis (CFA) is employed to confirm the factor structure and ensure the reliability and validity of the identified categories of benefits. By quantitatively analyzing the benefits of ChatGPT from students' perspectives, the study seeks to provide an insightful and comprehensive understanding that can enhance its development, implementation, and utilization in the field of education.

The structure of the paper is as follows. Section 2 provides a review of relevant literature and outlines the study's conceptual framework. Section 3 details the research methodology adopted, while section 4 presents the data analysis and key findings. Finally, section 5 concludes the paper by summarizing the results, discussing their implications, and highlighting the study's limitations.

2. MATERIAL AND METHOD

To develop a comprehensive scale for measuring the perceived benefits of using ChatGPT for students, we followed a structured process grounded in recommended best practices in scale development (Boateng et al., 2018; DeVellis, 2016). We began with an extensive review of empirical and conceptual literature on the educational use of ChatGPT and other AI-powered tools, focusing on themes such as personalized learning, knowledge acquisition, academic writing support, efficiency, and intelligent tutoring (Cotton et al., 2023; Dwivedi et al., 2023). Based on this review, we extracted commonly cited benefits and translated them into measurable statements aligned with our target population of students. In line with the established item development practices, we ensured clarity, singularity of meaning, and the use of age-appropriate language to suit our target student population (DeVellis, 2016; Hinkin, 1995). This process resulted in an initial pool of 41 items (see Table 1, in next page).

To establish face validity, and enhance the clarity and relevance of the items, we conducted in-depth interviews with 10 domain experts, including 5 university teachers and 5 researchers, whose areas of specialization were related to the adoption and impact of educational technologies. Although the final survey was administered to students, these experts were consulted due to their practical understanding of how students interact with educational technologies. Their insights ensured that the item phrasing was age-appropriate and clearly interpretable, and aligned with learning contexts. Based on their feedback, 11 items that were observed to be redundant were dropped, and few items were reworded to enhance the understandability. Hence the initial pool was reduced to 30 items.

To validate the benefits quantitatively, we conducted a survey of students studying in higher educational institutions (HEIs) of Delhi – National Capital Region (NCR). 5 different HEIs were selected using convenience sampling, and self-administered questionnaires were distributed to the students of those HEIs. The questionnaire comprised 30 items assessing the perceived benefits of using ChatGPT (see Table 1), measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Additionally, it included demographic questions related to students' gender, level of education, academic discipline, and frequency of ChatGPT usage.

TABLE 1. Items on ChatGPT's benefits

ITEMS	REFERENCE
• ChatGPT enables me to build new knowledge basis existing knowledge. (I1) • ChatGPT helps me gather varied information from various resources. (I2) • ChatGPT can give me specific and tailored answers to my questions. (I3) • ChatGPT can create personalized answers based on my input. (I4) • ChatGPT enhances productivity in task completion. (I5) • ChatGPT simplifies task completion. (I6) • ChatGPT increases my productivity. (I7) • ChatGPT is an effective learning and educational tool (I8) • ChatGPT helps me in meeting my learning objectives. (I9) • ChatGPT assists me in improving my ability to work and is an effective learning tool. (I10)	**Jo (2024)**
• ChatGPT assists me to write articles and essays. (I11) • ChatGPT provides me with the best possible writing ideas. (I12) • ChatGPT provides creative ideas to share with students. (I13) • ChatGPT assists in language translation. (I14) • ChatGPT is an effective tool for problem-solving. (I15)	**Farhi et al. (2023)**
• ChatGPT enhances accuracy in sentence structure. (I16) • ChatGPT provides explanations for language errors. (I17) • ChatGPT helps in improving accuracy of word choice. (I18) • ChatGPT provides particular and specific information on the topic. (I19) • ChatGPT has faster writing speed. (I20)	**Mahapatra (2024)**
• ChatGPT is a helpful and effective tool for learning. (I21) • ChatGPT is good as a complimentary learning resource. (I22) • ChatGPT provides explanations that are effective and appropriate. (I23) • ChatGPT responses are well-structured. (I24)	**Shoufan (2023)**
• ChatGPT can provide personalized tutoring and feedback according to my learning needs and progress. (I25) • ChatGPT can illuminate ideas in writing. (I26) • ChatGPT can provide information in diverse fields. (I27) • ChatGPT can help students save time. (I28) • ChatGPT can assist students understand theories and concepts more effectively. (I29) • ChatGPT is capable of personalizing learning for students by delivering adaptive and individualized learning experiences. (I30)	**Ngo (2023)**

Out of the 600 distributed questionnaires, a total of 528 responses were received, indicating a response rate of 88%. Prior to analysis, rigorous data cleaning process was conducted to ensure data quality and reliability. First, responses were checked for missing data. Questionnaires with substantial missing values (e.g., more than 10% unanswered questions) were excluded, as incomplete data can bias results (Hair et al., 2019). Second, responses were examined for vague or inconsistent answers, such as uniform use of a single response option (e.g., marking all 3s or all 5s), which is indicative of straight-lining or inattentive responding (Meade & Craig, 2012). Third, entries were screened for contradictory responses across related items. In total, 13 responses were excluded based on these criteria, resulting in a final valid sample of 515 responses used for further analysis.

Table 2 indicates the profile of the respondents.

TABLE 2. Sample Profile

Variable	Categories	No. of respondents	Response %
Gender	Female	271	52.6
	Male	244	47.4
Level of education	Under-graduate	312	60.6
	Post-graduate	147	28.5
	Doctoral	56	10.9
Educational discipline	Management	218	42.3
	Engineering	96	18.6
	Science	75	14.6
	Commerce	62	12.0
	Arts and Humanities	23	4.5
	Media and Communication	41	8.0
Frequency of using ChatGPT	Daily	225	43.7
	Weekly	215	41.7
	Occasional	75	14.6

3. RESULTS

We employed EFA and CFA techniques to identify various categories of ChatGPT's benefits. Using the cross-validation approach recommended in the literature (Murphy, 1984), we randomly divided the sample into two parts: part 1 which was considered as the derivation sample, and part 2 which was considered as the calibration sample. The derivation sample comprising 300 responses was used to explore the underlying factor structure through EFA. This sample size was deemed adequate as it satisfies the widely accepted guideline of at least 5 to 10 responses per item (Hair et al., 2019) and meets Comrey and Lee's (1992) classification of 300 as a "good" sample for factor analysis. The calibration sample comprising 215 responses was used to confirm the dimensions of the benefits and ensure their reliability and validity through CFA. A sample of over 200 is considered sufficient for CFA, especially for models of moderate complexity with a reasonable number of constructs (Hair et al., 2019; Kline, 2016). Therefore, both sample sizes meet established psychometric standards for robust factor analytic procedures.

Common Method Bias

To assess the presence of common method variance in the self-reported data, Harman's single-factor test was conducted on the derivation sample (n = 300) prior to EFA. An unrotated principal component analysis was conducted on all observed items. The results revealed that the first factor accounted for only 33.8% of the total variance, which is less than the 50% threshold recommended by Podsakoff et al. (2003). This indicates that common method bias is not a major concern in the present study.

EFA

EFA was conducted using the derivation sample with 30 items. To check the feasibility of employing EFA, we checked the results of Barlett's test of sphericity, which were found to be significant (chi-square = 7551.105, df = 351, $p<0.01$). Further, the Kaiser–Meyer–Olkin (KMO) measure was found to be 0.877 which indicated the relevance of sample size (Hair et al., 2013). Factors were extracted using Principal Component Analysis (PCA) with varimax rotation. PCA was chosen as a data reduction technique to identify key components that account for the maximum variance in the observed variables without assuming any specific underlying latent structure (Hair et al., 2019; Tabachnick & Fidell, 2013). Given the exploratory nature of this study and the focus on identifying dimensions of ChatGPT's perceived benefits, PCA served as a robust method to extract the most interpretable factor solution. Moreover, varimax rotation, which is an orthogonal rotation method, was applied to maximize the variance of squared loadings within each factor and enhance interpretability by minimizing cross-loadings (Field, 2018). This is particularly useful in early-stage scale development where the assumption is that extracted dimensions are relatively independent. Unlike other methods such as Maximum Likelihood (ML) estimation which are more suitable for confirmatory purposes (Fabrigar et al., 1999), PCA is widely recommended when the objective is to summarize data and explore its underlying structure. Hence, PCA with varimax rotation was considered appropriate and adequate for identifying preliminary factor structure prior to model confirmation through CFA.

Following the recommendations of Hair et al. (2013), we deleted 3 items (i.e., I10, I15, and I20) that had factor loadings < 0.5. This resulted in 27 items. The eigenvalue criterion (Hair et al., 2013) was applied to determine the number of factors to retain, with factors having eigenvalues greater than 1 being considered for inclusion. Using this criterion, six factors were extracted, which explained 78.239% variance in the data. Table 3 indicates the eigen values of the extracted factors.

TABLE 3. Eigen Values

Factor	Eigen value	% of variance	Cumulative % of variance
1	9.148	33.882	33.882
2	4.019	14.886	48.768
3	2.887	10.691	59.459
4	2.509	9.292	68.752
5	1.431	5.299	74.050
6	1.131	4.188	78.239

Table 4 shows the loadings of items on the extracted factors. As can be observed from the table, the items I21, I22, I23, I24, I29, I8 and I9 loaded together on one factor. As these items encompass the various aspects of how ChatGPT aids in the learning process, we labelled this factor as "Learning support" (LS). The next factor was labelled as "Content generation" (CG) as the items loaded on this factor (i.e. I11, I12, I13 and I14) indicate how ChatGPT can facilitate content generation by providing writing ideas to students. The factor related to the items I1, I2, I27, and I19 was labelled as "Knowledge acquisition" (KA), as these items involve ChatGPT's usage for expanding the existing knowledge and generating new insights. The next factor was named as

"Personalized learning" (PL) as the items loaded on this factor (i.e. I3, I4, I25 and I30) are related to ChatGPT's ability to adapt to the unique requirements of students. The next factor was found to be related to the items I16, I17, I18 and I26, which indicate how ChatGPT assists students in refining and structuring their ideas, thereby enhancing the clarity of their written work. Hence, we named this factor as "Academic writing" (AW). Finally, the items I5, I6, I7 and I28 loaded together which indicate how ChatGPT enables students to complete their tasks more effectively and efficiently. Hence the factor underlying these items was labelled as "Efficiency" (EF).

TABLE 4. Factor loadings

Factor	Item code	Item	Item loadings					
			1	2	3	4	5	6
Learning support (LS)	I21	ChatGPT is a helpful and effective tool for learning	0.762					
	I22	ChatGPT is good as a complimentary learning resource	0.750					
	I23	ChatGPT provides explanations that are effective	0.747					
	I24	ChatGPT responses are well-structured	0.733					
	I29	ChatGPT can assist students understand theories and concepts more effectively	0.727					
	I8	ChatGPT is an effective learning and educational tool	0.709					
	I9	ChatGPT helps me in meeting my learning objectives	0.686					
Content generation (CG)	I11	ChatGPT assists me to write articles and essays		0.924				
	I12	ChatGPT provides me with the best possible writing ideas		0.909				
	I13	ChatGPT provides creative ideas to share with students		0.889				
	I14	ChatGPT assists in language translation		0.838				
Knowledge acquisition (KA)	I1	ChatGPT enables me to build new knowledge basis existing knowledge			0.850			
	I2	ChatGPT helps me gather varied information from various resources			0.824			
	I27	ChatGPT can provide information in diverse fields			0.778			
	I19	ChatGPT provides particular and specific information on the topic			0.777			
Personalized learning (PL)	I3	ChatGPT can give me specific and tailored answers to my questions				0.894		
	I4	ChatGPT can create personalized answers based on my input				0.879		
	I25	ChatGPT can provide personalized tutoring and feedback according to my learning needs and progress				0.878		
	I30	ChatGPT i capable of personalizing learning for students by delivering adaptive and individualized learning experiences.				0.844		

Factor	Item code	Item	Item loadings					
			1	2	3	4	5	6
Academic writing (AW)	I16	ChatGPT enhances accuracy in sentence structure					0.849	
	I17	ChatGPT provides explanations for language errors					0.817	
	I18	ChatGPT helps in improving accuracy of word choice					0.787	
	I26	ChatGPT can illuminate ideas in writing					0.747	
Efficiency (EF)	I5	ChatGPT enhances productivity in task completion						0.924
	I6	ChatGPT simplifies task completion						0.908
	I7	ChatGPT increases my productivity						0.872
	I28	ChatGPT can help students save time						0.772

The internal consistencies of the 6 factors extracted through EFA, was assessed using Cronbach's alpha coefficients (see Table 5). All factors exhibited high internal consistency, with Cronbach's alpha coefficients exceeding the 0.70 threshold (Nunnally & Bernstein, 1994).

TABLE 5. Internal consistency

Factor	No. of Items	Cronbach's alpha coefficient
Learning support	7	0.917
Content generation	4	0.941
Knowledge acquisition	4	0.950
Personalized learning	4	0.905
Academic writing	4	0.889
Efficiency	4	0.900

CFA

To confirm the factorial structure and validate the reliability and validity of the factors emerged from EFA, we performed CFA using the calibration sample of 215 responses. CFA was conducted using two software packages i.e. WarpPLS and AMOS. The dual use of these platforms was adopted to enhance the robustness and credibility of the model evaluation. WarpPLS employs a Partial Least Squares Structural Equation Modeling (PLS-SEM) approach, which is variance-based and is primarily used for prediction-oriented analysis with relatively smaller sample sizes (Hair et al., 2019; Kock, 2017). On the other hand, AMOS employs a Covariance-Based Structural Equation Modeling (CB-SEM) approach, which is used for theory testing (Hair et al., 2019; Kline, 2016). The use of both methods ensured a comprehensive validation of the measurement model by addressing both predictive relevance (via PLS-SEM) and model fit adequacy (via CB-SEM).

CFA with WarpPLS

Firstly, CFA was applied through WarpPLS software (Kock, 2017). We assessed a measurement model comprising 27 items related to 6 factors that were extracted through EFA. Table 6 indicates the fit indices for the measurement model. As can be noted from table 6, the indices indicated a good fit to the data (Kock, 2015).

TABLE 6. Goodness of fit indices

Model fit index	Cut off criterion	Value
Average path coefficient (APC)	Significant	0.203, P<0.001
Average R-squared (ARS)	Significant	0.302, P<0.001
Average adjusted R-squared (AARS)	Significant	0.285, P<0.001
Average block VIF (AVIF)	<= 3.3	1.306
Average full collinearity VIF (AFVIF)	<= 3.3	1.528
Tenenhaus GoF (GoF)	>= 0.36	0.492
Sympson's paradox ratio (SPR)	>= 0.7	1
R-squared contribution ratio (RSCR)	>= 0.9	1
Statistical suppression ratio (SSR)	>= 0.7	0.800
Nonlinear bivariate causality direction ratio (NLBCDR)	>= 0.7	0.800

Table 7 illustrates the results of CFA. As can be observed from the table, the standardized loadings of all items were significant (p<0.001) and greater than 0.50, thereby providing support for indicator reliability (Hair et al., 2013). Further, the values of composite reliability (CR), as well as Cronbach's alpha (CA) for all 6 factors were above 0.70, which indicated their reliability (Hair et al., 2013). The values of average variance extracted (AVE) of all factors were greater than 0.50, which provided support for convergent validity (Fornell & Larcker, 1981).

TABLE 7. Confirmatory factor analysis (reliability and convergent validity) - WarpPLS

Factor	Item code	Item	Item loading	CR	CA	AVE
Learning support (LS)	I21	ChatGPT is a helpful and effective tool for learning	0.908	0.954	0.944	0.749
	I22	ChatGPT is good as a complimentary learning resource	0.891			
	I23	ChatGPT provides explanations that are effective	0.878			
	I24	ChatGPT responses are well-structured.	0.883			
	I29	ChatGPT can assist students understand theories and concepts more effectively	0.814			
	I8	ChatGPT is an effective learning and educational tool	0.854			
	I9	ChatGPT helps me in meeting my learning objectives	0.825			

Factor	Item code	Item	Item loading	CR	CA	AVE
Content generation (CG)	I11	ChatGPT assists me to write articles and essays	0.907	0.963	0.948	0.866
	I12	ChatGPT provides me with the best possible writing ideas	0.910			
	I13	ChatGPT provides creative ideas to share with students	0.962			
	I14	ChatGPT assists in language translation	0.942			
Knowledge acquisition (KA)	I1	ChatGPT enables me to build new knowledge basis existing knowledge	0.957	0.971	0.960	0.893
	I2	ChatGPT helps me gather varied information from various resources	0.959			
	I27	ChatGPT can provide information in diverse fields	0.937			
	I19	ChatGPT provides particular and specific information on the topic	0.927			
Personalized learning (PL)	I3	ChatGPT can give me specific and tailored answers to my questions	0.791	0.899	0.850	0.691
	I4	ChatGPT can create personalized answers based on my input	0.863			
	I25	ChatGPT can provide personalized tutoring and feedback according to my learning needs and progress	0.830			
	I30	ChatGPT is capable of personalizing learning for students by delivering adaptive and individualized learning experiences	0.839			
Academic writing (AW)	I16	ChatGPT enhances accuracy in sentence structure	0.885	0.930	0.900	0.769
	I17	ChatGPT provides explanations for language errors	0.888			
	I18	ChatGPT helps in improving accuracy of word choice	0.881			
	I26	ChatGPT can illuminate ideas in writing	0.853			
Efficiency (EF)	I5	ChatGPT enhances productivity in task completion	0.934	0.954	0.934	0.839
	I6	ChatGPT simplifies task completion	0.956			
	I7	ChatGPT increases my productivity	0.813			
	I28	ChatGPT can help students save time	0.952			

To establish discriminant validity, the correlation coefficients between constructs were compared with the square roots of the Average Variance Extracted (AVE) (see Table 8 in next page). Since all inter-construct correlations (off-diagonal) were lower than the corresponding square roots of AVE (reported on diagonal), discriminant validity was supported in accordance with Fornell and Larcker (1981). Additionally, the heterotrait–monotrait (HTMT) ratio was employed as a complementary method. As shown in Table 9, all HTMT values were below the recommended threshold of 0.85 (Henseler et al., 2015), further confirming discriminant validity.

TABLE 8. Discriminant validity - WarpPLS

	LS	CG	KA	PL	AW	EF
LS	**0.865**					
CG	0.207	**0.93**				
KA	0.631	0.128	**0.945**			
PL	-0.034	0.137	0.114	**0.831**		
AW	0.515	0.033	0.582	0.132	**0.877**	
EF	0.346	-0.045	0.177	0.034	0.319	**0.916**

TABLE 9. Discriminant validity - WarpPLS (HTMT Ratios)

	LS	CG	KA	PL	AW	EF
LS						
CG	0.219					
KA	0.664	0.134				
PL	0.071	0.152	0.125			
AW	0.559	0.047	0.625	0.152		
EF	0.370	0.050	0.189	0.075	0.349	

CFA with AMOS

To further validate the measurement model, CFA was performed with AMOS. During the model estimation, three items i.e. LS2, EF4, and PL4 were removed due to low standardized factor loadings (< 0.70). This threshold is commonly used to ensure adequate indicator reliability and convergent validity (Byrne, 2016; Hair et al., 2019). Moreover, based on the modification indices, the error terms of items KA2 and KA4 were allowed to covary. This adjustment was theoretically justified as both items shared conceptual similarity (Byrne, 2016). Allowing their errors to covary led to a better-fitting model without undermining construct validity. The final model was assessed using well-established fit indices, including the χ^2/df, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR). The model demonstrated acceptable fit with the following results: $\chi^2/df = 2.27$, CFI = 0.944, TLI = 0.935, RMSEA = 0.077, and SRMR = 0.053. These values fall within the commonly recommended thresholds (CFI, TLI > 0.90; RMSEA, SRMR < 0.08), indicating an adequate fit between the data and the hypothesized model (Byrne, 2016; Hu & Bentler, 1999).

To assess the reliability and validity of the model constructs, we examined the standardized item loadings, omega reliability coefficients, and AVE values (see Table 10 in next page). All standardized loadings exceeded the recommended threshold of 0.70 (Hair et al., 2019), thereby indicating strong indicator reliability. The omega coefficients for all constructs were above 0.80, suggesting high internal consistency (McNeish, 2018). Moreover, AVE values for all constructs exceeded the recommended threshold of 0.50, thereby supporting convergent validity (Fornell & Larcker, 1981).

Discriminant validity was evaluated using the Fornell–Larcker (1981) criterion (see Table 11 in next page). For all the constructs, the square roots of the AVEs were greater than the inter-construct correlations. Hence, discriminant validity was ensured for the model constructs (Fornell & Larcker, 1981; Hair et al., 2019).

TABLE 10. Confirmatory factor analysis (reliability and convergent validity) – AMOS

	ITEM	STANDARDIZED LOADING	OMEGA INDEX	AVE
AW	AW1	.835	0.900	0.692
	AW2	.863		
	AW3	.838		
	AW4	.790		
PL	PL1	.806	0.833	0.623
	PL2	.781		
	PL3	.781		
	PL4	.699	—dropped—	
CG	CG1	.990	0.945	0.813
	CG2	.958		
	CG3	.825		
	CG4	.820		
EF	EF1	.989	0.961	0.893
	EF2	.974		
	EF3	.867		
	EF4	.676	—dropped—	
KA	KA1	.984	0.952	0.833
	KA2	.884		
	KA3	.952		
	KA4	.822		
LS	LS1	.976	0.932	0.699
	LS3	.960		
	LS4	.818		
	LS5	.719		
	LS6	.796		
	LS7	.706		
	LS2	.669	—dropped—	

TABLE 11. Discriminant validity – AMOS

Construct	AW	PL	CG	EF	KA	LS
AW	**0.832**					
PL	0.141	**0.789**				
CG	0.044	0.173	**0.902**			
EF	0.313	0.006	–0.042	**0.945**		
KA	0.594	0.136	0.169	0.161	**0.913**	
LS	0.551	–0.043	0.184	0.336	0.601	**0.836**

Note: Diagonal elements indicate square roots of AVE

4. DISCUSSION

The study quantitatively analyzed the benefits of using ChatGPT from students' perspectives. The results indicate six key categories, namely Learning Support, Content Generation, Knowledge Acquisition, Personalized Learning, Academic Writing, and Efficiency. Each category reflects different aspects of how ChatGPT enhances the educational experience for students.

Learning Support

Learning support encompasses the various aspects of how ChatGPT aids in the learning process of students. As per the above findings, it can be observed that students consider ChatGPT to be a highly beneficial tool for their learning process. ChatGPT supports learning by providing clear and well-structured explanations, and making complex concepts more understandable. ChatGPT can break down complex topics into more understandable segments, thereby reducing cognitive load and enhancing comprehension. The ability of ChatGPT to simplify complex theories and concepts is particularly valuable in fields that require deep analytical thinking, such as science, technology, engineering, and mathematics (STEM). This finding aligns with those of Shoufan (2023) and Ngo (2023), who noted that ChatGPT makes challenging topics more understandable to students by using simpler language and providing relatable examples. This simplification not only aids in understanding but also boosts students' confidence in tackling difficult subjects, which can lead to increased engagement and improved academic performance. Moreover, ChatGPT can also serve as an excellent complementary learning resource, filling in gaps that may exist in students' understanding after traditional instruction. By offering diverse resources and supplementary information, ChatGPT enhances students' overall learning experience, ensuring they have access to a wide array of knowledge (Javaid et al., 2023).

Content Generation

The study also highlighted content generation as one of the key benefits of using ChatGPT. Content generation encompasses the ways in which ChatGPT assists students in creating written content. Our findings indicate that ChatGPT helps students in writing reports, essays and articles, which is a fundamental part of their academic work. Such support is particularly valuable in the early stages of content creation, where generating ideas and organizing thoughts can be challenging for students. ChatGPT can streamline this process by offering structured outlines and guiding students through the development of their arguments (Haleem et al., 2022; Vázquez-Cano et al., 2023). Moreover, ChatGPT's ability to provide a wide range of ideas, based on specific queries can help students explore different perspectives for their assignments and projects. Our finding is in line with that of Vázquez-Cano et al. (2023) who demonstrated that the summaries obtained through ChatGPT are outstanding in terms of content and style.

Knowledge Acquisition

Knowledge acquisition emerged as another benefit of using ChatGPT. The findings reveal that students perceive ChatGPT as a valuable tool for expanding their knowledge base. ChatGPT not only enables them to

build on their existing knowledge, but also help them acquire new information across various subjects. This benefit is crucial in today's educational environment, where the ability to rapidly acquire and integrate new knowledge across various disciplines is highly valued. Such cross-disciplinary knowledge not only gives an impetus to the learning process of students but also enables them to deal with the complexities of real-world problem-solving. ChatGPT's access to various learning resources allows students to explore topics in depth and from multiple perspectives, thus enriching their overall educational experience. This aligns with research by Jo (2024), who opine that ChatGPT contributes to knowledge acquisition by providing information that is immediate, accurate and personalized. By expanding students' knowledge base and providing them access to diverse information, ChatGPT serves as an invaluable tool in modern education, where knowledge acquisition and application are key to academic success.

Personalized Learning

The findings of our study suggest personalized learning as another impactful benefit of using ChatGPT. This benefit is characterized by ChatGPT's ability to customize its responses according to the personalized needs of individual students. Such customization allows students to receive relevant information that is tailored according to their current understanding and learning goals. Prior studies (e.g. Firat, 2023) indicate that personalized responses from ChatGPT can lead to more effective learning outcomes, by removing barriers such as shyness and hesitation in asking questions. ChatGPT also enhances personalized learning by offering adaptive learning experiences. It can adjust its level of complexity and the nature of its responses according to the student's progress, thereby providing a learning experience that evolves with the student. This adaptability is crucial for keeping students engaged and motivated (Rasul et al., 2023).

Academic Writing

The study identified academic writing as another benefit of ChatGPT. Our findings indicate that students perceive that ChatGPT can help improve sentence structure, vocabulary accuracy, and overall writing quality. ChatGPT plays a crucial role in refining and editing text. After drafting their content, students can use ChatGPT to refine their work by improving grammar, sentence structure, and overall clarity. ChatGPT's abilities to suggest grammatical corrections and alternative phrasing of the text, help students enhance their writing proficiency and produce more professional reports (Vázquez-Cano et al., 2023). Our finding resonates with those of Mahapatra (2024) who observed that ChatGPT has a positive impact on academic writing skills. ChatGPT provides real-time feedback on grammatical errors, which is particularly beneficial for students who may struggle with nuances of academic writing in English language (Mahapatra, 2024).

Efficiency

Finally, the study that ChatGPT is considered as a valuable aid for increasing efficiency and productivity by enabling faster task completion. In today's dynamic educational environment, time management and productivity are key to academic success. ChatGPT serves as a very useful tool for students by reducing the time spent on information retrieval. Instead of spending hours searching for reliable information from various

sources, students can use ChatGPT to quickly gather and organize the information they need (Jo, 2024; Ngo, 2023). This efficiency in accessing and utilizing information not only saves students' time but also enhances the depth and quality of their academic work. ChatGPT also boosts students' productivity by helping them manage their workload more effectively. By offering tools for idea generation, content organization and content refinement, ChatGPT enables students to work more efficiently and produce higher-quality work in less time (Albadarinet al., 2024).

5. CONCLUSIONS

On the basis of our findings, it can be concluded that ChatGPT can serve as an important tool in modern learning ecosystem. By providing learning support to students, and enabling them to acquire knowledge, generate content, improve academic writing, and efficiency, ChatGPT can significantly contribute to their academic success. By presenting empirical evidence of ChatGPT's benefits, this study contributes to the growing research on AI in education. It extends existing research by categorizing these benefits into distinct dimensions based on empirical evidence. Practically, the study provides valuable insights for educators, academic institutions, and policymakers on how to effectively integrate ChatGPT and similar AI tools into the curriculum. Educators can leverage the identified benefits of using ChatGPT, to improve student engagement and performance. They should explore ways how to integrate ChatGPT and other AI tools with their teaching pedagogies and also teach students to use it ethically and beneficially. Considering the interest and inclination of students towards using ChatGPT, academic institutions should consider investing in AI tools such as ChatGPT. AI tools can be integrated into teaching and learning processes to enrich students' academic experiences. Further, the policymakers should support the adoption of AI tools in education through funding, training, and development of guidelines/policies that ensure the ethical use of such tools. As the educational landscape continues to evolve with rapid technological advancements, understanding the practical benefits of AI tools such as ChatGPT becomes essential for shaping the future of learning.

5.1. Limitations and future lines of research

Although the study highlights several key benefits associated with ChatGPT, it has a few limitations that should be addressed in future studies. Firstly, the study relies on a convenience sample drawn from a single region in India, which may restrict the broader applicability of its findings. Future research could enhance the validity of the proposed framework on ChatGPT's benefits by employing more diverse and representative samples. Secondly, the findings of the study are based on students' perspectives only. Future studies could explore the perspectives of teachers to have a more holistic idea of the benefits of ChatGPT. Thirdly, the study hasn't explored the interrelationships of the identified categories of benefits. Future studies could explore those relationships and can also examine the impact of these benefits on educational outcomes such as student engagement and motivation. Fourth, the study did not consider potential cultural or national differences in how students perceive and use ChatGPT. Future research could investigate cross-cultural perspectives to deepen the relevance and generalizability of the findings. Finally, the study did not perform comparative analyses between the eliminated and retained questionnaires. While responses were excluded

based on criteria such as incompleteness or vague answering patterns, the study didn't explore whether these excluded participants differed systematically from the retained ones. Future studies are encouraged to test for such differences.

6. AUTHOR CONTRIBUTION

Conception and Design – Author 1.
Acquisition of data – Author 2.
Analysis and interpretation of Data – Author 2.
Drafting the article- Author 1.
Revising it for intellectual content – Author 1, Author 2.
Final approval of the completed article – Author 1, Author 2.

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Future Mathematics Teachers' Perceptions of Using ChatGPT in the Classroom

Percepciones de los futuros profesores de matemáticas sobre el uso de ChatGPT en el aula

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Mustafa Güler
ORCID: 0000-0002-4082-7585
Trabzon University, Turkey
mustafaguler@trabzon.edu.tr

Erdem Çekmez
ORCID: 0000-0001-8684-2820
Trabzon University, Turkey
erdemcekmez@trabzon.edu.tr

Zeynep Arslan
ORCID: 0000-0002-7864-0636
Trabzon University, Turkey
zeyneparslan@trabzon.edu.tr

ABSTRACT

Although artificial intelligence (AI) has become a potential driver in the field of education, little is known about stakeholders' perspectives. To address this issue, this qualitative inquiry paper attempted to determine the views of pre-service teachers regarding the role of AI in mathematics instruction. A total of 72 pre-service mathematics teachers participated in the survey, which consisted of open-ended questions. The gathered data was analyzed by seven-phase method. Although pre-service teachers believe ChatGPT can support students in terms of cognitive and affective factors, it has some disadvantages including preventing thinking and ethical concerns. In addition, the study reports the areas in which the participants thought of using ChatGPT in mathematics education. Finally, the paper discusses the use of ChatGPT in educational settings and applications of AI in teacher education.

KEYWORDS Artificial Intelligence, ChatGPT, Mathematics education, Future Teachers, Perspectives

RESUMEN

Aunque la inteligencia artificial (IA) se ha convertido en un motor potencial en el ámbito de la educación, se sabe poco sobre las perspectivas de las partes interesadas. Para abordar esta cuestión, este trabajo de investigación cualitativa trató de determinar las opiniones de los profesores en formación sobre el papel de la IA en la enseñanza de las matemáticas. Un total de 72 profesores de matemáticas en formación participaron en la encuesta, que consistió en preguntas abiertas. Los datos recogidos se analizaron mediante el método de siete fases de Lester et al. (2020). Aunque los PT creen que ChatGPT puede apoyar a los estudiantes en términos de factores cognitivos y afectivos, tiene algunas desventajas, incluyendo la

prevención del pensamiento y las preocupaciones éticas. Además, el estudio informa de las áreas en las que los participantes pensaban utilizar ChatGPT en la enseñanza de las matemáticas. Por último, el artículo analiza el uso de ChatGPT en entornos educativos y las aplicaciones de la IA en la formación de profesores.

PALABRAS CLAVE inteligencia artificial, ChatGPT, educación matemática, futuros profesores, perspectivas

1. INTRODUCTION

Artificial intelligence (AI) is a common product of advances in computer, machine and information communication technologies and is a technology that allows technological tools to perform human-like actions (Chen et al., 2020). These platforms have the potential to present information in various formats to users by using a data repository. These technologies are believed to have the potential to change approaches and common practices in education (Mhlanga, 2023). With the growing popularity of AI systems, researchers are increasingly focusing on how these technologies can be used in education. This popularity is partly driven by factors such as more students achieving targeted learning outcomes and improved access to supportive teaching resources when needed (Ahmad et al., 2021; Wang-Kin, 2021; Zhang & Aslan; 2021). In this respect, Mohamed et al. (2022) stated that the use of AI in teaching can turn the learning process more interactive for students.

ChatGPT (OpenAI, n.d.) is one of the promising AI technologies that can perform human-like dialogs due to its natural language processing capability (Lim et al., 2023). It operates on a huge quantity of data, therefore can compose appropriate feedback based on the user input. The platform operates on the basis of complex algorithms to compose accordant output for users' demand, and it is constantly evolving based on its interaction with users, which causes it to turn into a more capable form (Mhlanga, 2023).

By using a documentary analysis approach, Mhlanga (2023) addressed the question of what future and current effects that ChatGPT offer in the field of education. One of the effects reported was that ChatGPT offers the opportunity to create intelligent tutoring systems where students can experience individualized learning. In this respect, the software can increase the participation of students by determining their knowledge deficiencies from the inputs provided by them, and then shaping the teaching process as necessary. In addition, he emphasized that the software has the function of suggesting learning materials to students, taking into account their learning priorities and interests. In this respect, he stated that ChatGPT can optimally adjust the limits of the content and the speed of presentation of information, without causing mental burnout, by monitoring the development of students throughout learning process. Chung (2023) summarized the possible contributions of ChatGPT, mentioned by educators in the literature, to students as finding answers to problems, summarizing information, facilitating collaboration, an auxiliary tool in preparation for exams, drafting assistance and providing feedback. In another study, Castillo et al. (2023) investigated the experiences of Peruvian university students about ChatGPT. The findings of the study showed that students thought that the responses provided by ChatGPT are accurate and it has a user friendly interface. As a result of this positive attitude, it has been determined that the software is widely used among students as an auxiliary tool in completing their homework and comprehending difficult-to-understand content. Besides students, ChatGPT also has the potential to support educators. As a result of his literature review,

Chung (2023) reported that educators utilized ChatGPT to develop course materials, decide how to approach students with special needs, perform language translation, prepare assessment tasks and evaluate student performance.

In addition to the potential benefits, the emergence of the software has also raised some doubts and concerns among educators. One of the main concerns is that students use ChatGPT entirely for answering exam questions —referred to as AI-assisted cheating— so that teachers do not get a sense of what students are learning (Chung, 2023; Guo & Wang, 2025). In order to avoid this undesirable situation some researchers have suggested differentiating the structure of the exams. In this regard, Zhai (2022) proposes the creation of new assessment formats that include questions that emphasize creativity and critical thinking that ChatGPT cannot handle. Choi et al. (2023) recommend instructors restricting students' access to ChatGPT in the examinations, and also asking questions that require not only recalling but also analyzing factual knowledge. Similarly, Stutz et al. (2023) state that the exams consisting of questions belonging to the higher levels of Bloom's taxonomy, such as analysis, may be a precaution against this issue. Another reported drawback of the software is that students can have their homework solved directly by ChatGPT without having to think about it, and this, in turn, may prevent them from acquiring the targeted competencies (Sánchez-Ruiz, et al., 2023). In addition, the fact that students use ChatGPT too often may cause them to become too dependent on ChatGPT in the problem-solving process and in accessing information, thus not developing critical thinking skills and not building self-confidence (Sánchez-Ruiz, et al., 2023). Considering all that has been said, it is seems reasonable to expect that if students constantly resort to ChatGPT to overcome the difficulties they face in the learning process, this will weaken the interaction between teachers and students and teachers will not be able to monitor students' progress.

1.1. ChatGPT in the context of mathematics education

Published research on the use of ChatGPT in mathematics education state that the inclusion of ChatGPT in the teaching process will provide many advantages. The software is claimed to have great potential in solving mathematical problems and learning mathematical knowledge, besides, it can be used as a tool by teachers to give feedback to students and evaluate student achievement (Wardat et al., 2023). Wu (2021) argued that the introduction of AI-assisted teaching has an extremely effective on basic mathematics education and teaching. As a result of their literature review Mohamed et al. (2022) concluded that ChatGPT will make students more critical and responsible for solving everyday problems, and will allow them to better understand algebra, geometry, statistics, and helps students gain mathematical and cognitive skills. In support of these results, Sánchez-Ruiz, et al. (2023) state that ChatGPT is a tool that can help in learning mathematics, as it provides opportunities for easy access to large sets of information and extensive support in doing homework. Apart from providing answers to mathematical problems, the authors assert that the software allows students to better understand the problem-solving process as it explains step by step how to solve them as well.

To determine how ChatGPT performs on mathematical problems that differ in difficulty and content, Dao and Le (2023) examined ChatGPT's ability on the questions that appeared in the Vietnamese national high school graduation examination. For this purpose, drawing on the Bloom taxonomy the authors divided

the questions that appeared in the relevant exam into four sets: knowledge, comprehension, application and high application. A second classification was carried out for the subject area to which the questions belonged. The findings of the study showed that the success rate of the software dramatically changed with respect to both difficulty and subject area. While the success rate of the software is between 75% and 90% in the questions classified as knowledge level in the exams held between 2019-2023, it was between 0% and 22% in the questions classified as high application. In particular, the inability of the software to interpret and make sense of graphics in questions containing graphical information has caused it to not be successful in problem solving processes that require visual reasoning.

In another study Wardat et al. (2023) aimed to investigate the views of math educators based on their experience of the use of ChatGPT. Because the software can take on the role of a personal assistant, keep up with a student's learning pace, and support the understanding of mathematical concepts, the participants of the study generally agreed that ChatGPT was very useful for students who needed help in the problem-solving process. Especially in the field of Euclidean geometry, the participants believed that the software is very competent to provide instructional guidance to students. Another shared belief among the participants was that the software is very successful in having students comprehend difficult mathematics topics in a clear way. Aside from positive features, the authors made a few caveats regarding the use of the software. They revealed that the software did not demonstrate a deep understanding regarding geometry, hence was not able to properly correct misconceptions. In addition to this, the validity of the solutions provided by ChatGPT to mathematical problems depended on a number of factors such as the quality of the input data, complexity of the equation, and the clarity of the written instructions to the system. The authors conclude that ChatGPT can be a useful instructional tool on condition that guidelines for fair usage are developed.

As it is understood from the opinions and views of the educators about ChatGPT, the software has possible positive and negative effects on the learning process and it is necessary to think about what kind of arrangements should be made on how to use the software in order to benefit from it. It seems important and an open issue to establish the necessary principles for its fair and responsible use and maximum benefit. The existing body of literature predominantly examines the advantages and drawbacks of ChatGPT in the realm of mathematics education through the lens of researchers or educators. Yet, the viewpoints of prospective teachers, who possess a degree of proficiency with such software, regarding the potential merits and drawbacks of these tools, have not been extensively explored. Consequently, there exists an unanswered query regarding the perceptions of these individuals. This study seeks to address this gap in the current literature. With this in mind, this paper examines the perspectives of pre-service mathematics teachers regarding the use of ChatGPT in mathematics classrooms.

2. MATERIAL AND METHOD

2.1. Research Design

The present study employs a qualitative descriptive methodology, as advocated by Yin (2002), to investigate the perceptions of prospective educators regarding the integration of ChatGPT in mathematics education. A structured questionnaire was administered through Google Forms to pre-service mathematics teachers

in their final semester. Qualitative research methodologies are commonly utilized to gain a comprehensive insight into a specific phenomenon. Such studies have the potential to provide valuable insights that can inform educational practices, as demonstrated by Lochmiller (2016), and to elucidate the intricacies of individuals' experiences and the underlying meanings of their actions, as highlighted by Ravindran (2019).

2.2. Participants

The participants of this study consisted of 72 pre-service mathematics teachers enrolled in the mathematical modelling course. Therefore, it can be stated that a purposive sampling method (Kanaki & Kalogiannakis, 2023) was employed. The researcher conducting the study, who is also the instructor for the course, implemented diverse instructional strategies to enhance the learning experience. As part of this, the first three weeks of the course were dedicated to the use of AI tools in education. In the first week, a software engineer affiliated with Amazon UK was brought in to deliver a comprehensive presentation on ChatGPT to the pre-service teachers (PTs). Subsequently, the participants were tasked with engaging in a series of activities during the subsequent two weeks. Students were asked to perform tasks, including but not limited to those in Fig. 1. The reason for giving tasks was to enable PTs to interact with ChatGPT and compare the answers they received with their existing knowledge and to develop a critical perspective towards this tool. To conclude the study, the participants were requested to complete a survey comprising open-ended inquiries aimed at eliciting their perspectives on the integration of ChatGPT within mathematics education settings.

FIGURE 1. Examples of tasks given to students

1. What are the types of proofs in mathematics? What are the stages of these types of proofs? (Test the theorems whose proofs you know here)
2. What is a lesson plan? Which components does it consist of?
3. Pose a word problem about linear equations. Then solve this problem.
4. What are effective teaching strategies for the concept of variable in algebra?
5. What are the common misconceptions students have about probability?

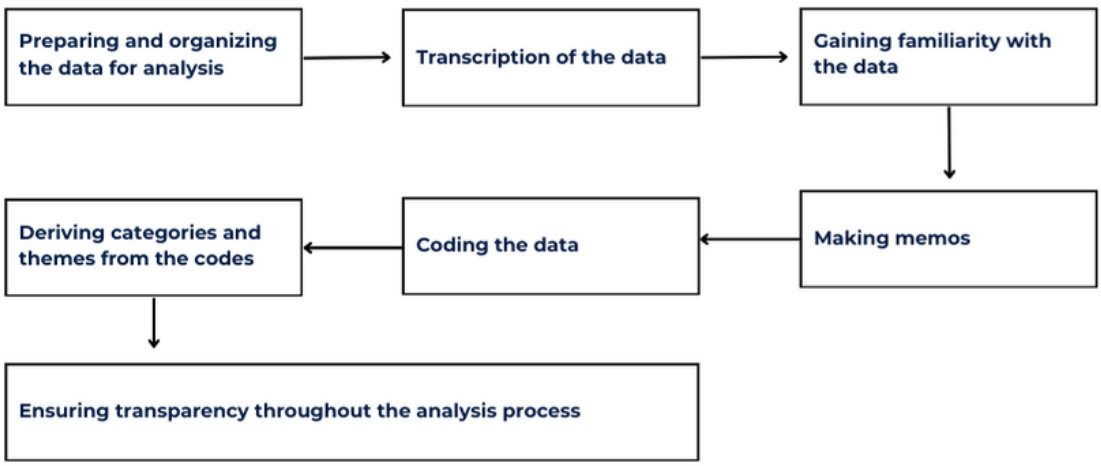
2.3. Instrument

Questionnaires are frequently employed as a method to investigate the beliefs and attitudes held by a specific subset of the population (Marshall & Rossman, 2014). The present research endeavor was undertaken to delve into the perspectives of prospective mathematics teachers regarding the integration of ChatGPT within mathematics instructional settings. To achieve this aim, a questionnaire devised by the researchers was administered to elicit and evaluate the viewpoints of these individuals. The questionnaire was disseminated using Google Forms to individuals enrolled in their final semester of pre-service mathematics teacher education. The questionnaire comprised open-ended inquiries designed to uncover various insights, including the likelihood of candidates incorporating ChatGPT into their teaching practices, their reflections on its potential benefits and drawbacks, as well as the anticipated impact on the traditional role of the teacher. For a selection and the purpose of each questions, please refer to Appendix 1.

2.4. Data Collection and Analysis

The process of qualitative data analysis is characterized by its non-linear and iterative nature, leading researchers to refrain from adhering to a strictly sequential analytic procedure (Lester et al., 2020). In response to the inherent complexity that can ensue from this approach, Lester et al. (2020) have proposed a structured methodology comprising seven distinct phases. These phases encompass initial tasks such as data preparation and organization, transcription of data, gaining familiarity with the data corpus, making memos, coding the data, deriving categories and themes from the coded content, and ensuring transparency throughout the analysis process (see Fig. 2). In the present research, the methodology employed by the researchers for data management involved aforementioned approach. Initially, the data collected through Google Forms was structured and transcribed into Microsoft Word. Subsequently, the researchers engaged in multiple independent readings of the compiled data to gain a comprehensive understanding. To facilitate a preliminary comprehension of the dataset, an initial analysis was conducted by the researchers prior to embarking on an in-depth examination. During this phase, provisional codes were formulated to categorize the data. Subsequently, with the aid of memos, the process of coding the data commenced. This phase entailed linking statements within the dataset to specific codes, thereby enabling the derivation of overarching themes from the textual passages. At the conclusion of this phase, data coding commenced with the aid of memos. During this process, textual statements were systematically linked to specific codes, and overarching themes were derived from these coded segments. The analysis of the gathered data was conducted through the application of constant comparative analysis, as outlined by Merriam (1998). Initially, each researcher independently scrutinized the data to pinpoint recurring patterns and themes. Subsequently, a collaborative session was held where the two researchers deliberated on their individual analyses, compared their findings, and collectively honed in on the principal areas of growth that surfaced from the identified common themes.

FIGURE 2. **The seven steps in the Analysis of the Data**



3. RESULTS

PTs' responses were grouped under three headings: advantages, disadvantages, and possible classroom applications of ChatGPT.

3.1. Advantages of the Use of ChatGPT

The statements of pre-service mathematics teachers regarding the advantages of using ChatGPT emerged under five themes: enhancing the learning experience, facilitating the teacher's responsibilities, increasing student motivation, providing access to information, and improving student performance and skills. Codes related to the themes are summarized in Table 1.

TABLE 1. PTs' views on the advantages of the use of ChatGPT

MAJOR THEMES	MINOR THEMES	CODES
Enhancing the Learning Experience	Content diversity and richness	Access to different resources Presentation of different learning materials
	Personalized learning	Providing a special working environment for the student Providing a learning experience according to the students' needs
Facilitating the teacher's responsibilities	Providing materials and resources	Increasing the variety of activities and materials Providing access to ready-to-use resources
	Time saving	Helping to use time effectively Saving time and effort
Increasing Student Motivation	Making lessons interesting	Lecturing based on new technologies Providing learning opportunities for students' interests
	Opportunity for interaction and feedback	Providing immediate feedback to students Providing interactive learning experiences that increase motivation
Providing Access to Information	Fast and easy access to information	Providing quick access to accurate and up-to-date information Enhancing the efficiency of students' research endeavors
Improving Student Performance and Skills	Presenting different perspectives	Show students new and different solutions Developing students' problem solving skills
	Deepening students' thinking skills	Enriching students' learning styles Enhancing students' capacity for independent and innovative thinking

As can be seen in Table 1, PTs who refer to enhancing the learning experience emphasize the enrichment of content and personalized learning. For example, the statement of PT60 coded PT in the context of advantages is as follows:

> I think ChatGPT can be used to prepare an effective learning environment because it can offer students the opportunity to progress according to their own learning pace, regardless of time, and guide them accordingly. Thus, the learning process can become more effective and efficient.

Another advantage that PTs point out is that ChatGPT will facilitate the teacher's work in the classroom. In this context, some of the responses mentioned the contribution in terms of time, while others emphasized the support in terms of materials and resources. In this sense, PT11 asserted that:

> ChatGPT provides teachers with access to different activities, instructional games, assessment, and evaluation tools. Through ChatGPT, teachers can access information quickly instead of scanning various articles or theses. ChatGPT helps teachers in designing activities, using materials, the lesson planning process and learning about students' possible misconceptions during the teaching process.

According to some PTs, another benefit of ChatGPT is that it increases students' motivation. Accordingly, while ChatGPT has the potential to increase student motivation with its innovative approach, the reasons for the increase in motivation were attributed to making the lesson interesting. In addition, some of the participants stated that ChatGPT provides easy access to information, which they perceived as an advantage.

3.2. Disadvantages of the Use of ChatGPT

Six themes emerged from the statements of pre-service mathematics teachers regarding the disadvantages of using ChatGPT: prevention of thinking, ethical issues, social isolation and communication impediments, lack of reliability and data accuracy, social and psychological harm, and workforce implications. Table 2 (in next page) summarizes the codes related to the themes.

The responses from the PTs showed that they thought that one of the biggest disadvantages of ChatGPT is its potential to hinder thinking. In this context, some responses point out that ChatGPT may make learning more challenging by providing students with pre-packed knowledge, while other responses suggest that it may encourage student laziness. For example, teacher PT24 stated that:

> I think that such applications in mathematics education can cause laziness, especially because they accustom the student to ease. After using such applications, the student may move away from learning by doing and experiencing, which is the most effective learning method.

Some PTs believe that ChatGPT will have a negative impact on students' homework. The biggest reservation of the participants who think so is that the purpose of the assignments will not be fulfilled. For instance, PT31 highlighted that:

> By using this application in the assignments given by the teacher, they can do their homework without making any effort and potentially distracting themselves from the purpose of the assignment. In this case, students may have difficulty reinforcing what they have learned.

In the realm of mathematics education, participants expressed concerns regarding the potential negative impact of AI on students' mathematical thinking. For instance, PT15 articulated the following viewpoint:

> If students see ChatGPT as a helper to hold their hands every time they are in trouble, it may even be harmful, let alone beneficial. This is because students' mathematical thinking could be hindered, and their intellectual development could be compromised as a result.

TABLE 2. PTs' views on the disadvantages of the use of ChatGPT

MAJOR THEMES	MINOR THEMES	CODES
Prevention of Thinking	Free-riding	- Provoking free-riding.
		- The effect of ready knowledge causes learning difficulties.
	Encouraging laziness	- Suspension from research. - Decreased desire for learning.
	Negative effects on student homework	- Student homework assignments are done by the software. - Assignments not reaching their goal.
	Negative effects on mathematical thinking	- Reducing the opportunity to practice and encouraging rote thinking. - Blunting creativity and originality. - Preventing meaningful and permanent learning. - Reducing interpretation skills. - Worsening computational and reasoning skills.
Ethical Issues	Assessment and evaluation issues	- The use of ChatGPT in exams. - Negative impact on evaluation processes.
Social Isolation and Communication Impediment	Communication and social interaction	- Negative impact on students' communication skills. - Decline of social interaction through the use of artificial intelligence. - Decreased communication. - Weakening of the teacher-student bond.
Lack of Reliability and Data Accuracy	Misinformation and credibility	- The risk of obtaining misinformation. - Potential for inaccurate information.
Social and Psychological Damage	Cultural and social impacts	- Cause of cultural and social problems. - Potential for addiction.
Workforce	Unemployment and economic hardship	- Increasing unemployment among teachers. - Leading economic problems. - Reducing the need for teachers.

PTs' perspectives on the adverse implications of utilizing ChatGPT predominantly revolve around ethical considerations. A subset of the participants highlighted concerns regarding potential ethical dilemmas associated with the technology. Specifically, some individuals expressed apprehensions that the deployment of ChatGPT could potentially foster academic dishonesty, thereby exacerbating cheating behaviors among students. Conversely, others underscored the challenges in rendering impartial judgments, citing complexities in their assessment and evaluation methodologies. For instance, participant PT48 articulated that "ChatGPT can be misused. For example, it can have harmful uses such as cheating. I think this behavior is one of the harmful aspects of such tools."

Moreover, the discourse surrounding the drawbacks of ChatGPT extended to considerations of its reliability and the risk of disseminating inaccurate information to learners. Additionally, participants raised concerns about the potential for students to develop a reliance on ChatGPT, which could potentially give rise to cultural and social issues within educational settings. Notably, a subset of PTs expressed apprehensions that the widespread adoption of ChatGPT could encroach upon their professional domain, potentially diminishing the demand for traditional educators and precipitating economic challenges within the

educational landscape. These multifaceted concerns underscore the nuanced ethical and pedagogical considerations that underpin PTs' apprehensions regarding the integration of ChatGPT in educational contexts.

3.3. Potential Area of Use of ChatGPT in Mathematics Instruction

Finally, future teachers' views on how to use ChatGPT in mathematics teaching revealed five themes: lesson preparation, alternative teaching methods and material design, problem-solving, assessment and evaluation, and increasing engagement and motivation. The minor themes and codes associated with these major themes are summarized in Table 3.

TABLE 3. PTs' views on the potential area of use of ChatGPT in mathematics instruction

MAJOR THEMES	MINOR THEMES	CODES
Lesson preparation	Question and activity preparation	- Finding warm-up questions. - Asking for examples related to the objectives. - Seeking high-stake tests questions.
	Lesson planning	- Preparing a lesson plan. - Subject research.
Alternative teaching methods and material design	Misconceptions and alternative teaching methods	- Investigating misconceptions. - Learning how to eliminate misconceptions. - Ways to identify misconceptions. - Designing different activities and instructional games.
	Graphs and visuals	- Graph drawing. - 3-Dimensional display. - Meeting visual needs.
	Finding materials and resources	- Preparing concept maps. - Finding pictures related to the topic. - Asking for and creating material ideas.
Problem-solving	Reviewing students' solved problems	- Determining mistakes and misconceptions. - Understanding source of errors.
	Support in problem solving	- Getting help in solving complicated questions.
Assessment and evaluation	Measurement tool preparation	- Developing alternative measurement tools. - Designing appropriate assessment and evaluation tools for the subject. - Assessing student achievements.
Increasing engagement and motivation	Engaging and motivating content	- Finding interesting math related videos, stories or pictures. - Educational games . - Attracting activities for active participation.

The responses of the PTs provided important results on how they would use ChatGPT in mathematics education. In relation to instructional preparation, the participants articulated their intentions to leverage ChatGPT for formulating questions, designing activities, structuring lesson plans, and elucidating the underlying concepts within the instructional framework. Notably, the PTs highlighted the utility of ChatGPT in sourcing questions from past high-stakes examinations, devising warm-up exercises, and crafting practice

problems. For instance, PT51 stated that "For example, mathematical inequality expressions can be written to ChatGPT and asked to prepare word problems representing these expressions". Furthermore, some participants expressed their inclination towards seeking assistance from ChatGPT for exploring alternative pedagogical approaches and enhancing their instructional materials. Specifically, the discussions around alternative methods predominantly revolved around strategies for identifying and rectifying misconceptions among students. The responses underscored the potential of ChatGPT in facilitating a more nuanced and comprehensive approach to instructional design and pedagogical strategies within the domain of mathematics education. For example, PT71 stated that:

> AI applications such as ChatGPT can inform teachers about what kind of teaching techniques can be used to overcome students' misconceptions. For this, instead of the teacher having to scan articles and theses one by one, AI can do it for him/her.

In addition, some participants stated that the visualization feature of ChatGPT holds potential as an alternative instructional tool in educational settings. This observation underscores the prominence of graphics, visual aids, and three-dimensional structures in leveraging the educational utility of ChatGPT. For instance, PT40 highlighted that:

> I think that such technologies can be used to associate the solution of equations in mathematics with graphs because these subjects are quite abstract concepts for students. Ensuring their concretization through visual representations can be an important area of use.

In the study, responses pertaining to misconceptions were identified within the overarching theme of problem-solving. A subset of participants highlighted the potential of leveraging artificial intelligence to pinpoint and comprehend misconceptions by analyzing incorrectly solved student problems. This application was perceived as valuable for educational purposes. Additionally, PTs expressed the view that such technological tools could enhance measurement and evaluation processes within the educational context. Specifically, they suggested employing alternative assessment methods and developing measurement instruments to gauge student performance. Furthermore, the prospective teachers indicated that ChatGPT could play a role in fostering student engagement and motivation. In this sense, PT58 stated that:

> Students may experience motivation problems in math class. Applications such as ChatGPT can increase student curiosity and be effective in increasing their motivation towards mathematics. Consequently, students' mathematical thinking is also enhanced, leading to more profound and lasting learning outcomes.

4. DISCUSSION

This paper attempted to examine the views of future mathematics teachers regarding the use of ChatGPT, one of the promising AI technologies, in mathematics education. The findings revealed the perspectives of PTs regarding the anticipated advantages, drawbacks, apprehensions, and plausible applications of ChatGPT within the mathematics education. AI software such as ChatGPT are becoming major milestones in academia and their implications are being investigated (Sánchez-Ruiz et al., 2023; Uğraş et al., 2024). Yet

little is known about how these technologies contribute to students' learning and how they can be used. In the present study, the PTs' awareness of ChatGPT applications and their active use of it enabled us to better understand their approaches to AI technologies. In other words, these thoughts of the teachers can also be considered as an output of their own experiences.

Faculties of education aim at developing certain competencies in future teachers. Two of these are subject matter knowledge, and pedagogical content knowledge which is about how to teach the subject (Güler & Çelik, 2019). While proponents of AI frequently assert that their intention is not to replace teachers (Ford, 2018), the performance of AI, especially in subject matter knowledge, has been examined by various researchers. The reason behind this research is undoubtedly the idea that users can interact with AI and learn from it. As a matter of fact, the results of the current study revealed that the PTs regarded ChatGPT as an assistant in terms of not only subject matter knowledge but also pedagogical content knowledge. However, some researchers point out that ChatGPT's performance in different mathematics subjects is not very good. For example, a study conducted by Bagno et al. (2024) pointed out that ChatGPT's performance in linear algebra is not as good as expected. Similarly, the study conducted by Nguyen et al. (2023) showed that ChatGPT has difficulty in place value and number line problems. The lack of reliability and data accuracy highlights the need for careful monitoring and validation of AI tools. As for the pedagogical content knowledge aspect, as documented in Wardat et al. (2023), ChatGPT may fall short in providing appropriate feedback and in handling misconceptions. Moreover, it harbors the potential to engender its own misconceptions. Therefore, if not properly checked, ChatGPT can sometimes produce inaccurate or misleading information, which could negatively impact learning outcomes (Hasanein & Sobaih, 2023). Although some participants were aware of these risks, it is possible that others were not. Therefore, teacher educators should be aware of the current perceptions of PTs regarding the use of ChatGPT and provide information on ChatGPT for improving students' problem solving skills may not always result positively. Even researchers directly demonstrate the potential of ChatGPT in improving academic achievement, they also indicate the need for the correct and safe use of this technology and even the need for guidelines for it (e.g. Wardat et al., 2023).

On the other hand, PTs' perception of ChatGPT as an authority in terms of pedagogical content knowledge (effective material selection, sample question selection, lesson plan preparation) may cause significant problems. Because both lesson plans and selected questions should contain differences according to the achievement level of the class (Cai & Wang, 2006), student's prior knowledge (Burton & Burton, 2016), and the objectives of the teaching that are to be assessed. In other words, designing an effective teaching environment requires taking into account different classroom variables. This result brings to mind the question of whether PTs need support at these points in their professional development. For this reason, it may be considered to compare professional needs with the questions asked to ChatGPT in future studies.

ChatGPT presents information based on language patterns; however, it does not have the ability to independently evaluate the accuracy of this information or conduct an in-depth analysis of reality. PTs stated that this situation is one of the obstacles to improve students' mathematical thinking. According to Schoenfeld (2017), powerful mathematical thinkers should be able to engage in sense making and "productive struggle" (p. 421). According to Perkins (2016), challenging tasks encourage students to do harder mathematics and to think critically about answers. For this reason, it is valuable to know that this risk mentioned

by PTs is encountered in mathematics classrooms. The negativities that may be caused by directly solving a problem or doing a mathematical proof through ChatGPT should also be taken into consideration in the purposes of using these tools in the classroom.

Alternative assessment approaches have a critical role on assessing students' learning outcomes. These approaches focus on evaluating students' progress in the process rather than result-oriented tests. For this purpose, tasks, project tasks and homework assignments that students will work on in out-of-school learning environments often have an important place (Birgin & Baki, 2009). Alternative assessment requires students to perform, create, produce and act (Borić & Zečević, 2021). Despite this importance, it was previously suggested that this situation should be taken into consideration in the reform studies since alternative assessment was perceived as unreliable by teachers (Watt, 2005). However, since the use of AI applications in education has been discussed, it can be said that the negative view of alternative assessment has gained a different dimension. Many studies point to ethical issues such as cheating and plagiarism as risks of using ChatGPT in education (e.g. Galindo-Domínguez et al., 2025; İpek et al., 2023; Lee et al., 2024). The fact that PTs in this study expressed a similar situation may indicate that they are likely to use a limited alternative assessment when they become teachers. In this sense, as Herbold et al. (2023) suggested, teaching concepts based on AI models must be re-imagined, like math using the calculator to teach general concepts first, then using AI tools to free up time for other learning goals.

Finally, the results show that some of the PTs are concerned that AI may replace teachers in the near future. It is known that this concern is not limited to the teaching profession. In addition to lowering employees' self-efficacy and self-management, AI awareness contributes to an anxious and insecure feeling (Alisic & Wiese, 2020). According to Schiff (2021), despite the fact that AI cannot replace human teachers, it can encroach on the job market for human teachers. The clearer one's vision of AI is, the more threats one may perceive from it (Wang et al., 2023). Therefore, teacher education institutions have an important role to play in assisting future teachers acquire this vision.

5. CONCLUSIONS

This study highlights PTs' perspectives on the integration of ChatGPT into mathematics classrooms and reveals both its potential benefits and challenges. While ChatGPT can support both subject matter knowledge and pedagogical content knowledge, concerns remain regarding its reliability, feedback quality, and impact on provoking students' mathematical thinking. The results suggest that while PTs recognize ChatGPT as a useful tool, they also acknowledge the risks associated with its uncritical use in the classroom. This underscores the need for teacher education programmes to equip future educators with a critical understanding of AI tools and to enable them to make effective use of the technology while reducing its limitations.

As AI continues to evolve, its role in education should be carefully examined to align with best pedagogical practices. Teacher educators should promote AI literacy among PTs by helping them develop strategies to meaningfully integrate ChatGPT while maintaining the core elements of mathematical reasoning and student engagement. Furthermore, concerns about AI replacing teachers or influencing assessment practices emphasize the need for well-defined guidelines on the use of AI in education. Future research should explore how AI

can be incorporated into teacher education to enhance professional competences while addressing ethical and pedagogical concerns. By doing so, educators can harness the potential of AI without compromising it.

6. LIMITATIONS AND FUTURE IMPLICATIONS

Although this study provides valuable insights into PTs' perspectives on the use of ChatGPT in mathematics classrooms, some limitations should be acknowledged when interpreting the results. First, the sample consisted of 72 PTs from a specific educational context, which may limit the generalizability of the findings to other majors or levels of teaching experience. A more diverse sample including in-service teachers and educators from different educational systems may provide a broader perspective on AI integration in mathematics education. Second, the study is based on self-reported data, which may be influenced by participants' personal experiences, biases, or limited exposure to AI tools. Future research could include observational methods or experimental designs to assess PTs' actual interactions with ChatGPT in classroom settings. Third, although the study primarily focused on ChatGPT, a variety of AI tools with different capabilities exist. Investigating multiple AI-supported platforms may offer a more comprehensive understanding of how different AI applications support or hinder mathematics teaching and learning. Finally, this study did not measure the long-term effects of ChatGPT use on PTs' pedagogical development or students' learning outcomes. Future longitudinal studies could examine the effects of sustained AI use over time.

7. AUTHOR CONTRIBUTION

Mustafa Güler: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Project administration.

Erdem Çekmez: Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing.

Zeynep Arslan: Conceptualization, Investigation, Resources, Writing - original draft, Writing - review & editing.

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Appendix 1. Survey questions

QUESTION	THE PURPOSE
What do you think about chatbots based on artificial intelligence? Do you think this technology can be used in teaching and learning environments? How?	Identifying the purposes of using artificial intelligence in education
Do you think that artificial intelligence applications such as ChatGPT in mathematics education will have benefits? If yes, explain by giving concrete examples.	Determining positive opinions (advantages) on the purposes of using ChatGPT in education
Do you think that artificial intelligence applications such as ChatGPT in mathematics education will have disadvantages? If yes, explain by giving concrete examples.	Determining negative opinions (disadvantages) on the purposes of using ChatGPT in education
Do you have any concerns or hesitations about using ChatGPT in mathematics education in the future? If so, what are they?	
In which ways ChatGPT can be used in a math lesson? Can you give concrete examples?	Determining opinions on the ways of using ChatGPT in education

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Accesibilidad tecnológica y Autismo. Nivel de formación del Profesorado de Educación Secundaria, Bachillerato y Formación Profesional

Technological accessibility and Autism. Level of Training of Secondary Education, Baccalaureate and Vocational Training Teachers

RECIBIDO 11/03/2025 ACEPTADO 01/06/2025 PUBLICADO 01/12/2025

José María Fernández-Batanero
ORCID: 0000-0003-4097-5382
Universidad de Sevilla, España
batanero@us.es

José Fernández-Cerero
ORCID: 0000-0002-2745-6986
Universidad de Sevilla, España
jfcerero@us.es

Marta Montenegro-Rueda
ORCID: 0000-0003-4733-289X
Universidad de Granada, España
mmontenegro@ugr.es

RESUMEN

La accesibilidad digital constituye un factor clave para la inclusión educativa del alumnado con Trastorno del Espectro Autista (TEA). Aunque las tecnologías digitales tienen el potencial de mejorar la enseñanza y promover un aprendizaje más equitativo, la falta de formación docente en accesibilidad sigue siendo una barrera significativa. El presente estudio tiene como objetivo principal conocer el nivel de formación y conocimiento tecnológico que el profesorado de Educación Secundaria, bachillerato y Formación Profesional presenta con respecto a las Tecnologías de la Información y la Comunicación (TIC) en el ámbito de la accesibilidad y el alumnado con TEA. Asimismo, se explora como la influencia de variables ordinales (edad, años de experiencia docente y nivel educativo) y nominales (género, titularidad del centro y comunidad autónoma) en dicha formación. Para llevar a cabo esta investigación, se utilizó un diseño transversal con enfoque descriptivo y predictivo de tipo cuantitativo. La muestra final fue de 3353 profesores españoles. Para la recogida de información se utilizó un cuestionario elaborado ad-hoc. Los resultados del estudio mostraron que los profesores encuestados presentan un nivel bajo de competencia digital en accesibilidad tecnológica para el alumnado con TEA, siendo los docentes de niveles educativos superiores (Bachillerato y FP) los que presentan una menor capacitación. Así mismo, se identifican diferencias significativas en la competencia digital según género, comunidad autónoma y titularidad del

centro. Estos hallazgos evidencian la necesidad de programas formativos específicos que aborden la accesibilidad digital y la atención al alumnado con TEA en todos los niveles del sistema educativo.

PALABRAS CLAVE accesibilidad, TEA, TIC, formación del profesorado

ABSTRACT

Digital accessibility is a key factor for the educational inclusion of students with Autism Spectrum Disorder (ASD). Although digital technologies have the potential to improve teaching and promote more equitable learning, the lack of teacher training in accessibility remains a significant barrier. The main objective of this study is to find out the level of training and technological knowledge that Secondary Education, Baccalaureate and Vocational Training teachers have regarding Information and Communication Technologies (ICT) in the field of accessibility and students with ASD. It also explores the influence of ordinal variables (age, years of teaching experience and educational level) and nominal variables (gender, ownership of the centre and autonomous community) on this training. In order to carry out this research, a cross-sectional design with a descriptive and predictive quantitative approach was used. The final sample consisted of 3353 Spanish teachers. An ad-hoc questionnaire was used to collect information. The results of the study showed that the teachers surveyed have a low level of digital competence in technological accessibility for students with ASD, with teachers at higher educational levels (Baccalaureate and Vocational Training) being the least qualified. Likewise, significant differences in digital competence are identified according to gender, autonomous community and ownership of the centre. These findings highlight the need for specific training programmes that address digital accessibility and care for students with ASD at all levels of the education system.

KEYWORDS Accessibility, ASD, ICT, Teacher Training

1. INTRODUCCIÓN

El Trastorno del Espectro Autista (TEA) es un trastorno del neurodesarrollo caracterizado por alteraciones persistentes que afectan distintas áreas del desarrollo (comunicación, interacción y la conducta). Según el Manual Diagnóstico y Estadístico de los Trastornos Mentales (DSM-5), se pueden identificar cuatro criterios diagnósticos principales: dificultades en la comunicación e interacción social (criterio A), patrones repetitivos y restringidos de comportamiento, intereses o actividades (criterio B), manifestación de los síntomas desde las primeras etapas del desarrollo (criterio C) y una afectación significativa en la vida diaria de la persona (criterio D) (American Psychiatric Association, 2014).

En los últimos años, la prevalencia del TEA ha aumentado significativamente debido a mejoras en los métodos de detección y cambios en los criterios diagnósticos (Montagut et al., 2011). Según la Organización Mundial de la Salud (OMS, 2017), aproximadamente 1 de cada 160 niños tiene TEA, aunque estudios epidemiológicos sugieren un incremento en la prevalencia a nivel mundial (Manenner et al., 2018).

En el contexto educativo español, el número de estudiantes con TEA ha aumentado de manera considerable. De acuerdo con datos del Ministerio de Educación y Formación Profesional y la Confederación Autismo España (2023), la presencia de este alumnado en educación no universitaria ha crecido un 160 % desde el curso 2011/2012. Sin embargo, su la continuidad en estudios postobligatorios sigue siendo un desafío: los datos más recientes (2021/2022) reflejan que solo un 3,03 % de estos estudiantes accedió a Bachillerato y un 4,23 % a Formación Profesional, en comparación con el 26,99 % que cursaba Educación Secundaria

Obligatoria (ESO). Esta disminución representa una barrera para su desarrollo académico y profesional, limitando sus oportunidades de inserción social y laboral (Confederación Autismo España, 2023; García-González et al., 2022).

A partir de esta problemática, el presente estudio se propone analizar el grado de formación y competencia digital del profesorado de Educación Secundaria, Bachillerato y Formación Profesional en relación con la accesibilidad tecnológica dirigida al alumnado con TEA, identificando posibles brechas formativas y factores asociados. Esta investigación cobra especial relevancia en el marco de la educación inclusiva, donde la accesibilidad digital y la preparación docente son elementos esenciales para garantizar la equidad.

Cabe señalar que este trabajo forma parte de un estudio más amplio centrado en la evaluación de la formación y competencia digital del profesorado en el uso de las TIC como recurso para la atención educativa del alumnado con discapacidad. En este caso, el análisis se focaliza específicamente en el ámbito del TEA, con el objetivo de generar evidencia empírica que contribuya al desarrollo de prácticas más inclusivas en las etapas educativas postobligatorias.

La hipótesis de partida es: el profesorado de Educación Secundaria, Bachillerato y Formación Profesional presenta un bajo nivel de formación y competencia digital en accesibilidad tecnológica para el alumnado con TEA.

Teniendo en cuenta lo anteriormente expuesto, nos planteamos las siguientes preguntas de investigación:

- ¿El profesorado de Educación Secundaria, Formación Profesional y Bachillerato cuenta con la formación necesaria para garantizar la accesibilidad tecnológica a estudiantes con TEA autismo?
- ¿Factores como el género, la comunidad autónoma o la titularidad del centro educativo influyen significativamente en el nivel de competencia digital docente en accesibilidad?
- ¿El nivel de competencia digital docente en accesibilidad varía en función de factores como la edad, la experiencia profesional o el nivel educativo en el que se imparte docencia?

Este estudio adquiere relevancia por diversas razones fundamentales:

En primer lugar, debido a la escasez de investigaciones previas, ya que, tanto a nivel nacional como internacional, existe una limitada producción científica que aborde de manera específica la relación entre TEA autismo, TIC y formación del profesorado de Educación Secundaria, Bachillerato y Formación Profesional. Como se ha evidenciado en revisiones bibliográficas (Durán Cuartero, 2021), este es un campo de estudio poco explorado, lo que resalta la necesidad de generar conocimiento actualizado y basado en evidencia. En segundo lugar, nos permite la identificación de brechas en la formación docente, pues al evaluar el nivel de competencia digital del profesorado en materia de accesibilidad para alumnado con TEA, el estudio permitirá detectar posibles deficiencias en la formación tecnológica, lo que servirá como punto de partida para diseñar estrategias de mejora en la capacitación docente. En tercer lugar, es el posible impacto en el marco de la educación inclusiva, ya que la accesibilidad digital es clave para garantizar el derecho a una educación equitativa. Identificar el grado de preparación del profesorado en esta área contribuirá a mejorar las estrategias de enseñanza y la inclusión educativa, permitiendo que el alumnado con TEA acceda a oportunidades de aprendizaje en igualdad de condiciones. Por último, la contribución a

la mejora de planes de formación. En este sentido, los resultados de esta investigación podrán servir como base para diseñar y actualizar programas de formación docente, asegurando que las TIC sean utilizados de manera efectiva para favorecer la autonomía y el aprendizaje del alumnado con TEA.

2. MARCO TEÓRICO

2.1. Accesibilidad tecnológica y diseño universal en el alumnado con TEA

El avance de las tecnologías digitales ha abierto nuevas posibilidades para mejorar el aprendizaje y la inclusión del alumnado con discapacidad, especialmente de aquellos con Trastorno del Espectro Autista (TEA) (Chaidi & Drigas, 2023; Rajagopal & Chandrashekaran, 2024). Un componente clave en este proceso es la accesibilidad tecnológica, que no se limita al acceso físico a los dispositivos, sino que abarca también su usabilidad y el diseño universal, entendido como la creación de entornos y recursos digitales utilizables por todas las personas sin necesidad de adaptación. Este principio está recogido en el Real Decreto Legislativo 1/2013, que establece que los productos y servicios deben ser comprensibles y utilizables por todas las personas en condiciones de seguridad, comodidad y autonomía.

La incorporación de tecnologías accesibles y el diseño universal en entornos educativos favorece experiencias de aprendizaje más personalizadas y motivadoras, contribuyendo a la autonomía del estudiante y a la equidad en la participación (Kalemkuş, 2024, López Bouza y Moral Pérez, 2021). Investigaciones recientes destacan que, cuando se implementan adecuadamente, estas herramientas pueden reducir las barreras de acceso al aprendizaje y mejorar la integración del alumnado con TEA en el aula (Bölte et al., 2021; Parsons et al., 2019). Sin embargo, la falta de formación del profesorado en materia de accesibilidad digital sigue siendo un obstáculo significativo.

2.2. Formación docente y aplicación tecnológica en el alumnado con TEA

El nivel de competencia digital docente es un factor determinante para la integración de tecnologías accesibles en el aula. En el contexto español, diversos estudios han señalado la insuficiente preparación del profesorado en esta área (Fernández Batanero et al., 2024; Gallardo Montes et al., 2023; Lledó et al., 2020). A nivel internacional, se observan hallazgos similares: investigaciones como las de Saladino et al. (2020) y Gallardo-Montes y Capperucci (2021) evidencian la necesidad de fortalecer la capacitación del profesorado en accesibilidad digital y diseño universal para la enseñanza.

Algunos estudios han resaltado la importancia de la formación docente en tecnologías de asistencia y accesibilidad (Fernández-Cerero et al., 2024). Por ejemplo, Luque y Rodríguez Infante (2009) destacaron que una adecuada formación en accesibilidad universal permite a los docentes facilitar la inclusión educativa del alumnado con discapacidad. Más recientemente, Santos Suares et al. (2024) propusieron un programa de formación continua en tecnología de asistencia para apoyar a estudiantes con TEA, subrayando su impacto positivo en el proceso de enseñanza-aprendizaje.

Otro recurso clave es el uso de inteligencia artificial (IA) en la educación inclusiva. Investigaciones recientes indican que la IA puede ayudar a los docentes a adaptar contenidos y estrategias de enseñanza a las

necesidades individuales del alumnado con TEA, favoreciendo una enseñanza más efectiva y personalizada (Estrada et al., 2024; Luckin et al., 2021).

La investigación sobre la competencia digital del profesorado ha analizado el impacto de variables como la edad y el género en el nivel de dominio de herramientas digitales. Mas García et al. (2024) concluyeron que el profesorado percibe un nivel intermedio de competencia digital, independientemente de estas variables, aunque a mayor edad, se reporta un menor nivel de competencia percibida. Además, aunque en términos generales no se observan diferencias significativas por género, sí se identifican variaciones en función de las dimensiones específicas de la competencia digital analizadas.

Estudios como los de Pérez-Navío et al. (2021) y Moreno-Guerrero et al. (2020) sugieren que los docentes más jóvenes, al haber estado expuestos a la tecnología desde una edad temprana, tienen mayor facilidad para integrar herramientas digitales en sus metodologías de enseñanza. Por otro lado, se ha documentado que las mujeres tienden a obtener puntuaciones menores en competencia digital en comparación con los hombres, lo que refleja una posible brecha de género en este ámbito (Aznar-Díaz et al., 2019; Romero et al., 2023).

Ante estas carencias, se han desarrollado diversas propuestas formativas para mejorar la preparación del profesorado en accesibilidad digital (Chen, 2022; Nijakowka & Guz, 2024). Programas recientes han demostrado que la formación específica en esta área no solo incrementa los conocimientos de los docentes, sino que también mantiene un alto grado de motivación durante el proceso (Corte y Quezada, 2024; Tárraga et al., 2024).

Finalmente, revisiones sistemáticas han puesto de manifiesto la necesidad de incorporar la tecnología de asistencia en la formación docente para garantizar la accesibilidad y la inclusión educativa (Ancaya Martínez et al., 2024; Seale, 2014). Estas estrategias formativas pueden contribuir a reducir las brechas existentes y mejorar la integración de las TIC en la enseñanza de alumnado con necesidades específicas de apoyo educativo.

3. METODOLOGÍA

Partimos de un enfoque descriptivo, en tanto en cuanto persigue obtener información que permita realizar un diagnóstico de esta realidad, seleccionado para ello una metodología de corte cuantitativo y el estudio tipo encuesta, siendo la técnica utilizada para recoger la información el cuestionario.

3.1. Instrumento de recogida de información

El instrumento de recogida de información fue un cuestionario elaborado ad hoc, denominado “Cuestionario de Capacitación Docente en Competencias Digitales Inclusivas como Apoyo al alumnado con Trastorno del Espectro Autista (CODITEA)”. Estaba formado por 30 ítems, divididos en 3 dimensiones: aspectos generales (G), formación y experiencia en TIC con personas con TEA (FyETIC) y accesibilidad (ACC). Cada afirmación debe ser valorada mediante una escala Likert de acuerdo-desacuerdo de 6 puntos, donde 1 es MN= Muy Negativa; 2 es N= Negativa; 3 es LN= Ligeramente Negativa; 4 es LP= Ligeramente Positiva; 5 es P= Positiva y; 6 es MP= Muy Positiva.

Para su validación (validez de contenido), participaron 32 jueces, seleccionados mediante el llamado "Coeficiente de competencia experta" o "Coeficiente K" obtenido mediante la aplicación de la siguiente fórmula: K = ½ (Kc + Ka), donde Kc es el "Coeficiente de conocimiento" o información que tiene el experto acerca del tema o problema planteado; y Ka es el denominado "Coeficiente de argumentación" o fundamentación de los criterios de los expertos (Cabero-Almenara, et al., 2016). En este sentido, el Coeficiente K resultó ser de 0.8, significando que los jueces participantes presentaban un nivel alto de competencia experta, asegurando así la validez de contenido del instrumento utilizado en el estudio.

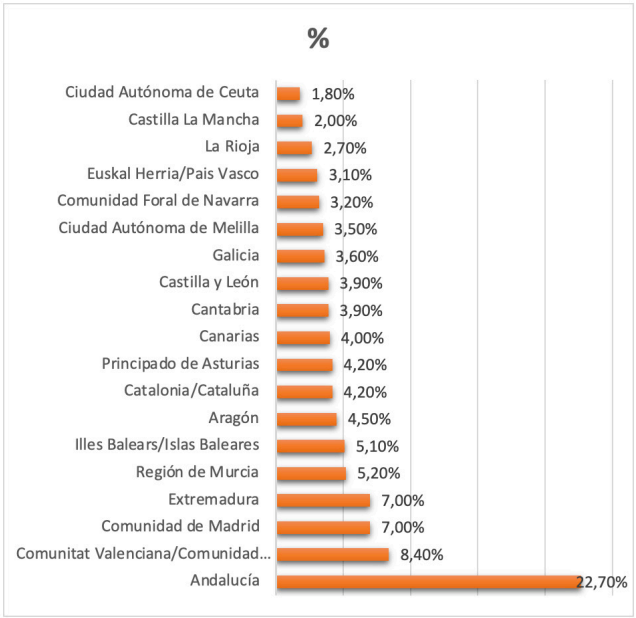
La fiabilidad del instrumento se obtuvo mediante dos estadísticos, el alfa de Cronbach y la Omega de McDonald (Ventura-León y Caycho-Rodríguez, 2017), los valores obtenidos en la dimensión de accesibilidad fueron para el alfa de Cronbach (.94) y el Omega de McDonald (.95). En este sentido y siguiendo a O´Dwyer y Bernauer (2014), los resultados obtenidos demuestran una alta confiabilidad en la dimensión estudiada. Además, a nivel general del instrumento se utilizó el Análisis Factorial Exploratorio (AFE) bajo el método de máxima verosimilitud con rotación varimax. Se obtuvo un valor de 0.934 en la prueba de adecuación muestral KMO (Kaiser-Meyer-Olkin) y la prueba de esfericidad de Bartlett resultó significativa ($\chi^2 = 4305.923$, $p < 0.05$). La versión final explicó el 85.25 % de la varianza verdadera. Además, el análisis factorial confirmatorio (AFC) mostró que los datos de los docentes se ajustaban adecuadamente al modelo teórico propuesto. Los coeficientes cumplían con los umbrales establecidos por Bentler (1989) y Schumacker y Lomax (2004).

El instrumento final fue administrado en línea mediante la herramienta Google Forms, y puede consultarse en la siguiente dirección web: https://bit.ly/CODITEA-EVALUACION

3.2. Muestra

En este estudio se ha trabajado con una muestra de 3353 profesores españoles. Su distribución se muestra en la Figura 1.

FIGURA 1. Porcentaje de representación por Comunidades autónomas



Con respecto a las características de la muestra, hay que decir que estaba conformada por 1466 hombres (43,70 %) y 1793 mujeres (53,50 %). Entre las representaciones minoritarias están las opciones: No Binario (2.00 %) y Prefiero No Indicarlo (0.80 %). Aunque las mujeres superan a los hombres en participación, la diferencia del 9.80 % sugiere un equilibrio razonable en la distribución de género entre estas dos categorías principales.

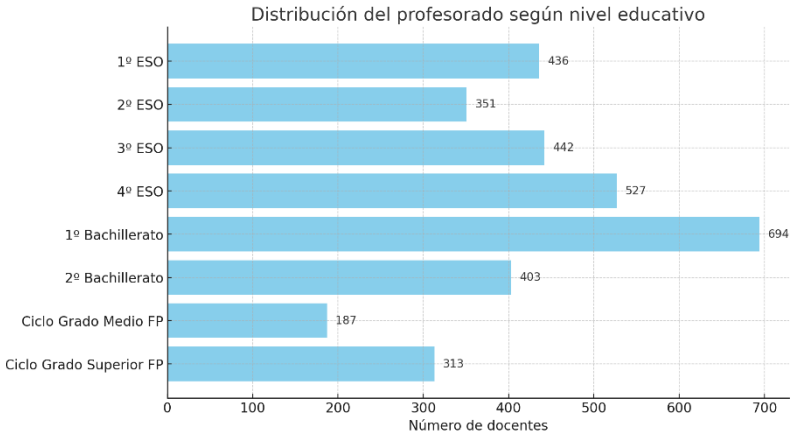
En función a la edad del profesorado el grupo más numeroso es el representado por aquellos que oscilan entre los 41 y 55 años (1167; 34.80 %), seguidos de entre 31 y 40 años (F=992; 29.60 %), más de 55 años (F=608; 18.10 %) y por último aquellos que tienen menos de 30 años (F=586; 17.50 %).

En relación con la experiencia docente el rango de 1 a 5 años es el más representado, con un 22.60 % (F=759) de los participantes, de 6 a 10 años constituye el 17.50 % (F=587), los rangos de 11 a 15 años (12.00 %), de 21 a 25 años (12.30 %) y más de 30 años (13.10 %) muestran participaciones similares.

Sobre la titularidad del centro, hay que comentar que el 72.00 % (F=2413) son públicos, el 15.40 % (F=517) de carácter privado y el 12.60 % (F=423) de carácter concertado. La distribución se ajusta a las características generales del sistema educativo español, con una clara predominancia de los centros públicos, seguidos por una presencia menor pero significativa de centros privados y concertados.

En relación con el nivel educativo en el que imparten docencia, su distribución es la siguiente (Figura 2).

FIGURA 2. Nivel educativo en el que imparte docencia



La alta representación de la Enseñanza Secundaria Obligatoria se alinea con su carácter obligatorio, lo que implica una mayor demanda de docentes en este nivel. La distribución refleja la estructura piramidal del sistema educativo, con una base amplia en la ESO que se va estrechando en niveles superiores.

3.3. Análisis de datos

Para el tratamiento de los datos recogidos a través del cuestionario CODITEA, se aplicaron diversas técnicas estadísticas adecuadas al enfoque cuantitativo del estudio. Inicialmente, se realizaron análisis descriptivos de medidas de tendencia central (media, mediana, moda) y de dispersión (desviación estándar y varianza) para valorar el nivel de competencia digital en accesibilidad tecnológica del profesorado encuestado.

Posteriormente, se llevaron a cabo pruebas inferenciales para contrastar las hipótesis planteadas. En concreto, se utilizó la prueba t de Student para comparar medias entre grupos en función del género, así como análisis de varianza (ANOVA) para examinar diferencias según la comunidad autónoma, la titularidad del centro y la experiencia profesional. En aquellos casos en los que se detectaron diferencias significativas, se aplicaron pruebas post hoc (HSD de Tukey) para identificar los grupos responsables de dichas diferencias.

Asimismo, se comprobaron los supuestos de normalidad y homogeneidad de varianzas mediante la prueba de Levene. La adecuación de los datos para el análisis factorial se verificó mediante la prueba KMO (Kaiser-Meyer-Olkin), que obtuvo un valor de 0.934, y la prueba de esfericidad de Bartlett, que resultó significativa ($\chi^2 = 4305.923$, $p < 0,05$), indicando la pertinencia de aplicar análisis factorial exploratorio y confirmatorio en la validación del instrumento.

El análisis de los datos se realizó utilizando el software estadístico IBM SPSS (versión 26.0), garantizando el rigor y la fiabilidad en el tratamiento de la información recogida.

4. RESULTADOS

A continuación, se presentan los resultados obtenidos del cuestionario, organizados de acuerdo con las preguntas de investigación planteadas.

Con respecto a la primera pregunta de investigación (Q1), si el profesorado de Educación Secundaria, Formación Profesional y Bachillerato cuenta con la formación necesaria para garantizar la accesibilidad tecnológica a estudiantes con TEA, los resultados muestran un nivel de formación digital en accesibilidad del profesorado bajo, como se puede ver en el análisis de las medidas de tendencia central analizadas (evaluaron conocimientos sobre uso de tecnologías accesibles, adaptación de contenidos digitales, manejo de herramientas de asistencia y diseño universal para el aprendizaje) (Tabla 1). Esta tabla ofrece una visión global y detallada de la distribución de las respuestas, mediante las medidas de tendencia central y de dispersión. De este modo, no solo se presenta el nivel promedio de competencia digital, sino también la concentración y variabilidad de las respuestas, lo que permite interpretar con mayor precisión la consistencia del bajo nivel de formación reportado en los resultados.

El análisis de las medidas de tendencia central de las dimensiones correspondientes a los ítems del cuestionario nos arroja los siguientes resultados:

En relación con la media de los ítems los encuestados tienen una valoración baja (1.85) sobre su nivel de conocimiento con la accesibilidad tecnológica como apoyo al alumnado con TEA. Con respecto a la mediana (valor central de la distribución o la puntuación que divide la muestra en dos mitades iguales), las puntuaciones son menores que la media (1.25), lo que sugiere una posible concentración de puntuaciones bajas. Sobre la puntuación que

TABLA 1. Medidas de tendencia central

Medias de tendencia central	Accesibilidad
Media	1.85
Mediana	1.25
Moda	1.00
Desviación estándar	1.14
Varianza	1.31

más se repite (Moda=1) muestra que las puntuaciones más frecuentes son bajas, indicando consistencia con la mediana y la media.

La desviación estándar obtenida (1.14), nos indica una variabilidad relativamente constante en las respuestas. Por lo que se refiere a la varianza (1.31), proporciona valores bajos, indicando que las respuestas no son extremadamente dispersas, confirmándose las medidas anteriormente analizadas.

A nivel general, las respuestas están concentradas cerca de los valores más bajos de la escala Likert (valores 1 y 2, de los 6 posibles), lo que podría reflejar una percepción limitada de formación en accesibilidad en TIC relacionadas con personas con TEA. Este patrón destaca áreas de mejora significativa, como la formación en accesibilidad y el uso de TIC para apoyar a estudiantes con TEA.

Con respecto a la segunda pregunta de investigación (Q2), sobre si factores como el género, la comunidad autónoma o la titularidad del centro educativo influyen significativamente en el nivel de competencia digital docente en accesibilidad, se procede al análisis de los resultados obtenidos en la prueba T de Student según la variable género para la dimensión de accesibilidad. (Tabla 2).

TABLA 2. Género y competencia digital. Estadísticas de grupo

	Género	N	Media	Desviación estándar	Media de error estándar
Accesibilidad	Mujer	1793	1.9204	1.06491	.02515
	Hombre	1466	1.7850	.93072	.02431

Con relación a la dimensión 1 (Aspectos generales en TIC y TEA), la media obtenida por las mujeres ha sido de 1.92. Los hombres han obtenido una media de 1.78; por lo que las mujeres presentan una media significativamente mayor en esta dimensión.

TABLA 3. Género y competencia digital. Prueba de muestras independientes para la dimensión analizada

		Prueba de Levene de igualdad de varianzas		Prueba t para la igualdad de medias							
		F	Sig.	t	gl	Significación		Diferencia de medias	Diferencia de error estándar	95 % de intervalo de confianza de la diferencia	
						P de un factor	P de dos factores			Inferior	Superior
Dimensión 03: Accesibilidad	Se asumen varianzas iguales	49.676	<.001	3.818	3257	<.001	<.001	.13534	.03545	.06583	.20485
	No se asumen varianzas iguales			3.869	3242.561	<.001	<.001	.13534	.03498	.06676	.20392

Con relación a los resultados obtenidos en la dimensión 3 (Accesibilidad), también las mujeres obtienen una media más alta (1.92) frente a los hombres (1.79) (Tabla 2).

Al aplicar la Prueba de Levene los resultados muestran que F=49,676, p<0.001, las varianzas no son iguales, por lo que se analizan los resultados que no asumen varianzas iguales (Tabla 3).

Los resultados de la prueba T (t(3242.561) =3.869, p<0.001) indica que hay una diferencia estadísticamente significativa entre las medias por parte de las mujeres (0.13534).

De nuevo, se calculó el Tamaño del efecto (d de Cohen), el resultado arrojó un valor de d=1.007. El tamaño del efecto es pequeño, lo que indica que el género tiene un impacto pequeño en esta dimensión (Tabla 4).

TABLA 4. Prueba t para igualdad de medias

	T(gl)	P	Diferencia de Medias	IC 95 % inferior	IC 95 % superior	D de Cohen
Varianzas iguales	3.82 (3257	.001	.14	.07	.2	1.01
Varianzas no iguales	2.87 (3242)	.001	.14	.07	.2	1.01

Con respecto a si la comunidad autónoma donde se imparte docencia determina de forma relevante el nivel de competencia digital en materia de accesibilidad, se procede al análisis de la varianza (ANOVA) (Tabla 5).

TABLA 5. Varianza (ANOVA) según la variable comunidades autónomas para las tres dimensiones del cuestionario

		Suma de cuadrados	gl	Media cuadrática	F	Sig.
Accesibilidad	Entre Grupos	452.685	18	25.149	28.860	<.001
	Dentro de grupos	2905.347	3334	.871		
	Total	**3358.032**	**3352**			

Al analizar la dimensión Accesibilidad y las comunidades autónomas, los resultados globales obtenidos del ANOVA (F (18. 3334)=28.860, p<0.001) y el tamaño del efecto (0.135) nos indican unas diferencias entre comunidades autónomas. Con relación a las pruebas post hoc (HSD Tukey), se observan diferencias significativas entre comunidades como Madrid, Cataluña y Valencia frente a otras como Extremadura y Ceuta.

Con respecto a si la variable titularidad del centro de trabajo en el que se imparte docencia determinan de forma relevante el nivel de competencia digital (tabla 6).

TABLA 6. Análisis de la varianza (ANOVA) (Titularidad del centro de trabajo de los encuestados y dimensiones)

		Suma de Cuadrados	gl	Media cuadrática	F	Sig.
Accesibilidad	Entre grupos	35.762	2	17.881	18.030	<.001
	Dentro de grupos	3322.270	3350	.992		
	Total	**3358.032**	**3352**			

Se puede observar que los resultados obtenidos revelan que los centros públicos tienen puntuaciones significativamente más altas que los centros privados y concertados. En los subconjuntos homogéneos, los centros Concertados (Media=1.6452) y Privados (Media=1.7085) forman un grupo con puntuaciones más

bajas. Mientras que los centros Públicos (Media=1.9627) tiene las puntuaciones más altas. La interpretación es que los encuestados de centros públicos perciben que tienen más formación y experiencia en TIC con personas con autismo, así como una mayor accesibilidad. Por tanto, se rechaza la hipótesis nula.

Con respecto a la tercera pregunta de investigación (Q3), sobre si el nivel de competencia digital docente en accesibilidad varía en función de factores como la edad, la experiencia profesional o el nivel educativo en el que se imparte docencia, se procede al análisis de las correlaciones según estas variables y los ítems del cuestionario.

Con relación a los resultados obtenidos en la dimensión Accesibilidad, los resultados del ANOVA han sido de F(7. 3345)=3.194, p=0.002, por lo que se identifican diferencias significativas entre los grupos.

El tamaño del efecto (Eta cuadrado), presenta un valor de 0.007; esto indica que el 0.7 % de la varianza en las puntuaciones está relacionada con los años de experiencia. El tamaño del efecto vuelve a ser pequeño.

TABLA 7. Análisis de la varianza (ANOVA) (Años de experiencia docente de los encuestados y Dimensiones)

		Suma de cuadrados	gl	Media cuadrática	F	Sig.
Accesibilidad	Entre grupos	22.299	7	3.186	3.194	.002
	Dentro de grupos	3335.733	3345	.997		
	Total	**3358.032**	**3352**			

Al realizar las pruebas post hoc (HSD de Tukey), el grupo de “Más de 30 años” tiene puntuaciones significativamente más bajas que el grupo “De 1 a 5 años”. Al realizar la comparación significativa (p=0.01) entre el grupo de “Más de 30 años” y el “De 1 a 5 años”, se presenta una diferencia de medias de -0.21109.

TABLA 8. HSD Tukeya, b. Dimensión 03: Accesibilidad

Años de experiencia docente:	N	Subconjunto para alfa = 0.05
		1
No aplicable	16	1.6250
Más de 30 años	438	1.7123
De 6 a 10 años	587	1.7749
De 11 a 15 años	403	1.8210
De 21 a 25 años	414	1.8342
De 16 a 20 años	278	1.9065
De 1 a 5 años	759	1.9234
De 26 a 30 años	458	1.9490
Sig.		.285

Se visualizan las medias para los grupos en los subconjuntos homogéneos.

[a]. Utiliza el tamaño de la muestra de la media armónica = 101.935.

[b]. Los tamaños de grupo no son iguales. Se utiliza la media armónica de los tamaños de grupo. Los niveles de error de tipo I no están garantizados.

La Interpretación a estos resultados es que los docentes con más de 30 años de experiencia perciben menor accesibilidad en comparación con los docentes con menos experiencia, lo que podría reflejar una percepción crítica adquirida a lo largo del tiempo.

Las conclusiones generales de estos resultados es que, en todas las dimensiones hay diferencias significativas en las puntuaciones entre los grupos de años de experiencia docente. El grupo sin experiencia docente destaca por sus puntuaciones más altas en la Dimensión 1.

Aunque las diferencias son significativas, los tamaños del efecto (máximo de 1,9 %) son pequeños, lo que sugiere que los años de experiencia explican solo una pequeña proporción de la varianza.

Los resultados sugieren la necesidad de formación continua, especialmente en accesibilidad y formación en TIC con personas con TEA, para reducir diferencias entre los grupos de experiencia docente.

5. DISCUSIÓN

Los hallazgos de este estudio confirman la hipótesis de que el profesorado de Educación Secundaria, Bachillerato y Formación Profesional presenta un bajo nivel de formación y competencia digital en accesibilidad tecnológica (1.85) para atender al alumnado con TEA. A partir del análisis de las medidas de tendencia central, se observa que la mayoría de los docentes evaluados tienen una percepción limitada de sus conocimientos sobre accesibilidad digital, con una media baja en la dimensión de accesibilidad. Este resultado está en línea con investigaciones previas que han señalado deficiencias en la formación docente en tecnologías de asistencia y accesibilidad digital (Fernández Batanero et al., 2024; Gallardo-Montes et al., 2023).

Además, los datos revelan que el nivel educativo impacta negativamente en la percepción de conocimientos y competencias TIC. Esto implica que, a medida que los docentes trabajan en niveles educativos superiores, su conocimiento sobre accesibilidad digital disminuye. Este hallazgo es especialmente relevante, ya que pone en evidencia la necesidad de reforzar la formación docente en accesibilidad tecnológica, particularmente en niveles superiores como Bachillerato y Formación Profesional, donde la tasa de alumnado con TEA se reduce considerablemente (Confederación Autismo España, 2023).

Uno de los objetivos del estudio fue analizar el impacto de factores como género, comunidad autónoma y titularidad del centro en la competencia digital en accesibilidad. En este sentido, los resultados indican que las mujeres presentan puntuaciones ligeramente más altas que los hombres en accesibilidad tecnológica, aunque el tamaño del efecto es pequeño. Esto coincide con estudios previos que han identificado diferencias de género en el uso y percepción de la competencia digital docente (Mas García et al., 2024), aunque sin una brecha significativa en términos generales.

Por otro lado, se encontraron diferencias significativas entre comunidades autónomas en la percepción de competencia digital en accesibilidad, lo que sugiere desigualdades en la formación y recursos tecnológicos disponibles en cada región. Comunidades como Madrid, Cataluña y Valencia presentaron puntuaciones más altas en comparación con Extremadura y Ceuta. Esto podría explicarse por factores como las políticas educativas autonómicas y el acceso a programas de formación en TIC y accesibilidad (Pérez-Navío et al., 2021).

En cuanto a la titularidad del centro educativo, los resultados muestran que el profesorado de centros públicos presenta una mayor percepción de formación en accesibilidad tecnológica que los docentes de centros privados y concertados. Esto podría estar relacionado con la oferta formativa y los recursos disponibles en los centros públicos, así como con la obligatoriedad de atender a una población estudiantil más diversa e inclusiva (Gallardo-Montes y Capperucci, 2021).

Los datos también reflejan que los docentes con mayor experiencia perciben una menor competencia en accesibilidad digital en comparación con los docentes más jóvenes y con menos años de experiencia. Esto coincide con estudios previos que han señalado que los docentes más jóvenes, al haber crecido en un

entorno digital, tienden a sentirse más cómodos utilizando herramientas tecnológicas en el aula (Aznar-Díaz et al., 2019; Moreno-Guerrero et al., 2020).

A pesar de que las diferencias son estadísticamente significativas, el tamaño del efecto es pequeño, lo que sugiere que la experiencia docente no es un factor determinante, aunque sí relevante. Esto refuerza la necesidad de estrategias de formación continua en accesibilidad digital para todos los docentes, independientemente de su trayectoria profesional.

6. CONCLUSIONES

Las conclusiones generales del estudio son las siguientes:

- El profesorado de Educación Secundaria, Bachillerato y Formación Profesional presenta un nivel bajo de competencia digital en accesibilidad tecnológica para el alumnado con TEA.
- Los docentes de niveles educativos superiores (Bachillerato y FP) tienen una menor percepción de competencia en accesibilidad digital, lo que podría influir en la baja continuidad del alumnado con TEA en estos niveles.
- Se identifican diferencias en la competencia digital según género, comunidad autónoma y titularidad del centro. Las mujeres muestran una ligera ventaja en accesibilidad digital, los centros públicos obtienen mejores resultados que los privados y concertados, y existen diferencias significativas entre comunidades autónomas.
- Los docentes más jóvenes y con menos años de experiencia presentan una mayor percepción de competencia digital en accesibilidad, lo que sugiere una brecha generacional en el uso de TIC inclusivas.
- Se recomienda la implementación de programas de formación docente en accesibilidad digital, adaptados a los diferentes niveles educativos y realidades regionales, con el fin de garantizar una educación inclusiva y equitativa para el alumnado con TEA.

6.1. Implicaciones y recomendaciones

Los resultados de este estudio evidencian la necesidad de reforzar la formación docente en accesibilidad digital y en el uso de las TIC orientadas al alumnado con TEA. A partir de estos hallazgos, se derivan diversas implicaciones y recomendaciones fundamentales:

Desarrollo de programas de formación continua: Se recomienda la implementación de cursos y talleres específicos sobre accesibilidad tecnológica y tecnologías de asistencia, tanto en la formación inicial como en la formación permanente del profesorado (Santos Suares et al., 2024).

Incorporación de accesibilidad digital en los planes de estudio: Es necesario que la formación docente en TIC incluya de manera transversal el uso de herramientas accesibles y el diseño universal del aprendizaje, con el objetivo de garantizar la inclusión educativa de los estudiantes con TEA (Luque & Rodríguez Infante, 2009).

Reducción de desigualdades regionales: Dado que se han observado diferencias entre comunidades autónomas, es fundamental que las políticas educativas regionales prioricen la formación en accesibilidad digital y la dotación de recursos tecnológicos inclusivos en todos los territorios (Confederación Autismo España, 2023).

Fomento del uso de la inteligencia artificial y la realidad aumentada: Tecnologías emergentes como la IA, la realidad aumentada y los robots de asistencia social pueden desempeñar un papel clave en la personalización del aprendizaje y la accesibilidad educativa para el alumnado con TEA (Estrada et al., 2024; Poglitsch et al., 2024).

Formación diferenciada según niveles educativos: Dado que los docentes de Bachillerato y Formación Profesional tienen una menor percepción de formación en accesibilidad digital, es necesario diseñar estrategias específicas para estos niveles, asegurando que el alumnado con TEA tenga continuidad educativa en todas las etapas.

6.2. Limitaciones y prospectiva

Al tratarse de un estudio con un diseño transversal, los datos recogen una fotografía puntual del nivel de formación docente en accesibilidad digital, pero no permiten analizar la evolución de la competencia digital a lo largo del tiempo. Otra limitación es que la medición de la competencia digital en accesibilidad se basa en la percepción subjetiva de los docentes, lo que puede generar sesgos de respuesta. Por otro lado, aunque el estudio proporciona datos cuantitativos detallados, no incluye información cualitativa sobre las experiencias y percepciones de los docentes respecto a la accesibilidad digital. Entrevistas o grupos focales podrían ofrecer un mayor contexto sobre las barreras y necesidades formativas. Por último, decir que, aunque el estudio proporciona datos cuantitativos detallados, no incluye información cualitativa sobre las experiencias y percepciones de los docentes respecto a la accesibilidad digital. Entrevistas o grupos focales podrían ofrecer un mayor contexto sobre las barreras y necesidades formativas.

De cara a un futuro, sería también interesante realizar algún estudio de corte empírico longitudinal, con recogida directa de datos, en varios momentos y mediante metodología observacional.

7. CONTRIBUCIÓN DE AUTORES

Autor 1 ha sido responsable de la Obtención de financiación y la Administración del proyecto. Autor 1, Autor 2 y Autor 3 han contribuido en partes iguales en: Conceptualización; Curación de datos; Análisis formal; Investigación; Metodología; Software; Recursos; Supervisión; Validación; Visualización; Redacción - borrador original; y Redacción - revisión y edición. El Autor 3 actúa como autor de correspondencia.

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El estudio ha sido aprobado por el Comité de Ética de la Investigación de la Universidad de Sevilla con código de aprobación SICEIA-2024-002080. El estudio se llevó a cabo con las normas éticas establecidas en la Declaración de Helsinki de 1964 y sus modificaciones posteriores normas éticas comparables. Se obtuvo el consentimiento informado de todos los participantes incluidos en el estudio.

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An Integrative Analysis of Preservice Teachers' Intentions to Utilize Digital Tools for Instructional Purposes

Un análisis integrador de las intenciones de los profesores en formación de utilizar herramientas digitales con fines educativos

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Erhan Ünal
ORCID: 0000-0002-5349-4193
Afyon Kocatepe University, Turkey
eunal@aku.edu.tr

Ahmet Murat Uzun
ORCID: 0000-0002-1852-8802
Afyon Kocatepe University, Turkey
auzun@aku.edu.tr

ABSTRACT

This study examines preservice teachers' intentions to embrace digital tools for instructional practices through the Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), and the Task Technology Fit Model (TTF). A cross-sectional research design was employed to test a hypothetical model through a self-report survey administered to instructional technology course participants. A total of 210 participants took part in the research, with survey data collected regarding preservice teachers' opinions on embracing digital learning tools in their future practices. The partial least square structural equation modeling (PLS-SEM) approach was utilized to scrutinize the study's hypotheses, with the proposed model yielding valid and reliable results. The study revealed that task technology fit was the most influential predictor of preservice teachers' intention to utilize digital learning tools for future instructional practices. Perceived usefulness and subjective norms were other significant predictors of behavioral intention, whereas attitude and perceived behavioral control demonstrated no predictive power. Consequently, this study adds to the body of knowledge by introducing an integrated framework based on TAM, TPB, and TTF in the context of preservice teachers' technology utilization using digital learning tools.

KEYWORDS Digital Tools, Instruction, Intention, Preservice Teacher, Predictor

RESUMEN

Este estudio examina las intenciones de los profesores en formación de adoptar herramientas digitales para las prácticas de instrucción a través del Modelo de Aceptación de la Tecnología (TAM), la Teoría del Comportamiento Planificado (TPB) y el Modelo de Ajuste de la Tecnología a la Tarea (TTF). Se empleó un diseño de investigación transversal para poner a prueba un modelo hipotético a través de una encuesta de autoinforme administrada a los participantes del curso de tecnología educativa. Un total de 210 participantes tomaron parte en la investigación, con los datos de la encuesta recogidos

en relación con las opiniones de los profesores en formación sobre la adopción de herramientas de aprendizaje digital en sus futuras prácticas. Se utilizó el modelo de ecuaciones estructurales de mínimos cuadrados parciales (PLS-SEM) para analizar las hipótesis del estudio, y el modelo propuesto arrojó resultados válidos y fiables. El estudio reveló que la adecuación de la tecnología a la tarea era el factor predictivo más influyente en la intención de los profesores en formación de utilizar herramientas digitales de aprendizaje para futuras prácticas docentes. La utilidad percibida y las normas subjetivas fueron otros predictores significativos de la intención conductual, mientras que la actitud y el control conductual percibido no demostraron poder predictivo. En consecuencia, este estudio se suma al cuerpo de conocimientos mediante la introducción de un marco integrado basado en TAM, TPB, y TTF en el contexto de la utilización de la tecnología de los profesores en formación utilizando herramientas digitales de aprendizaje.

PALABRAS CLAVE herramientas digitales, instrucción, intención, profesor en formación, predictor

1. INTRODUCTION

Although the integration of digital technologies within learning environments is not itself anything new, the use of these technologies increased rapidly with the COVID-19 outbreak (Pozo et al., 2024). Technological advancements have also significantly impacted upon modern teaching and learning methods, with the rapid and innovative growth of Internet technologies having led to the creation of numerous digital tools and apps, smart devices such as laptop and tablet computers, as well as the ubiquitous smartphone revolution (Ng, 2015). Consequently, scholars and practitioners have explored the various ways in which these technologies may be employed for educational purposes (Taylor et al., 2021).

Technology use in delivering instruction was already prevalent in education for many years; however, almost overnight the pandemic forced the rapid and almost universal adoption of digital tools for the enhancement of education (Paetsch & Drechsel, 2021) in that most face-to-face courses were replaced by online education, which had a profound impact on students. Pandemic distance learning required students to possess a high degree of self-regulation concerning their learning environment and to find new ways of communicating with their peers and instructors. At the same time, the novel situation offered opportunities to experience new educational applications. To learn more about the possible benefits of distance learning, this study examines how the first online semester during the pandemic contributed to pre-service teachers' intentions to use digital learning materials in the future. Pre-service teachers enrolled in a German university (n = 348. As such, the world has witnessed a paradigm change in recent years, with contemporary students utilizing a diverse range of programs and resources to produce their assignments rather than relying on traditional tools such as pen and paper (Haleem et al., 2022). In light of the many ways digital technologies have enriched education, from facilitating student learning to fostering digital citizenship and promoting lifelong learning (Ng, 2015), it is imperative that future educators are sufficiently prepared to make effective use of these tools in the classroom. On this, Ertmer (1999) defined technology integration barriers as internal and external, with teachers' technical and pedagogical knowledge having a significant impact on the meaningful integration of technology in education. Furthermore, Hew and Brush's (2007) pioneering study identified barriers to technology integration, revealing that the technological knowledge and skills of teachers was a factor that affected their use of technology in the classroom.

In earlier research, Inan and Lowther (2010) revealed computer proficiency as an important determinant of teachers' technology integration, whilst a meta-analysis by Wilson et al. (2020) revealed that courses related to technology integration enhanced preservice teachers' technological and pedagogical knowledge. In this regard, Ottenbreit-Leftwich et al. (2018) stated that equipping preservice teachers with appropriate knowledge and experience related to technology integration may help them to overcome obstacles in their future classroom teaching. However, whilst technological knowledge and skill are considered major factors for effective technology integration, the perception toward and adoption of technology are also essential issues. The successful utilization of digital resources within educational courses therefore relies significantly on the actions of teachers (Müller & Leyer, 2023). Prior to starting teaching, the assessment of preservice teachers' technology acceptance levels would help provide institutions with valuable information of interest to various stakeholder groups.

In order to better prepare future educators to deliver benefit from the effective use of digital learning tools in their instruction, teacher preparation programs need to provide student teachers with adequate hands-on experience with the use of digital learning resources in the classroom environment (Paetsch & Drechsel, 2021) in that most face-to-face courses were replaced by online education, which had a profound impact on students. Pandemic distance learning required students to possess a high degree of self-regulation concerning their learning environment and to find new ways of communicating with their peers and instructors. At the same time, the novel situation offered opportunities to experience new educational applications. To learn more about the possible benefits of distance learning, this study examines how the first online semester during the pandemic contributed to pre-service teachers' intentions to use digital learning materials in the future. Pre-service teachers enrolled in a German university (n = 348. Teachers need to be leaders in technology-supported environments, hence they should adopt and utilize digital tools in their teaching practices (Sharma & Saini, 2022). For this reason, the decisions made by preservice teachers' on their expected use of these tools require investigation, as well as the factors that could influence their decisions.

Several models exist which may be used to scrutinize technology acceptance such as the Technology Acceptance Model (TAM) (Davis, 1986), the Theory of Planned Behavior (TPB) (Ajzen, 1985), the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003), and the Task Technology Fit Theory (TTF) (Goodhue & Thompson, 1995). Several studies have incorporated these models in the investigation of user acceptance. For example, the TAM was used in researching inservice teachers' acceptance of technology (Hong et al., 2021; Wohlfart & Wagner, 2024), preservice teachers' acceptance of technology (Teo et al., 2015), preservice teachers' intentions to use Web 2.0 tools (Şimşek & Ateş, 2022), and preservice teachers' acceptance of educational robots (Casey et al., 2021). In other studies, the TPB was used in researching preservice teachers' adoption of technology-enabled learning (Hou et al., 2022) and preservice teachers' intentions to use technology during their teaching practices (Habibi et al., 2023; Yusop et al., 2021). Additionally, Dahri et al. (2024) employed TTF to investigate factors related to mobile-based teacher training.

Additionally, the adoption of digital tools in teaching has been studied. For example, Sharma and Saini (2022) used the TAM to explore higher education instructors' intentions to continue integrating electronic resources into instructional practices, and Polly et al. (2022) examined how inservice and preservice teachers perceived digital technology in terms of its importance, usefulness, competency, and interest. During the COVID-19 pandemic, research was conducted to reveal instructors' inclinations toward teaching online

(Aivazidi et al., 2021; Sangeeta & Tandon, 2020), whilst following the pandemic, similar research was conducted separately with inservice (Khong et al., 2022) and preservice teachers (Wang, 2022). The research to date in this area has tended to focus mostly on teachers as participants and the investigation of their technology adoption behaviors. As the success and efficacy of digital technology usage attempts may depend on users' technology acceptance (Sharma & Saini, 2022), it would be reasonable to determine predictors of digital tools usage during teacher education. Preservice teachers' intentions regarding the use of digital tools in their future professional teaching career may help serve as a predictor of their actual usage once employed as teachers in the classroom. Thus, the intention of prospective teachers to benefit from digital tools in the classroom is considered a crucial subject to explore.

The current study favored use of the TAM, TPB, and TTF models, which may be used to predict a teacher's propensity to utilize technology in their future teaching. The TAM was selected for the current study since it is considered a strong model for learning technologies (Granić & Marangunić, 2019) and is employed mainly in research on technology acceptance. However, one important issue related to the TAM is that it neglects to account for subjective beliefs or perceived behavioral control, wherein abilities, resources, and opportunities are deemed essential for forecasting the intention to utilize a technology (King & He, 2006; Mathieson, 1991). Given this limitation, the TPB was considered for the current research since it is also known as a successful theory for the prediction of user intention based on essential variables such as subjective norms and perceived behavioral control. Compared with the TAM, the TPB is considered more independent of content, and its constructs are therefore applicable to any behavior (Ajzen, 2020). Lastly, given the plethora of digital tools available for instructional purposes, it is considered essential to understand their various characteristics and capabilities, as well as their alignment with users' goals and intended objectives (Goodhue & Thompson, 1995). Consequently, TTF was also integrated into the scope of the current investigation.

According to the literature, there have been various research studies regarding inservice teachers' or preservice teachers' adoption of technology. The current study presents one of the first attempts to combine three models to explore digital tools acceptance in the context of preservice teachers. The combining of these three models is expected to shed additional light on preservice teachers' adoption of digital learning tools for their future instructional practices compared to research reliant upon only a single model. Preservice teachers can gain experience of using digital educational materials and are generally encouraged to utilize technology in their teaching and learning as part of their teacher education (Paetsch & Drechsel, 2021). Thus, prior to the start of their professional teaching career, the use of an integrated model may help to identify both positive and negative factors related to the use of digital tools in teaching. Moreover, the results of the current study are expected to help instructors to use the most appropriate digital tools in the education of preservice teachers.

In light of the aforementioned literature and prior research, the current study examined preservice teachers' intentions to embrace digital tools for instructional practices through the TAM, TPB, and TTF. Regarding the current study's significance, the findings are expected to expand upon existing knowledge of the factors driving preservice teachers' intentions to benefit from digital learning tools by uncovering potential connections between variables. As such, the research outcomes are expected to offer implications pertinent to both teaching practitioners and educational managers.

2. THEORETICAL BACKGROUND

2.1. Digital Learning Tools

Digital technology has significantly impacted the field of education (Wang et al., 2024). The term "digital technologies" includes both software and hardware such as desktop computers, mobile devices, recording devices, smartboards, Web 2.0 tools, and multimedia tools (Ng, 2015). Multiple variants of these technological advancements have spawned new delivery and teaching methods such as online learning and blended learning (Khong et al., 2022)the coronavirus disease 2019 (COVID-19 as well as significantly changing traditional face-to-face classroom teaching methods (Müller & Leyer, 2023). Incorporating these instruments into pedagogical processes has resulted in positive outcomes for students such as increased engagement and motivational development required for 21st-century skills (Taylor et al., 2021). Timotheou et al. (2023) conducted a detailed evaluation of research that examined the effects of digital technology on education. The research findings revealed that the utilization of digital technologies facilitated students' learning in particular academic disciplines and fostered the growth of their skill sets in areas such as creativity, problem solving, and computational thinking. Additionally, digital technologies have been shown to improve students' motivation, attitude, and academic confidence.

Several countries and international organizations have developed standards and requirements for educators in the 21st century, including Turkey's Ministry of National Education (2017), the International Society for Technology in Education (2017), and the European Framework for the Digital Competence of Educators (European Commission, 2017). These various standards incorporate the design, development, and implementation of effective learning processes and the integration of appropriate technologies within learning environments. Regarding effective technology integration, teachers require both appropriate knowledge and strong beliefs (Ertmer & Ottenbreit-Leftwich, 2010). As such, future educators must acquire proficiency in the utilization of these resources and possess a favorable view of technology integration in the classroom by effectively learning to employ digital tools in conjunction with sound pedagogical practices. In this regard, among the many types of digital technologies currently available, the following were selected within the scope of the current study (Bower, 2016; Bower & Torrington, 2020):

- **Online repository tools** can be used to store and access instructional documents, presentations, videos, and other electronic files. These tools usually offer organized folder systems where permissions can be set to control who can access and edit files or folders.
- **Learning management systems (LMS)** enable teachers to manage their course activities and students' work. Additionally, students can also access their course materials, course activities, and assignments, as well as monitor their own progress. LMS functionality also enables teachers to create assignments and tests, monitor student progress, report and record statistics, and to supervise course administration.
- **Online meeting platforms** can be used to conduct virtual meetings and classes, with features including video, audio, and chat utilized to facilitate and enhance the instructional process and acquisition of knowledge. Additionally, users can see and hear each other as well as benefit from synchronous features such as screen sharing.

- **Presentation tools** enable teachers to develop interactive course presentations where they can add text, pictures, tables, graphics, music, and video into slides to create more effective teaching.
- **Video tools** enable teachers to produce interactive videos for instruction and learning with features that include both video and still images, transitions between elements, and other editing options that help create almost professional standard audiovisual materials.
- **Animation platforms** enable teachers to create compelling animations to support student learning. These platforms offer templates, drag-drop functionality, and interactive elements as well as the use of multimedia content.
- **Infographics, concept maps, and poster tools** can be utilized to create visual materials that combine text, charts, and images or icons to promote concept organization, knowledge summarization, and for the visualization of ideas.
- **Assessment platforms** can be used to create course assessment material and to implement digital exams or quizzes, enabling teachers to create online tests with varied question types, automated feedback and grading functions, and also performance monitoring.

Other emerging tools worthy of note are coding tools, and the use of virtual reality (VR) and augmented reality (AR) applications which can further help teachers to create a more meaningful and effective teaching and learning experience.

2.2. Teacher Education in Turkey

In Turkey, preservice teachers are required to complete various undergraduate courses based on field knowledge, professional teaching knowledge, general knowledge, as well as various elective courses (Yükseköğretim Kurulu [Turkish Higher Education Council], 2018). Each area includes courses that help these future educators to develop skills in their chosen subject area (e.g., mathematics education, preschool education). One of the professional teaching knowledge courses is on instructional technology, which includes topics such as the conceptual background of instructional technology, instructional materials design, message design principles, instructional technology contemporary tools and approaches, and digital teaching tools. Overall, the course helps preservice teachers to gain both the required academic knowledge and practical expertise in applying various instructional technologies in their teaching practices.

Turkey's Ministry of National Education (2017) has also created Competencies for the Teaching Profession which comprise three main areas: professional knowledge and skills, attitudes, and values. According to the professional skill competency area, teachers should be able to utilize technology and materials within their teaching practices (Milli Eğitim Bakanlığı [Turkish Ministry of National Education], 2017). The aforementioned instructional technology course is therefore integral to equipping preservice teachers with the necessary knowledge and skills related to technology integration. Historically, the Turkish Ministry of National Education has conducted a number of technology integration initiatives, with the Movement of Enhancing Opportunities and Improving Technology project (known by its Turkish acronym, FATIH) having been in play since 2010 (Milli Eğitim Bakanlığı [Turkish Ministry of National Education], 2010). The project provides both hardware and software infrastructure to classrooms nationwide, as well as focusing on the creation

of instructional e-content, integrating information and communication technologies (ICTs) into curricula, the organization of inservice teacher training, and encouraging safe Internet usage by both teachers and students. The FATIH project aims that preservice teachers be prepared to effectively utilize ICTs in education so that they can maximize the benefits for students prior to starting their professional teaching careers.

2.3. Hypothesized Model Development

Regarding technology use in learning environments, supplying ICT tools alone to schools holds no guarantee that teachers and students will benefit from the latest technology-enhanced teaching strategies as opposed to conventional instructional methods. Various factors are known to affect teachers' adoption and use of technology in their teaching practices (Ursavaş et al., 2019). According to a longitudinal study conducted by Pozo et al. (2024), teachers have generally used digital tools more following the pandemic than they did previously, inferring that teachers accept and adopt such tools after long-term usage (in this case, from emergency online teaching during the pandemic). In an earlier study, Li et al. (2016) explored preservice teachers' acceptance of technology through two models, the TPB and TAM, and indicated that self-efficacy, attitude, and perceived ease of use were significant predictors. Research by Mei et al. (2018) identified factors affecting preservice teachers' adoption of Web 2.0 tools for foreign language teaching, in which perceived usefulness, facilitating conditions, and technological pedagogical content knowledge influenced intention. Similar research includes a study by Lee et al. (2022), who explored foreign language teachers' adoption of online teaching by combining the TAM and TTF models; Wong et al. (2013) who used the UTAUT model to explore predictors of whiteboard usage by preservice teachers; and Tang et al. (2021) who integrated the TPB, TAM, and UTAUT models plus individual factors connected to a mobile technology-enhanced teaching platform used by university instructors. As teachers' technology adoption and utilization is a multifaceted behavior (Ursavaş et al., 2019), it is considered well worth examining this behavior using more than one acceptance model. As such, understanding the predictors of this behavior in terms of preservice teachers may help to better guide the design of teacher education programs to ensure newly qualified teachers can effectively use educational technology in the classroom (Anderson et al., 2011).

The literature on information systems, particularly in terms of the TAM, TPB, and TTF models, has mostly scrutinized users' intention to utilize certain technologies based on emphasis of their acceptance or adoption of those technologies. The TAM, which is an adaption of the Theory of Reasoned Action (TRA), focuses on predicting and explaining users' behaviors toward technology (Davis et al., 1989) through the elements of perceived usefulness (PU) and perceived ease of use (PEU), attitude (AT), and behavioral intention (BI) (Davis et al., 1989). The TPB, which is an extension of TRA (Ajzen, 1985), is a significant and popular theory employed to explain different types of human behavior (Ajzen, 2001). According to the TPB, any human behavior can be identified according to three constructs: attitude (AT), perceived behavioral control (PBC), and subjective norms (SN) (Ajzen, 1985). The TTF model predicts an information system's success by considering the task-technology fit; i.e., it is the characteristics of tasks and technology that impact the fit between tasks and technology (Goodhue & Thompson, 1995). Within the scope of the current study, the TAM, TPB, and TTF models are proposed as a theoretical framework to effectively assess the behavioral intention of preservice teachers to utilize digital learning tools in their instructional activities.

The TAM, which has gained significant acceptance in the area of instructional technology, was initially introduced by Davis in 1986. The model consists of four variables (PU, PEU, AT, and BI), with relationships between each of these variables: PU and AT predict BI; PEU and PU predict AT; and PEU predicts PU (Davis, 1986). PU is the level to which an individual believes that the adoption of a given system will increase their job efficiency, whereas PEU is how easy they consider the technology would be to use in practice (Davis, 1989).

In the context of digital learning tools' adoption, Teo (2012) combined the TAM and TPB models for surveying preservice teachers to determine how they planned to utilize technology in their teaching. The study revealed that TAM variables and SN were associated with behavioral intention. Furthermore, it was concluded that favorable attitudes and perceptions regarding the usefulness of technology was a driver for preservice teachers to utilize technology. In a more recent study, Almulla (2022) researched how university instructors intended to utilize digital learning tools during the COVID-19 pandemic via an extended TAM, the results of which confirmed the main propositions of the TAM. Concerning the current study, preservice teachers' attitudes regarding the potential benefits of incorporating digital technologies into their teaching may impact upon their inclination to utilize these resources in their future teaching practices. Utilizing digital learning tools for different instructional purposes can consequently influence their teaching behaviors and shape perceptions regarding the usefulness of digital learning tools and, as a result, they may be more likely to adopt and utilize digital tools in their future teaching careers. Previous literature has shown significant linkage between PU and BI for technology-rich learning environment acceptance (Parkman et al., 2018) and for teaching intention of Web 2.0 tools (Şimşek & Ateş, 2022). The usefulness of digital tools that preservice teachers perceive may affect their feelings toward these tools, a relationship that was validated by prior research on teachers' intention to teach online (Bajaj et al., 2021) and technology acceptance of preservice mathematics teachers (Gurer, 2021).

Moreover, preservice teachers' thoughts with regards to the utilization of digital tools in their future teaching will likely influence their attitudes towards and usefulness of digital tools. In other words, the difficulty or ease of using certain digital learning tools, as experienced directly by preservice teachers, may affect their feelings towards those digital tools and their belief in their usefulness. These PEU–PU and PEU–AT relationships were validated in research by Eksail and Afari (2020), Georgiou et al. (2023), and Islamoglu et al. (2021). Accordingly, the following research hypotheses were formed for the current study based on the existing published literature:

H1: Perceived usefulness of digital learning tools influences preservice teachers' intention to use these tools for instruction.

H2: Perceived ease of use of digital learning tools influences preservice teachers' attitudes toward utilizing these tools for instruction.

H3: Perceived usefulness of digital learning tools influences preservice teachers' attitudes toward utilizing these tools for instruction.

H4: Perceived ease of use of digital learning tools influences preservice teachers' perceived usefulness of these tools for instruction.

The TPB can be used in order to explain factors affecting a set of human behaviors. Accordingly, the behavioral intention of certain actions is influenced by AT, SN, and PBC (Ajzen, 1985), since AT is an underlying inclination to respond positively or negatively to a psychological construct (Fishbein & Ajzen, 2010) and SN describes the perceived societal pressure to engage in an action or not to (Ajzen, 1991). As such, these constructs are considered to positively and directly affect the intention of the behavior.

Previous studies have incorporated the TPB and validated proposed relationships among its constructs in several research areas. As an example, Habibi et al. (2023) studied preservice teachers' technology integration by combining the TPB with technological pedagogical and content knowledge, revealing that all constructs were significantly influential to behavioral intention. Teo and Tan (2012) studied the reasons behind student instructors' embrace of technology and utilized the TPB to discover significant correlations among the constructs. In subsequent research, Teo et al. (2016) analyzed teachers' intention to employ technology by extending the TPB. The variables considered were PU, PEU, management expectations, and technical support, and it was revealed that whilst AT and PBC increased technology integration intention, SN did not.

The current study posits that preservice teachers' positive or negative attitudes toward digital tools can influence their behavioral intentions. Consequently, it is presumed that preservice teachers intend to utilize digital learning tools in their future teaching practices when they possess favorable attitudes toward these tools; a relationship previously validated in the literature (Müller & Leyer, 2023; Teo, 2012).

Understanding the views of preservice teachers' social circuits might also influence their behavioral intention. In essence, the opinions of significant others such as peers, instructors, and administrators may dominate preservice teachers' intention to utilize digital tools for instructional purposes. Research by Songkram and Osuwan (2022) on teachers' intentions of using use digital learning materials corroborated the SN–BI connection, as well as in a study on teachers' intention to benefit from mobile applications for science teaching by Ateş and Garzón (2022). Moreover, preservice teachers' perceived control beliefs impact their behavioral intention, which can be explained as the behavior of using digital tools for teaching is affected by their abilities and the environmental resources available when using digital tools in their teaching. Several studies have already proven this relationship, including Hou et al. (2022) and Watson and Rockinson-Szapkiw (2021). Accordingly, the current study formulated the following hypotheses based on the existing literature:

H5: Attitudes toward utilizing digital learning tools influence preservice teachers' intention to use these tools for instruction.

H6: Subjective norms to utilize digital learning tools influence preservice teachers' intention to use these tools for instruction.

H7: Perceived behavioral control over utilizing digital learning tools influences preservice teachers' intention to use these tools for instruction.

The TTF model primarily emphasizes how information technology fits the specific demands of various tasks (Goodhue & Thompson, 1995). The predictors of perceived performance are utilization and task technology fit, which are functions of task characteristics and technology characteristics (Goodhue & Thompson, 1995). This model is theorized as information technology is used where the features of a certain

information technology are considered a match with the users' tasks (Lo Presti et al., 2021). The task-technology fit variable, which is defined as "the degree to which a technology assists an individual in performing his or her portfolio of tasks" (Goodhue & Thompson, 1995, p. 216), was therefore selected for use in the current study. In terms of the current research, the TTF relates to the fit between the instructional tasks that preservice teachers desire to carry out and the characteristics of the appropriate digital technologies. Thus, it can be stated that TTF perception affects the adoption of digital learning tools. If preservice teachers have a higher TTF perception, they perceive the tools as easy to use and therefore useful for their teaching, which corroborates empirical research by Pal and Patra (2021) and also Wu and Chen (2017). Therefore, the TTF variable was utilized in the current study to analyze the TAM constructs' connections, with the following three hypotheses:

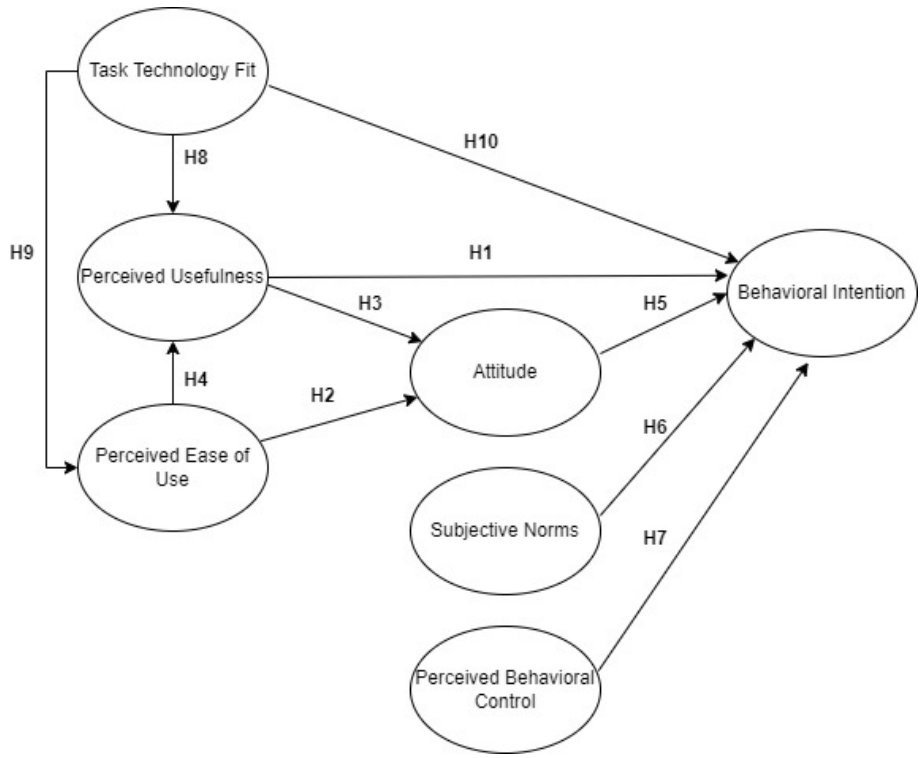
H8: Task-technology fit of digital learning tools influences preservice teachers' perceived usefulness of these tools for instruction.

H9: Task-technology fit of digital learning tools influences preservice teachers' perceived ease of using these tools.

H10: Task-technology fit of digital learning tools influences preservice teachers' intention to use these tools for instruction.

The relationships and the 10 hypotheses formulated in the current study are illustrated in Figure 1.

FIGURE 1. Hypothesized model



3. MATERIAL AND METHOD

The study implemented a cross-sectional research design to test the devised hypothetical model. A self-report survey based on the TAM, TPB, and TTF models was administered with the aim of reaching the study's goal.

3.1. Participants

The sample was selected using the convenience sampling method from a university located in the Aegean region of Turkey. The study group comprised 215 preservice teachers who received an instructional technology course from the university's faculty of education as part of their undergraduate teacher training program.

Power analysis was performed using G*Power software (Faul et al., 2009) to check the minimum appropriate sample size, with an effect size of .15, error type of .05, and a power setting of .80. The minimum sample size for the study was revealed to be 92, demonstrating that the 215-participant sample was satisfactory. Prior to the survey being administered, the study's objective was explained to the participants and they were directed to read the study's consent form and give their consent if they wished to join the study. The participants were also informed of their right to withdraw from the study at any point. The data collection process produced a total of 210 valid cases that were subjected to data analysis, with 81% (n = 170) of the participant preservice teachers identifying as female and 19% (n = 40) as male. The participant preservice teachers were distributed across six teaching departments, with 57 (27.1%) enrolled to the English Language Education department, 56 (26.7%) to Preschool Education, 30 (14.3%) to Guidance and Psychological Counseling, 24 (11.4%) to Science Education, 22 (10.5%) to Elementary Mathematics Education, and 21 (10.0%) to the Turkish Language Education department. The participants averaged 20.8 years old with a 2.68 standard deviation.

3.2. Data Collection Procedure

The self-report survey included questions to collect personal information on the participants' demographics plus questions regarding theoretical constructs. Previous questionnaires from the existing literature regarding the TAM, TPB, and TTF models were first analyzed prior to creating an initial pool of survey items. Then, those items that were considered to be well suited to each construct based on the study's purpose were selected and a 7-point, Likert-type scale established to evaluate the PU, PEU, SN, and TTF constructs with three items, while the ATT, PBC, and BI constructs were assessed with four items. The researchers then adjusted the items according to the study's setting, with adapted items for PU ("Using digital tools improves my teaching performance") and PEU ("Learning to use digital tools is easy") from a study by Wu and Yu (2022), for ATT ("Using digital tools would be: (unpleasant / pleasant)") from Taylor and Todd's (1995) research, for SN ("People who influence my behavior think that I should use digital tools") from Teo, Zhou, et al.'s (2019) study, for PBC ("I have the knowledge necessary to use digital tools in teaching") from Teo, Zhou, et al. (2019), for TTF ("In my opinion digital tools' functions are enough to help me complete

my work for teaching") from Lu and Yang (2014), and for BI ("I intend to use digital tools for teaching as often as needed") from the study published by Baber (2021). Two researchers then independently translated each item from English to Turkish, then two specialists fluent in both languages reviewed the materials and made recommendations. Following revision of the items, a Google Forms survey was created and administered to the participant preservice teachers at the end of the teaching semester, since at that point they would be most likely to possess a working knowledge of digital teaching tools and other course-related topics.

3.3. Data Analysis

Partial least square structural equation modeling (PLS–SEM) approach was utilized to scrutinize the study's 10 formulated hypotheses. The PLS–SEM approach was selected since the current study aimed at prediction rather than theory testing or confirmation and that the proposed model was an extension of the TAM, TPB, and TTF models created to explore key drivers of the dependent construct (Hair et al., 2011) SEM is equivalent to carrying out covariance-based SEM (CB-SEM).

Initially, the collected data were analyzed so as to identify any missing data or outliers. The analytical process was undertaken in two closely related stages, with the measurement and then the structural models. First, the model's reliability and validity issues were calculated, and where satisfactory, the second stage tested the hypothetical relationships using SmartPLS 3.3.5 software.

4. RESULTS

4.1. Measurement Model

A reliability and validity examination was performed in order to evaluate the appropriateness of the measurement model, the results of which are presented in Table 1 (in next page).

Regarding the model's reliability, item reliability was assessed based on their factor loadings, which should be higher than .70 according to Hair et al. (2019). The results revealed that all of the items had factor loadings that ranged between .816 and .955. Additionally, composite reliability (CR) and Cronbach's alpha values were utilized to fulfill the requirements for internal consistency reliability. Both the CR (Hair et al., 2019) and alpha values (Nunnally and Bernstein, 1994) were found to be higher than the minimum acceptable value of .70. Convergent and discriminant validity was then assessed to check whether the proposed model was considered valid. Convergent validity requires that AVE values exceed .50 (Hair et al., 2019). In the current study, the AVE values ranged from .728 to .877, confirming that convergent validity was ensured. Table 2 presents the results of discriminant validity tests.

Discriminant validity values were found to be satisfactory based on the criteria that AVE value square roots should be greater than the related construct correlations (Fornell & Larcker, 1981). Overall, the measurement model demonstrated satisfactory levels of reliability and validity to conduct the structural model analysis.

TABLE 1. Measurement model results

Construct	Item	Factor loading	Composite reliability	Cronbach alpha	Average variance extracted
Perceived usefulness (PU)	PU1	.928	.955	.930	.877
	PU2	.955			
	PU3	.926			
Perceived ease of use (PEU)	PEU1	.895	.897	.829	.744
	PEU2	.816			
	PEU3	.876			
Attitude (ATT)	ATT1	.902	.958	.942	.850
	ATT2	.926			
	ATT3	.940			
	ATT4	.920			
Perceived behavioral control (PBC)	PBC1	.918	.961	.945	.859
	PBC2	.935			
	PBC3	.911			
	PBC4	.943			
Subjective norms (SN)	SN1	.869	.904	.841	.758
	SN2	.893			
	SN3	.850			
Task technology fit (TTF)	TTF1	.825	.889	.812	.728
	TTF2	.895			
	TTF3	.837			
Behavioral intention (BI)	BI1	.892	.947	.925	.817
	BI2	.901			
	BI3	.937			
	BI4	.884			

TABLE 2. Discriminant validity results

	ATT	BI	PBC	PEU	PU	SN	TTF
ATT	**.922**						
BI	.441	**.904**					
PBC	.380	.459	**.927**				
PEU	.207	.379	.637	**.863**			
PU	.408	.609	.378	.364	**.937**		
SN	.337	.536	.472	.415	.577	**.871**	
TTF	.409	.632	.515	.391	.514	.488	**.853**

(diagonal values = square root of AVE; off-diagonal values = correlations of paired constructs)

4.2. Structural Model

Associations between the proposed model's components were tested by way of structural model analysis. First, the collinearity issue was measured according to Variance Inflation Factor (VIF) values among the model's constructs. The measured VIF values were found to be lower than the threshold value of 5, indicating that no multicollinearity problem was detectable. The bootstrapping resampling technique was then employed

with 5,000 subsamples in order to determine whether or not the path values of the links and the *t* values for each hypothesis were significant. The model's prediction accuracy was then confirmed by *R*2. The outcomes of testing the study's 10 hypotheses are both illustrated in Figure 2 and also reported in Table 3.

TABLE 3. Results of hypotheses testing

Hypothesis	Path	VIF	β	*t*	*p*	Supported?
H1	PU → BI	1.748	.285	3.415	.001	Yes
H2	PEU → ATT	1.153	.067	1.019	.308	No
H3	PU → ATT	1.153	.383	6.176	.000	Yes
H4	PEU → PU	1.180	.193	2.619	.009	Yes
H5	ATT → BI	1.329	.115	1.869	.062	No
H6	SN → BI	1.735	.135	2.168	.030	Yes
H7	PBC → BI	1.538	.071	1.006	.315	No
H8	TTF → PU	1.180	.439	6.457	.000	Yes
H9	TTF → PEU	1.000	.391	6.811	.000	Yes
H10	TTF → BI	1.711	.336	4.598	.000	Yes

The results indicated that seven of the 10 hypotheses were accepted based on the structural model analysis.

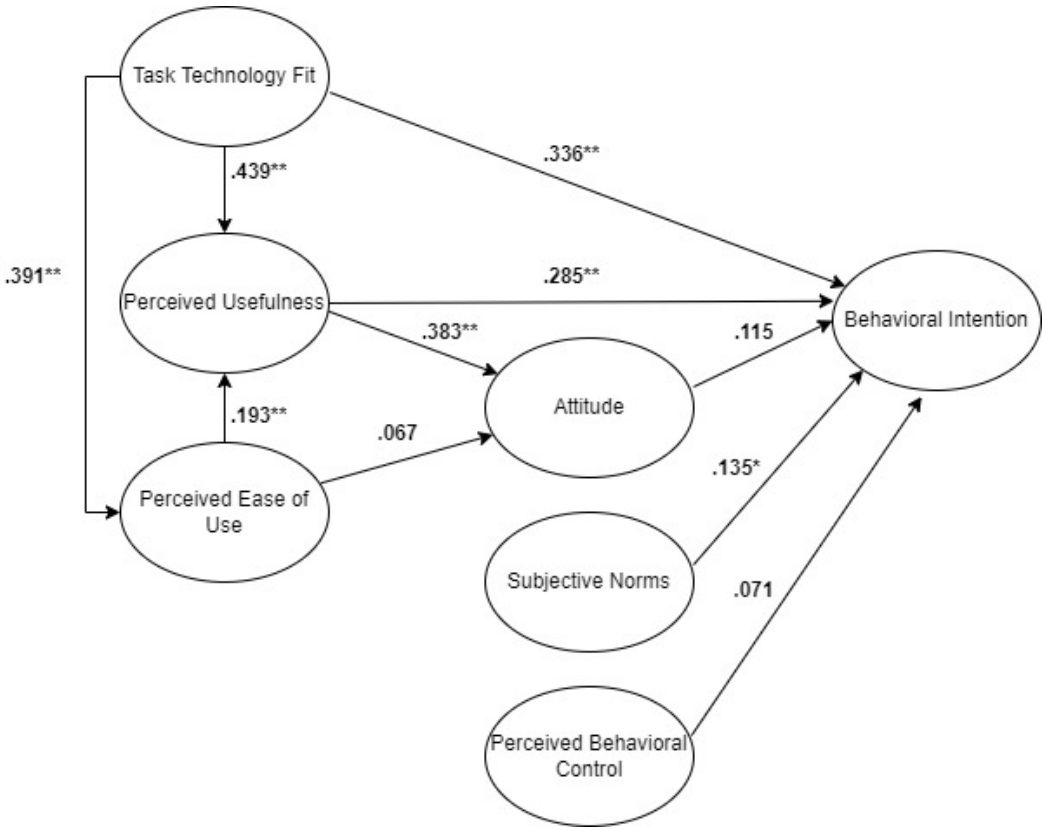
For hypotheses of the TAM model, the perceived usefulness (PU) construct was shown to influence behavioral intention (BI) to use digital learning tools (β = .285, $p < .001$) and attitude (ATT) towards digital tools (β = .383, $p < .001$), whilst the perceived ease of use (PEU) construct predicted perceived usefulness (PU) of digital tools (β = .193, $p < .01$). In contrast, perceived ease of use (PEU) did not significantly affect attitude (ATT) towards digital tools (β = .067, $p > .05$). Thus, hypotheses H1, H3, and H4 were accepted, while H2 was not supported.

For the TPB model's hypotheses, subjective norms (SN) significantly predicted behavioral intention (BI) to use digital learning tools (β = .135, $p < .05$), whereas attitude (ATT, β = .115, $p > .05$) and perceived behavioral control (PBC, β = .071, $p > .05$) exhibited no substantial influence on behavioral intention (BI). Therefore, hypothesis H6 was supported, while both H5 and H7 were rejected.

For the TTF model, a significant effect was revealed on perceived usefulness (PU, β = .439, $p < .001$), perceived ease of use (PEU, β = .391, $p < .001$), and behavioral intention (BI, β = .336, $p < .001$). Thus, hypotheses H8, H9, and H10 were all accepted.

The overall variance for the intention to use digital learning tools was 52%, suggesting that the proposed model was moderate in predicting the dependent variable (Chin, 1998).

FIGURE 2. Structural model



* p<.05, ** p<.01

5. DISCUSSION

The study's results showed that the hypotheses for the TAM and TPB models were partially confirmed, whilst relationships regarding TTF were fully supported in the proposed model. It can therefore be said that the research model had good explanatory power to understand preservice teachers' acceptance behaviors.

The study proved that the usefulness perception of digital tools significantly predicted preservice teachers' behavioral intentions to use digital tools in their future teaching practices. This result is consistent with research by Şimşek and Ateş (2022) and Teo, Sang, et al. (2019) on the acceptability of Web 2.0 tools for use in the classroom. This finding points to preservice teachers viewing digital tools as beneficial in classroom instruction and that their use helps to improve their teaching performance through their having received both theoretical and practical knowledge of digital tools and other related issues. It is suggested that this belief is what drives preservice teachers to utilize digital instruments in their future classroom instruction. As a result, it can be stated that perceived usefulness influences the willingness to use these digital tools. Additionally, perceived usefulness was shown to significantly influence attitude, a finding also supported by previous studies in the literature (Eksail & Afari, 2020; Georgiou et al., 2023; Gurer, 2021). Considering this relationship, the perceived benefits that digital tools offer may shape preservice teachers' feelings towards the use of such tools. Consistent with prior research on this, the current study found that the preservice

teachers' impressions regarding the easiness of using digital tools had a significant impact on their perceptions regarding the tools' usefulness (Almulla, 2022; Taylor et al., 2021). On the other hand, the perceived ease of using these digital tools did not influence their attitude. Although this result was contrary to that of previous studies by Almulla (2022) and Davis (1989), other research by Luik and Taimalu (2021) and Teo et al. (2018) supported it.

In the current study, the participant preservice teachers were experienced in the use of these digital tools; for example, how to log in, the functions of various menu elements, and how to develop instructional material. Thus, it can said that the preservice teachers' comfort level in the use of the digital tools may relate to their perception of their usefulness. On the other hand, if the preservice teachers perceived the digital tools to be easy or difficult to use, their feelings about these tools (i.e., their attitude) would not increase or decrease. Instead, the preservice teachers may have considered that digital tools that were easy to use might be seen as useful technology to utilize in their future teaching. To conclude, the assumptions regarding the TAM were partially supported in the current research context.

According to the proposed model, subjective norms were found to be a significant indicator of behavioral intention among the TPB variables, whilst the constructs of attitude and perceived behavioral control were not. Concerning the context of the current study, the participant preservice teachers each have their own social network, consisting primarily of their peers and instructors, and these networks may effectively explain the preservice teachers' plans to utilize digital tools for instructional purposes. Previous research has shown this to be the case; for example, Kreijns et al. (2013) discovered that teachers' subjective norms affected their intention to use digital learning materials, whilst Songkram and Osuwan (2022) found that teachers' behavioral intention to use digital learning platforms was positively correlated with their subjective norms during the COVID-19 pandemic. On the other hand, preservice teachers' control perceptions over digital learning tools were not found to influence their behavioral intentions in the current study. In terms of the prior literature, this finding supports the results reported by Teo and Lee (2010) and also Teo and van Schaik (2012), but contradictory to those of Habibi et al. (2023) and Hou et al. (2022). As Ajzen (1991) put forward, perceived behavioral control (PBC) has an association with the ease or difficulty of carrying out a particular behavior. It can be deduced from the results of the current study that the preservice teachers' confidence in their use of digital tools and the resources to promote those tools did not have a predictive effect on forming their intention to use them in their future teaching. This finding may be attributable to the limited opportunities that the preservice teachers were provided to engage with digital tools within authentic teaching and learning environments. Without having gained those experiences, it is possible that their intentions to use these tools may not have been influenced by their perceived behavioral control (Hou et al., 2022). Similarly, their attitudes toward digital learning tools did not show any influence on their behavioral intention. The literature contains mixed views regarding this finding; for example, some studies align with this view (e.g., Khong et al., 2022; Teo et al., 2011), while others were contradictory (e.g., Baturay et al., 2017; Müller & Leyer, 2023; Songkram & Osuwan, 2022). This suggests that preservice teachers' attitudes toward these tools, whether favorable or unfavorable, does not influence their decision to employ them within their future teaching practices. The following explanations are proposed regarding the non-significant influence of attitude. In the current study, preservice teachers learned theoretical and practical knowledge about digital learning tools. However, whilst they were familiar with the tools, they lacked actual experience

integrating these digital tools into real-life classes. Furthermore, the preservice teachers' attitudes may not have been able to form that quickly since their course only covered one semester of the curriculum. Davis et al. (1989) indicated the limited prediction of attitude in behavioral intention; therefore, the preservice teachers' perceptions of control and their positive or negative feelings regarding these tools may be shaped after having the opportunity to practice using the tools within authentic contexts, and the relationships between attitude and behavioral intention may then be more likely to manifest.

The current study showed TTF to be a significant factor affecting the constructs of behavioral intention, perceived usefulness, and ease of use. The significant links observed, as in TTF–PU and TTF–PEU, have also been confirmed in previous studies (Pal & Patra, 2021; Wu & Chen, 2017). Additionally, the significant link between TTF and BI was also supported by prior research by Kim and Song (2022). If preservice teachers evaluate the appropriate match between task and technology, they tend to utilize digital learning tools in their future teaching practices. Moreover, when preservice teachers perceive that the fit between task and technology is high, they will more likely consider that using the digital tools in question will contribute to their teaching performance and often regard them as requiring minimal effort. In the current study, the characteristics of various digital tools, such as the interface, menu, and the type of material that they can be used to design, were taught to the preservice teachers as part of their teacher training course on instructional technology. Thus, task-technology fit perceptions were shaped; hence, according to this belief, they may consider these tools useful and easy to use and thereby have a desire to continue using them in their future teaching practices.

The following implications are presented based on the results of the current study. The characteristics of digital tools are essential to preservice teachers being able to design and construct learning materials. Thus, teacher training program instructors who aim to equip preservice teachers with subject-matter knowledge and professional teaching knowledge should examine the specific features of any digital tools they propose to include in their lectures and practical teaching. In addition, when digital tools are perceived as being easy to use, preservice teachers will have a tendency to evaluate them as useful for their future teaching practices. As such, instructors should select digital tools based on ease of use criteria and also their tasks and technology fit. Another implication relates to the link between perceived usefulness and behavioral intention. It is considered essential to teach preservice teachers about the various types of instructional tools available, how to integrate them into teaching and learning, and the benefits of such practices, which can affect their overall perceptions of the usefulness of these tools. Additionally, the social circuit of preservice teachers should be considered as a means to encouraging them to utilize and integrate digital tools into their future teaching practices.

6. CONCLUSIONS

The proposed model provided valid and reliable results regarding preservice teachers' intention to benefit from the use of digital tools in their future teaching practices. Task-technology fit was shown to be the best indicator of intention to employ digital tools to facilitate instruction. Attitude and perceived behavioral control were not found to be predictive of behavioral intention, but subjective norms and perceived usefulness

were. As a result, the model can be said to have a moderate strength in explaining prospective teachers' intentions to employ digital tools for classroom learning. The current study contributes to the existing body of knowledge by introducing an integrated approach that combines the TAM, TPB, and TTF models.

6.1. Limitations

The current study presents certain limitations.

First, it may be possible that if the preservice teachers had used digital tools as part of their authentic teaching practice, such as use of the tools, designing materials, and integrating them within courses, their perceptions of control and attitudes could have influenced their behavioral intention. Therefore, future studies could focus on accepting digital tools after long-term usage through longitudinal studies or experimental designs.

Second, the current study opted to include the TAM, TPB, and TTF models, where alternatives such as motivation factors and expectation-confirmation theory could be considered in order to explore different factors that may affect preservice teachers' digital tools' acceptance.

Third, future studies of this nature could be conducted with both inservice and preservice teachers, enabling comparisons to be drawn between the two groups.

Fourth, the study employed a cross-sectional research method; however, in order to achieve a deeper understanding of the factors affecting preservice teachers' intention to use digital tools, qualitative research methods or mixed methods could be implemented in future studies. Moreover, the participant pool was primarily composed of female students. Future research should aim to replicate the study with a more evenly distributed gender representation.

Fifth, a self-report data collection tool was used which had a limitation concerning social desirability. Thus, to enable participants' actual behaviors and perceptions to be better understood, several tools such as observation forms and lesson plans could be included to examine the factors in play.

Sixth, the current study's sample consisted of preservice teachers from one university located in the Aegean Region of Turkey, which may limit the generalizability of the findings. Future studies could employ alternative sampling techniques with larger samples in Turkey or also in other countries for the purposes of cross-cultural comparison. Finally the collected data were analyzed according to the PLS–SEM method, which was aimed at prediction of the dependent construct. However, this method could be said to present certain limitations such as lacking any measure of goodness of model fit and working with small sample sizes compared to covariance-based SEM (Hair et al., 2011). As such, it may be advisable to conduct future research that analyzes data according to covariance-based SEM.

7. AUTHOR CONTRIBUTION

Conceptualization: Erhan Ünal, Ahmet Murat Uzun; Formal analysis: Erhan Ünal; Investigation: Erhan Ünal, Ahmet Murat Uzun; Methodology: Erhan Ünal; Writing – original draft: Erhan Ünal, Ahmet Murat Uzun; Writing – review & editing: Erhan Ünal, Ahmet Murat Uzun.

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Maker Education in Primary School: A Qualitative Study of Guidance and Evaluation of Teacher Training

La educación maker en educación primaria: un estudio cualitativo sobre la formación y el acompañamiento al profesorado

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Oriol Nadal
ORCID: 0000-0002-0449-0997
Rovira i Virgili University, Spain
oriol.nadal@urv.cat

Mireia Usart
ORCID: 0000-0003-4372-9312
Rovira I Virgili University, Spain
mireia.usart@urv.cat

Cristina Valls
ORCID: 0000-0001-5583-5695
Rovira I Virgili University, Spain
cristina.valls@urv.cat

ABSTRACT

Technological changes have profoundly transformed all areas of human life, including education (Sánchez-Caballé et al., 2020). This article focuses on the analysis of a Maker Teacher Training to implement Maker Education in primary school classrooms. The objectives are to identify the key aspects worked on in this training and to evaluate the strengths and weaknesses from the teachers' perspective. The methodology is qualitative, adopting an interpretive approach to understand the events of the research from the experience in two schools in the province of Tarragona. The data collection instruments are an observation rubric and semi-structured interviews. The results were analysed with the software ATLAS.ti and several aspects of the training were analysed in depth. The results show that the training covered different aspects such as the design, implementation, and evaluation of activities, although certain elements were little addressed. Teachers valued the personalisation of the training, the support they received, and the practical usefulness of the strategies acquired, highlighting a positive impact on pupils' interest and autonomy. Finally, it was emphasised that the training was comprehensive and positively considered, although there were some areas for improvement, such as inclusivity and the use of technological tools. The study reaffirms the need to provide maker training for teachers, promoting an interdisciplinary approach.

KEYWORDS Maker Education, Teacher training, Primary Education

RESUMEN

Los cambios tecnológicos han transformado profundamente todas las áreas de la vida humana, incluida la educación (Sánchez-Caballé et al., 2020). Este artículo se centra en el análisis de una formación docente en educación Maker para implementar esta metodología en aulas de educación primaria. Los objetivos son identificar los aspectos clave trabajados en dicha formación y evaluar las fortalezas y debilidades desde la perspectiva de los docentes. La metodología es cualitativa, adoptando un enfoque interpretativo para comprender los eventos de la investigación a partir de la experiencia en dos escuelas de la provincia de Tarragona. Los instrumentos de recopilación de datos son una rúbrica de observación y entrevistas semiestructuradas. Los resultados se analizaron con el software ATLAS.ti y se profundizó en varios aspectos de la formación. Estos muestran que la formación abarcó diferentes aspectos como el diseño, la implementación y la evaluación de actividades, aunque ciertos elementos fueron poco abordados. Los docentes valoraron la personalización de la formación, el apoyo recibido y la utilidad práctica de las estrategias adquiridas, destacando un impacto positivo en el interés y la autonomía de los alumnos. Finalmente, se enfatizó en que la formación fue integral y positivamente valorada, aunque se identificaron áreas de mejora, como la inclusividad y el uso de herramientas tecnológicas. El estudio reafirma la necesidad de ofrecer formación en educación Maker para los docentes, promoviendo un enfoque interdisciplinario.

PALABRAS CLAVE Educación Maker, formación docente, educación primaria

1. INTRODUCTION

In recent years, society has undergone social and economic changes, making it crucial to train young people to cope with this new reality. Digital technologies (DT) have transformed all areas of human life (Sánchez-Caballé et al., 2020), requiring continuous reflection on the effectiveness of strategies to develop digital competencies in an evolving information society (Morales et al., 2020; Tomczyk et al., 2023). Digitalisation, which has accelerated in the 21st century, requires citizens to adopt new strategies to face new challenges.

Over the recent years, educational research has significantly influenced teaching practices and perspectives on the learning process (Bautista-Vallejo y Hernández-Carrera, 2020). At the same time, it has evidenced the challenges faced by teacher training institutions in integrating technology into education (Santos et al., 2023). These challenges are especially pronounced when considering the gender digital divide, which has a profound impact, ultimately influencing future decisions regarding access and use of Information and Communication Technology ICT (Morante et al., 2020). Moreover, it is essential to rethink educational models in order to equip students with creative skills, problem-solving abilities, and technical-scientific competencies (Ruiz-Ortiz, 2023).

In this context of change, maker education has emerged as an innovative response that seeks to harness resources and solve everyday problems (Domínguez-González et al., 2018; Spieler et al., 2022). Indeed, creation, experimentation, and the art of making have existed ever since people have needed to develop tools and materials to face new challenges (Martin et al., 2020). In this sense, the teaching-learning process in maker education is based on the creation and modification of artefacts, whose final product aims at responding to a specific problem related to the environment of the educational community in which the project is developed (Blikstein, 2014). Specifically, in recent decades, many primary school teachers have shown interest in integrating maker culture into STEAM (Science, Technology, Engineering, Arts and Mathematics) in order to motivate pupils to actively participate in the teaching-learning process (Weng et al., 2022).

Parallel to this reality, makerspaces have been built in schools and public spaces (Rodríguez-Calderón y Belmonte-Izquierdo, 2021), where design and digital fabrication processes can be put into practice with digital tools such as 3D printers, laser cutters or cutting plotters. In fact, they are becoming an increasingly significant focus in education (Nikou, 2024). Fundamentally, it is a space where pupils use materials and resources to explore and experiment (Lock et al., 2020) and where they can develop several skills (Domínguez-González et al., 2018). In fact, Quintana-Ordorika et al. (2024) argue that integrating technology into the design and creation of artifacts is key to improving the learning experience. Countries such as the United States, the United Kingdom and Japan have already undertaken these initiatives, according to Bevan (2017). Indeed, in the Spanish context, the autonomous community of Catalonia is also working to introduce a maker culture through the FAIG project (Silva et al., 2024) and the integration of maker spaces in schools and high schools.

But, how is maker education defined? Specifically, it is defined as the combination of practice and development of skills, humanities, arts and knowledge (Lin et al., 2021). Fleming (2015) also describes it as a way of turning knowledge into action. Lundberg and Rasmussen (2018), above all, emphasize the importance of the learner creating an artefact in maker projects. However, among all the definitions, one of the most complete is that of Veldhuis et al. (2021), who defines it as "project-based learning through activities that focus on designing, building, modifying and/or reusing material objects with the aim of producing, through traditional craft techniques or digital technologies, some kind of 'product' that can be used, interacted with or demonstrated" (Veldhuis et al., 2021, p.1).

In particular, the current trend suggests that the concept of maker education is being introduced in a practical way through STEAM (Lin et al., 2021; Weng et al., 2022), as they complement each other; while the first can offer originality and the more creative part of design and creation, the second focuses on the transversality between these areas. This connection is also because STEAM activities, like maker activities, are related to solving everyday problems (Weng et al., 2022).

Maker education benefits pupils' holistic development, particularly by fostering creativity (Jia et al., 2021) and enabling the generation of new ideas (Alekh et al., 2018). In fact, it is effective when it promotes exploration and creativity (Spieler et al., 2022) and positively influences pupils' maker mindset, self-efficacy, motivation and interest (Martínez-Moreno et al., 2021; Hwang, 2017). Learning by doing enhances meaningful knowledge acquisition (Domínguez-González et al., 2018) and engages unmotivated pupils through exploration and experimentation (Otero & Blikstein, 2016). New challenges foster ongoing knowledge growth (Shively et al., 2021). Similarly, teamwork in maker education allows pupils to collaborate across different levels and areas (Torralba, 2019), encouraging mutual support (Forbes et al., 2021).

Since its beginnings, maker education has focused on creating without fear of error (Torralba, 2019). There is a need to communicate that it is positive to learn from mistakes without being afraid to try (Hughes et al., 2021). It is interesting to integrate mistakes as an important part of the teaching-learning process (Hughes et al., 2021), while promoting a safe environment where pupils are encouraged to take risks (Hughes et al., 2021). Frustration is initially an obstacle but it must gradually be transformed into motivation (Domínguez-González et al., 2018). The acceptance of the process of failure in the school is essential for the successful implementation of maker pedagogy. (Stevenson et al., 2019).

Maker education not only enhances cognitive and motivational skills but also addresses pupils' socio-emotional development (Carrasco & Valls, 2023). Studies show its positive impact on pupils with special educational needs. Lee et al. (2020) found in their cross-case qualitative approach that maker education effectively supported pupils with disabilities and low academic achievement. Similarly, Martin et al. (2020) demonstrated in their mixed methods study that autistic pupils successfully completed projects and improved their communication skills through a maker program. Hughes et al. (2018) highlight that maker education benefits learners with disabilities, learners with scattered attention and those with low motivation, often surprising pupils who typically struggle with academic performance.

Maker education enhances pupils' problem-solving skills by encouraging real-world solutions (Bevan, 2017; Forbes et al., 2021). Studies confirm significant improvements through maker interventions (Forbes et al., 2021; Stevenson et al., 2019). Given the benefits that maker education brings to pupils, teachers should promote this approach in the classroom. As these are approaches that present unconventional challenges to pupils (Torralba, 2019), teachers need guidance in designing, implementing, and evaluating maker projects (Forbes et al., 2021). For instance, Rodríguez-Calderón y Belmonte-Izquierdo (2021) propose a strategy to support teachers in selecting learning objectives, developing science and engineering activities, supporting planning and time management, and providing specific tools to develop a maker mindset.

However, public schools do not currently have sufficient financial resources to equip themselves with digital tools (Domínguez-González et al., 2018). While the importance of teacher training is recognized, there is a lack of research on both how to effectively prepare primary school teachers (Stevenson et al., 2019) and what the key challenges and opportunities are (Ioannou & Gravel, 2025). However, a clear consensus on its effectiveness in improving K-12 students' learning outcomes is still lacking (Lu & Zeng, 2025). To address this issue, this article explores in depth how teachers in two schools in the province of Tarragona (Spain) are supported during the integration process of Maker Education into their primary schools. Specifically, the training process is part of an educational project that aims, on the one hand, to provide these schools with digital and technological tools related to Maker Education (3D printers, laser cutters, vinyl cutters, among others) and, on the other hand, to provide pedagogical training to the teachers on how to use all these tools to improve the teaching-learning process of the pupils. In addition, the creation of a makerspace in each institution will be promoted to encourage these maker practices in the educational centres of Catalonia.

Therefore, the main aim of this research is to study the implementation of training for primary school teachers to introduce Maker Education in the classroom. To achieve this, the study focuses on two specific objectives: first (SO1), to determine the key aspects addressed in teacher training for implementing Maker Education, and second (SO2), to identify its strengths and weaknesses from the perspective of primary school teachers. Based on these objectives, the research seeks to answer two central questions: What aspects are covered in the training of primary school teachers for the implementation of Maker Education? What are the strengths and weaknesses of this training according to teachers' perspectives?

2. MATERIAL AND METHOD

A qualitative methodology was adopted, with an interpretative approach, aimed at making sense of research events and interpreting them from a participating teacher's perspective, with a view towards deepening in a particular case (Bisquerra, 2009).

The purpose of this design is to understand and identify in depth the aspects involved in the support and training of teachers in two schools in the province of Tarragona, to understand what this training brings to the teachers and the possible ways of improving it.

2.1. Instruments and procedures

In order to address the first specific objective (SO1), observations were made during the training sessions. A total of six sessions were held each month between January and July. The trainers support the whole school staff in the pedagogical application of maker education in their school. Observations make it possible to capture how the training process is implemented in its real context, providing a detailed perspective (Herrera, 2017). To collect this information, a rubric designed by Nadal et al. (2024) is used (Annex 2).

Specifically, this rubric was designed through an iterative process to evaluate the support provided to teachers in implementing maker education in schools. The initial prototype was developed during the TECLA project (2021-2022) and tested with teachers at one school in Barcelona. A Likert scale was used for evaluation, with an additional comments section for qualitative insights. Based on observations and feedback, the rubric underwent revisions, leading to a second prototype with 11 categories, incorporating new sections. The rubric aims to provide a comprehensive tool for assessing teacher training effectiveness in maker education, ensuring a structured and inclusive approach.

In concrete, it is focused on analysing the key aspects that ensure effective and enriching teaching for teachers in the context of educational maker activities. It has a total of 11 items, each divided into 2 to 6 sub-items. Key elements such as the promotion of active pupils' participation, the appropriate and safe use of tools or the teacher's ability to adapt resources to the needs and characteristics of the pupils are addressed. Attention is also paid to the management of time and pace of work, or the promotion of creativity and autonomy of pupils, both at individual and group level. Finally, interdisciplinary approaches are also included, such as optimising workspaces or effectively integrating pupils with special needs, prioritising both, equity and diversity, in the classroom.

The rubric consists of 4 evaluation indicators, ranked from 1 (not at all) to 4 (very much), which allow a detailed assessment of the teacher's performance on each item. In particular, the frequency with which each item is performed during the session is assessed. In addition, each indicator includes a comments section, which allows additional observations to be added to complement the analysis and to go into greater depth on the most relevant aspects of the process. Table 1 below provides a brief description of the rubric items:

TABLE 1. Summary of rubric items

1. Support in encouraging student participation	Focuses on maintaining engagement, fostering interaction, and promoting motivation while shifting responsibility to pupils.
2. Use of technological tools	Emphasizes the easy introduction of technological tools, promoting curiosity and confidence, and ensuring safety aspects when using machines and tools.
3. Design and session planning	Stresses aligning resources with pupils abilities, age, and curriculum goals.
4. Time management and work pace	Ensures activities fit within time limits and match pupils' levels.
5. Cognitive work	Planning tasks that pupils can connect to real-world experiences by proposing practical applications.
6. Creativity	Encouraging the development of new ideas to enhance pupils' work while promoting originality.
7. Autonomy/Group work	Focuses on equitable task distribution and conflict resolution.
8. Project-Based Learning	Integrating multiple disciplines and including effective pupils' assessment within this framework.
9. Spaces	Optimizing physical environments for maker activities, considering clean/dirty areas.
10. Students with special needs	Ensures inclusion of pupils with special needs and satisfies socio-emotional needs.
11. Equity	Fostering fairness and reducing gender inequalities.

TABLE 2. Summary of interview questions

Maker and STEAM	Concept of maker education: Inquires about how teachers understand maker education, their general vision, and how it can contribute to achieve learning competencies and objectives.
	Interaction with pupils: Explores the advantages and disadvantages of applying maker approach in the classroom, including how it helps promoting pupils interaction and engagement.
	STEAM implementation: Focuses on how they apply STEAM in their classroom, and how they integrate it with maker activities.
Project-Based Learning	Methodologies used: Determines what strategies are used in the classroom to implement project-based learning.
	Integrating maker education: Inquires how teachers integrate maker education into project-based learning.
	Pupils motivation: Analyses whether they have evidences of greater motivation, predisposition or interest in learning when working on projects or using technology.
Educational maker project	Knowledge of the project: Asks what teachers know about the project and what they expected from it.
	Evaluation of support: Assesses the support provided to the schools involved in the project.
	Suggestions for improvement: Seeks feedback on areas of improvement in the training process and whether anything was lacking.

On the other hand, to address the second specific objective (SO2), semi-structured interviews were conducted with 3 teachers from each school participating in the project. One of these participants was the head teacher of the school. The interviews were conducted at the end of the school year, in July 2024, after the training sessions had been completed, with the aim of obtaining an overall view of the training received. Through these interviews, the aim was to analyse how to adapt these practices pedagogically, how to develop the competences and motivation of pupils, or how to identify challenges and opportunities for their effective application in real educational contexts. Annex 1 contains all the interviews conducted, which complement and enrich the analysis presented. The semi-structured interviews were based on three main axes, described in table 2 in previous page.

2.2. Participants

For this study, a non-probabilistic purposive sampling, typical of qualitative research, was used. The participants were, therefore, teachers belonging to schools where maker education was applied, and were already equipped with the tools that the Catalan government offers to schools. The sample participating in this study is a total of 8 primary school teachers from the Autonomous Community of Catalonia (Spain), specifically from two schools in the province of Tarragona.

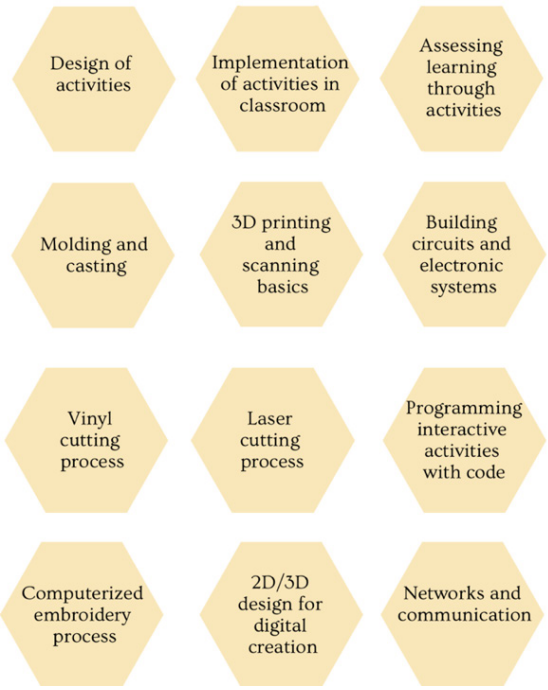
The schools gave permission to access their classrooms in order to analyse the training process. The training team also gave permission to access the support sessions, which greatly facilitated the data collection process. The selection of these two schools was strategic because, on the one hand, one of them has been integrating technology into its educational practice for a long time and the teaching staff is already trained in the integration of technological resources in the classroom. On the other hand, the other school was chosen because it did not have as much experience in the use of technology in the classroom. This way, a more global and representative view of the impact of maker education in the educational environment can be obtained.

Both schools have two other elements in common. Firstly, they have a similar pupils' profile. They are complex schools where most of the pupils come from different developing countries. There are very few local pupils. Although one is very central and the other one is on the outskirts of the same city, the neighbourhoods are similar, and both have a very similar family profile. Another common element is their participation in the same Maker Program, which integrates technology and pedagogical innovation into the classroom. The aim of this program is to promote the use of ICT through new methodologies to improve the teaching-learning process for pupils, especially in STEAM areas. The main participants in the Maker Program are 150 public schools throughout Catalonia. The following section describes the characteristics of the program in more detail.

2.3. Maker program

The program has a total duration of 4 academic years. Specifically, the sessions analysed correspond to one year of training. It consists of 6 sessions with a duration of 2 hours each, hence totalling 12 hours all the way through an academic year.

FIGURE 1. Overview of the Training Contents



Firstly, these centres receive an equipment package and are required to set up a makerspace. The space is equipped with advanced technology such as 3D printers, vinyl cutters, laser cutters or digital embroidery machines, among others. The program also includes pedagogical training on how to integrate these technological and digital tools to improve the teaching-learning process of pupils. Hands-on learning is encouraged, and teachers are supported to integrate maker education into their classrooms. To summarise what the training process and support consist of, the following figure (figure 1) shows some of the content covered during training.

This program follows the Framework for Evaluating Making in STEM Education (Marshall & Harron, 2018), which suggests five key sections for assessing maker competence: Ownership/Empowerment, Maker Habits, Production of an Artefact, Collaboration, and STEM Tools. The relationship between training content and the principle of this framework is then established, highlighting how it promotes meaningful and practical learning for teachers:

TABLE 3. Relationship between training content and framework

Dimension	Relation with teacher training
Ownership/ Empowerment	Pedagogical support and practical learning promote teacher's and pupil's autonomy, allowing pupils to be the protagonists of their own learning. The training also promotes the integration of maker-based learning for the integral development of the teacher and, in the end, of the pupils.
Maker habits	The training process aim to strengthen teachers' maker skills so that they can transfer these skills to their pupils. The training encourages the acquisition of essential habits such as experimentation, iteration and critical thinking. It also creates a direct link between the activities teachers design and pupils' everyday experiences, allowing them to integrate the knowledge and skills they acquire in the classroom into their daily lives, enriching their learning beyond the school environment.
Production of an Artifact	The program trains teachers to design, implement and evaluate maker activities in the classroom, in some cases with the end goal of creating an artefact. This approach allows teachers to integrate advanced technological tools into projects that promote hands-on and meaningful learning. In addition, each school has a makerspace for the production of these artefacts, giving pupils a dedicated place to realise their projects. Guidance is given on how to integrate transversality into the projects. In short, the aim is for teachers to be able to integrate content from different subjects, especially in STEAM areas, thus promoting interdisciplinary learning.

Dimension	Relation with teacher training
Collaboration	The training process promotes collaboration between teachers, as well as showing how to foster collaboration among pupils in maker projects. It emphasises the importance of taking into account the individual needs of each pupil and how to organise groups fairly to ensure active and equitable participation for all. The pedagogical support also promotes the exchange of experiences and good practices among teachers, enriching their work in the classroom. In fact, during the training process, discussion areas are created among teachers from the same school, but also among other teachers from nearby schools.
STEM tools	The training process also focuses on the correct use of advanced STEM tools, such as 3D printers, laser cutters and digital embroidery machines, and provides teachers with indications on their use and pedagogical application. Each centre has a makerspace equipped with these tools, allowing pupils to develop technology projects in a hands-on way. Teachers are also taught how to effectively integrate these technologies into the classroom to enhance pupils' learning.

2.4. Data analysis

An analysis of the rubric was conducted to assess the different aspects of teacher training. At the end of the observation process, the completed rubrics were analysed to identify patterns and trends. The analysis focused on determining the most frequently occurring rating for each item across all sessions.

The interviews were transcribed into a text file and then processed using the software ATLAS.ti 24.2.1 (Qualitative Research and Solutions). The analysis was then carried out in the following order: 1. Preparation and import of the interviews; 2. Creation of codes and sub-codes; 3. Analysis of the results and creation of networks. According to Lopezosa et al. (2022), this analysis allows the identification of the most salient aspects of the statements and also helps to identify patterns.

3. RESULTS

The first specific objective (SO1) was to determine which aspects are dealt with during teacher training. Table 4 shows in general terms which aspects the program focuses on. The left column shows the items that were to be observed. These items are the same as those used in the observation rubric by Nadal et al. (2024) in order to understand how the course develops, as well as the main content developed during training.

The second and third columns show the observation results for each item at each school analysed. In the last two columns, each item is rated. Specifically, it is a table of the frequency of actions. This rating starts with the lowest values (*Not at all*), which means that the content was never dealt with; secondly, the content was dealt with slightly (*Slightly*); thirdly, the content was dealt with significantly (*Moderately*); and finally, the content was dealt with a very significant number of times (*Considerably*). In table 4 (see next page) is a summary of the topics covered in the sessions.

TABLE 4. Sessions content summary

ITEM	QUALIFICATION SCHOOL 1	QUALIFICATION SCHOOL 2
1. Support in encouraging student participation	Slightly	Slightly
2. Use of technological tools	Slightly	Slightly
3. Design and session planning	Moderately	Moderately
4. Time management and work pace	Slightly	Slightly
5. Cognitive work	Considerably	Slightly
6. Creativity	Moderately	Slightly
7. Autonomy/Group work	Slightly	Slightly
8. Project-Based Learning	Moderately	Moderately
9. Spaces	Slightly	Slightly
10. Students with special needs	Slightly	Not at all
11. Equity	Slightly	Slightly

At first sight it can be seen that in most cases the content is dealt with *slightly* and *moderately*. This aspect is considered to be positive as it means that most aspects are covered in the training period. There are, however, some exceptions, e.g. item 10 on pupils with special needs, where very little work is done in the first school and practically none in the second one. In general, it can also be observed that for most of the items both schools treat the content in a similar way.

The items are described and compared between the two schools, highlighting their similarities and differences, to discuss each case or context individually. In the first item, pupils' participation is not very much encouraged in both schools (1. Support in encouraging pupils' participation). The same is true for the second item (2. Use of technological tools). In both schools, training in the use and application of tools is provided during one of the sessions, but not specifically during the other sessions.

It is relevant that item 3 (Design and session planning) is *moderately* addressed in both schools; in this case the trainer puts a lot of emphasis on how to design and plan sessions to introduce maker activities in the classroom. However, item 4 (Time management and work pace) is not fully promoted, with the qualification being *slightly* in both schools. In item 5 (Cognitive work) there are differences between the two schools. In the first school, there is a strong focus on cognitive work during the training sessions, whereas in the second school there is no focus on these aspects. This may be related to the fact that the second centre, unlike the first one, had already carried out maker activities before, which meant that many activities were already contextualised to the pupils' environment and their everyday life. Item 6 (Creativity) also shows differences between the two schools, with the first one working more on creativity-related aspects than the second one. On the other hand, items 7 (Autonomy/group work) and 9 (Spaces) are hardly addressed in the training sessions, in contrast to item 8 (Project-based learning) where a stronger focus is observed.

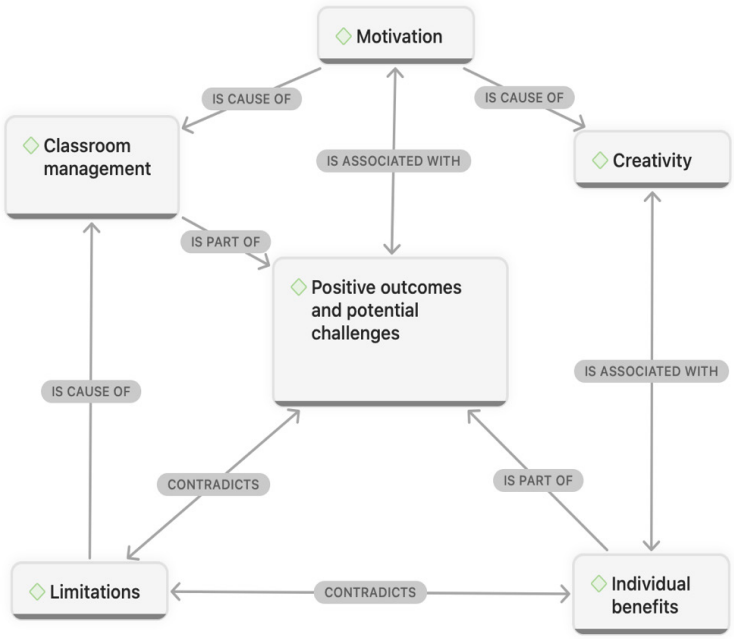
Finally, as a weakness to be pointed out, there is not much emphasis on the promotion of equity among pupils, nor is much attention paid on how to promote the inclusion of pupils with special needs

(items 10 and 11). In fact, in the first school, item 10 (Pupils with special needs) is hardly addressed, while in the second school this content is not addressed at all.

In short, it can be concluded that the sessions have a very specific focus on aspects such as design or the use of machines. Based on these results, it can be observed that some elements are transversal over several sessions, such as the interest of pupils (little promoted, but considered over several sessions). On the other hand, aspects such as training in the use of tools, are dealt with intensively in very few sessions.

The second specific objective (SO2) was focused on identifying the strengths and weaknesses of the training process, from the perspective of primary school teachers. After the analysis, a total of 388 quotations with a total of 47 codes were selected. The following diagram shows, the groupings into networks, which represent the teachers' assessment. First, conceptual network 1 (Figure 2) refers to positive outcomes and potential challenges:

FIGURE 2. Positive outcomes and potential challenges



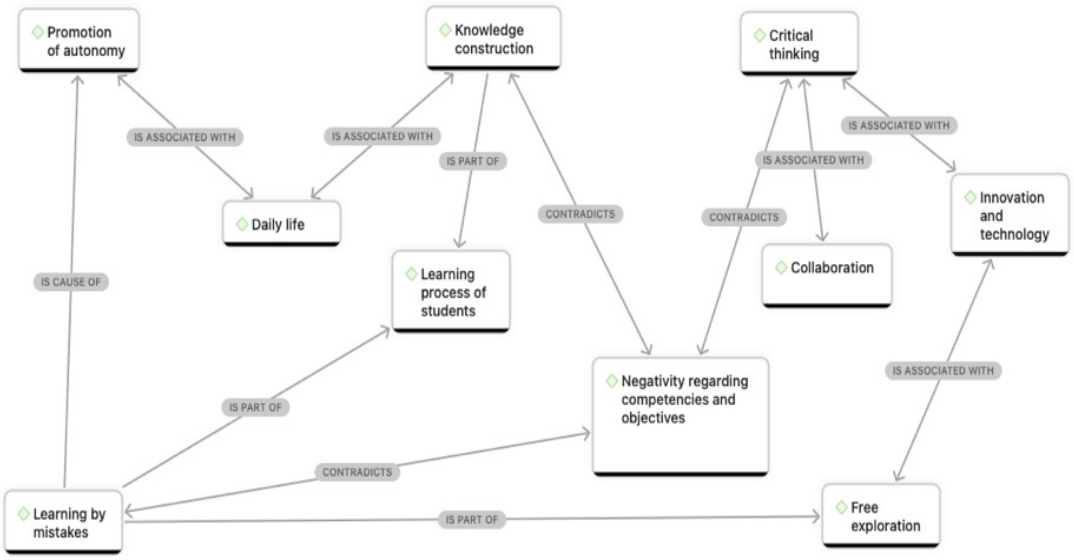
Conceptual network 1 (Figure 2) shows the potential of introducing maker education to pupils. Indeed, teachers admit that simulations have given them some practice in implementing maker activities and getting pupils excited. In addition, they point out that pupils' interest increases significantly when technology is introduced into the classroom, as it is attractive and generates greater enthusiasm during the sessions:

> *"Yes, for them technology is part of their daily life, much more than for us, and they find it easy and exciting, that's true*." (Teacher 2, School 1)

However, they also confirm some difficulties in the classroom when implementing the activities. In particular, they refer to the diversity of learners with different needs and the personalisation of learning. Overall

the teachers confirm that they have acquired a number of skills and knowledge during training, such as the ability to stimulate pupils' interest or the integration of technology and the promotion of creativity.

FIGURE 3. Pupils' learning process

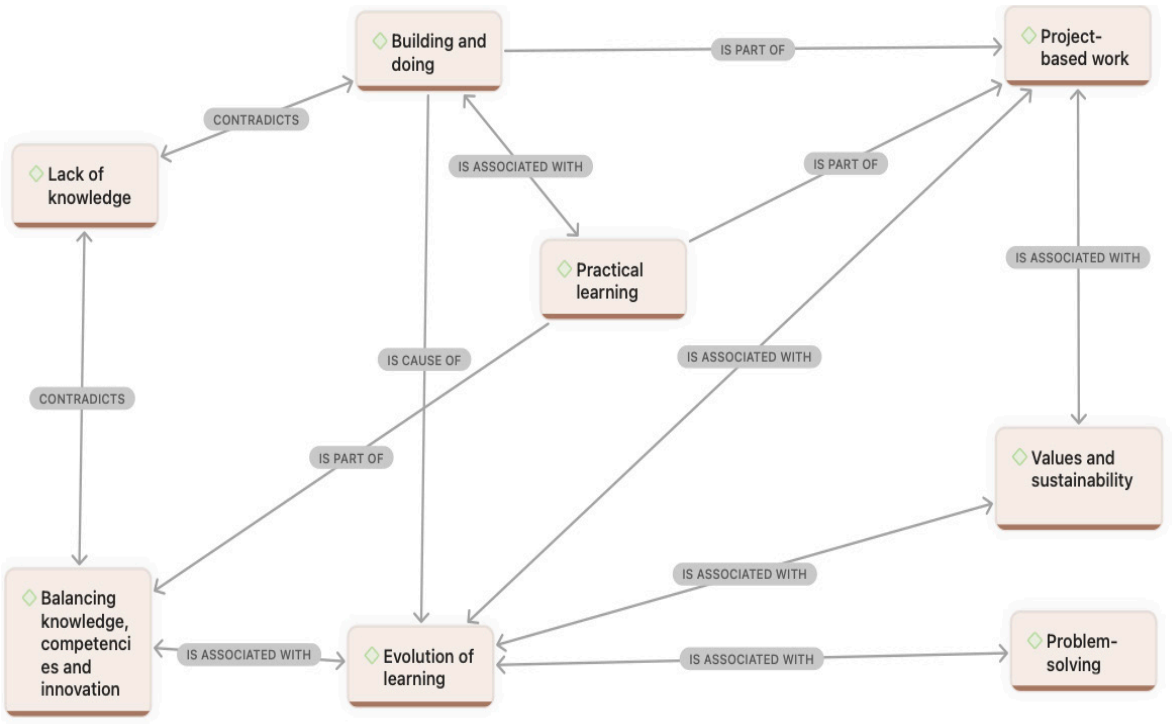


Conceptual network 2 (Figure 3) shows the interrelationship between the different benefits for learners and reflects a close link between learning by error and the other elements. It is also seen by teachers as one of the reasons why pupils become more autonomous and learn through exploration. The importance of constructing knowledge based on their interests, often related to their everyday lives, is emphasised, and can lead to more meaningful learning:

> *"It makes them take it more personally and go deeper into the content because they are the ones really building the knowledge by doing it."* (Teacher 4, School 1)

Similarly, in terms of critical thinking, the interviewees saw it as closely linked to collaboration and aspects of innovation and technology. Some of them have already worked with transversal projects and are now able to give them a new maker approach. In parallel, they state that activities based on real life contexts have had a positive impact, allowing pupils to see the practical application of what they have learned, as opposed to previous approaches that focused on theoretical activities or simulations that had little to do with everyday life.

FIGURE 4. Balancing knowledge, competencies and innovation



Conceptual network 3 (Figure 4) shows that, after training, teachers consider it key learning by doing and associate it with making, building and project-based work. Some teachers state that, after the training period, they understand the maker philosophy as something that goes beyond the simple act of creating objects and is linked to sustainability, being transferable to their everyday lives:

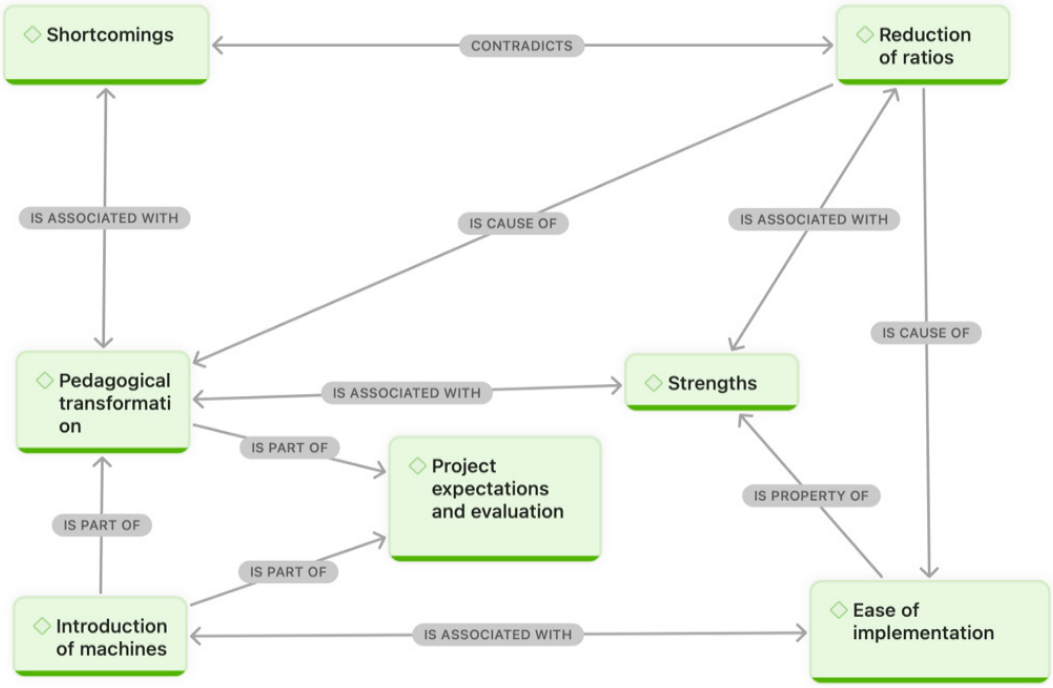
> *"I don't know, with the children we end up getting them to think about being creators of what they need rather than consumers."* (Teacher 5, School 2)

In relation to conceptual network 4 (Figure 5, in next page), they highlight pedagogical transformation as a strength derived from the training received. They emphasise the ease of implementation in the classroom and the gradual introduction of maker education. They also highlight as a strength the sessions designed to share experiences among teachers, as they encourage reflection and exchange of ideas.

Despite some reluctance at the beginning, as the training sessions progressed, teachers came to appreciate the impact on their pupils' skills and the learning they had acquired. Among other aspects, they appreciate the strategies and tools provided by the trainer, who accompanies them at all times. Undoubtedly, one of the most important aspects for the teachers is that the training is specifically personalised. Not only is it adapted to their needs, but it also responds to the practices and challenges of implementation in the classroom:

> *"It's very tailored to what we need, and very practical ideas for projects are being suggested. That adds a lot of value to the project because rather than being something generalised a more personalised support is being offered".* (Teacher 3, School 1)

FIGURE 5. Project expectations and final opinions



Another positive point they highlight is the opportunity to share training with teachers from other schools. This approach encourages the exchange of experiences and allows professionals to share experiences and strategies for overcoming challenges in similar contexts.

Overall, the evaluation of the training was positive but teachers also share some challenges that should be improved in future training implementations. The time commitment of the training sessions is a major challenge. As for the technological support, some teachers confirm that it could be more structured and consistent to fully satisfy their needs. Similarly, the pedagogical adaptation part is quite good, but there is also a shortcoming on which some teachers agree. They say that they feel lost when integrating them into the classroom with younger pupils. Similarly, they identify some difficulties, such as the diversity of needs in the classroom, but suggest reducing ratios and support from other teachers as possible solutions.

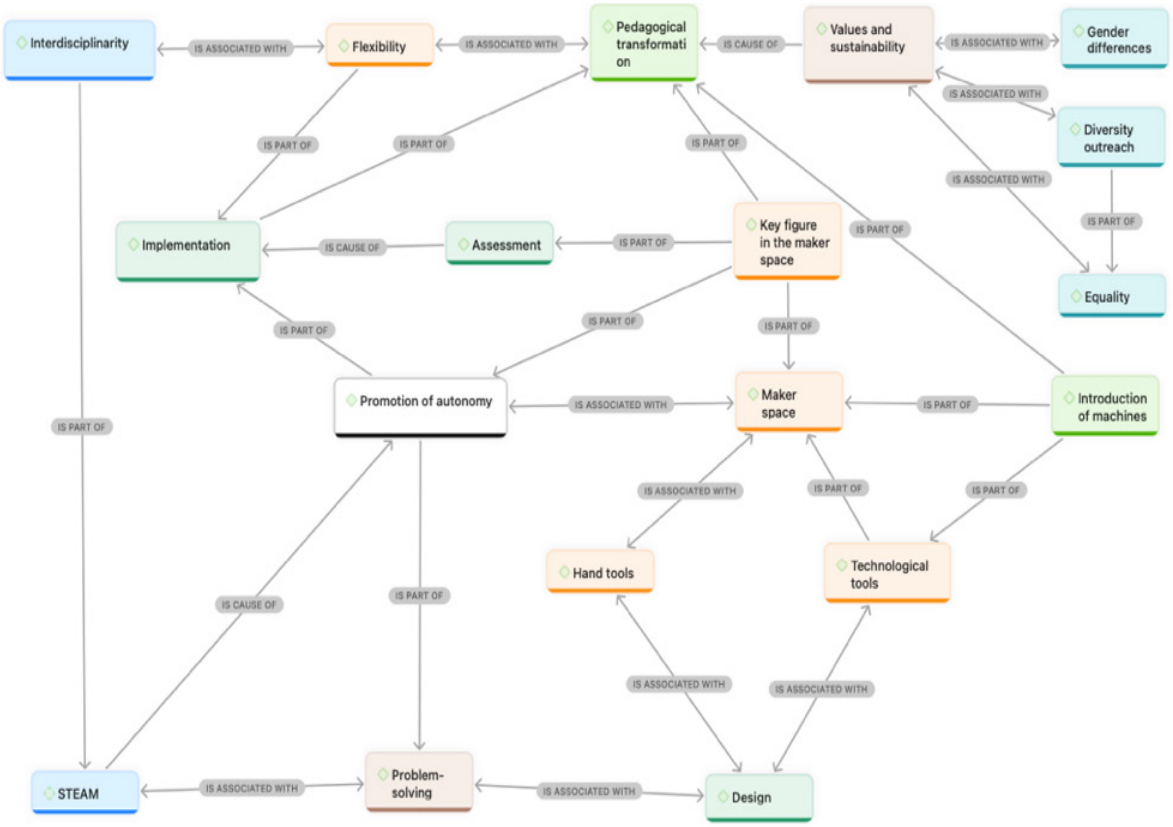
Finally, Figure 6 (in next page) shows a summary of all the interviews. The codes represent the relation of the implementation of maker activities after training. This application is characterised by its flexibility, allowing it to be adapted to different contexts and educational levels. Evaluation is something that worries teachers to some extent, although, after the training process, they have been able to gradually improve this point. Teachers also consider the space to be important and are very enthusiastic about the makerspaces that have been created in each of the schools. These are spaces where interdisciplinary work can be carried out with different subjects such as STEAM. Teachers emphasise not only the technical skills acquired, but also the importance of teaching values such as sustainability and DIY

(Do It Yourself). In these makerspaces, they confirm that after the training period they are able to include activities for all the pupils:

> *''They're working better now; you don't see anyone being bored. Everybody's doing something and that's because we've changed the methodology. We had children who weren't engaged in what was being done in class.''* (Teacher 5, School 2)

At the same time, they try to promote equity among pupils, as girls feel that they can also pursue technological careers. Finally, they also stress the importance of having a member of staff in charge of the makerspace to guide and support the pupils in carrying out projects. In conclusion, teachers are satisfied with training and affirm that a combination of technical and pedagogical elements is needed for a good implementation. Through these practical spaces and with an interdisciplinary approach, teachers aim to transform education into a creative process adapted to the current educational needs.

FIGURE 6. Synergy of skills and perspectives of the teacher training



4. DISCUSSION

Despite the lack of teacher training in maker education within schools (Gutiérrez-Esteban & Jaramillo-Sánchez, 2022), this training process, developed in the context of primary and secondary schools in Catalonia, highlights the variety of content addressed to teachers during implementation. The responses reflect a clear trend of satisfaction, especially in relation to the support and training received, over and

above the provision of material resources. These findings are in line with Forbes et al. (2021) and Torralba (2019), who highlight the importance of providing guidance to teachers during the implementation of such projects, as they often involve unusual challenges. Aligned with these findings, the present study concurs with Domínguez-González (2018), who highlights that the key to effective training is the ability to combine practical knowledge, skills, experiences, and competences of the participants. This fact reinforces the idea that a balance between theory and practice is essential for the successful implementation of educational maker projects.

Another benefit of teacher training is its personalised approach, allowing to adapt to the specific needs of teachers. In addition, key aspects such as the design, implementation and evaluation of maker activities are explored in depth, an approach that is consistent with that of some authors (Rodríguez-Calderón y Belmonte-Izquierdo, 2021; Forbes et al., 2021). In addition, the trainer provides concrete tools that are applicable to each teacher's context, in line with Rodríguez-Calderón y Belmonte-Izquierdo (2021).

An important aspect of training has been learning through error. From the first sessions there was some reluctance on the part of the teachers to accept change, especially when faced with the idea of adopting new methodologies. However, as the sessions progressed, a gradual change in their perspective was observed, with a more open and receptive attitude to the learning process. Situations of error were used as an opportunity to manage frustration, helping teachers to develop this key skill, which they could then transfer to their classrooms. This approach is in line with the theories of Torralba (2019), who advocates creating without fear of error, and Hughes et al. (2021), who highlight the importance of fostering positive attitudes towards error in a safe environment for making mistakes. Furthermore, training confirmed the findings of Domínguez-González (2018), who suggests that although initial frustration may be perceived as a barrier, with the right support it becomes a motivational driver. In a complementary way, Blikstein's (2014) ideas on tolerance and frustration are also confirmed. It has been observed in this research that they promote greater perseverance and teaches them how to work in heterogeneous teams. Furthermore, promoting contextualised problem-solving in daily challenges has been observed as a positive approach to optimizing the use of available resources. This approach reinforces the relationship between maker education and the practical connection with the environment, as noted by Spieler et al. (2022) and Martin et al. (2020), who highlight the inherent link between this educational approach, the efficient management of resources and the solution of everyday problems. Domínguez-González et al. (2018) also agree in that while implementing maker education, work is done collaboratively through problem-solving, as promoted during training. Similarly, to foster problem-solving, participants were tasked with creating or repairing an artefact artifact. This approach is in line with the theory of Blikstein (2014), who stated that the teaching-learning process involves the creation and modification of artefacts into end products to respond to a problem related to the environment of the educational community in which the project is developed.

An aspect highlighted by both, teachers and observers, is that one of the main points of the training focuses on how to stimulate pupils' interest. In this regard, it is observed that when teachers apply what they have learned, pupils demonstrate a high level of engagement and maintain sustained interest in the activities, which supports the theories of various authors (Martínez-Moreno et al., 2021; Hwang, 2017; Lin et al., 2021). This pupils' engagement is fundamental to the success of maker education. Furthermore, much of the knowledge during training was covered through practical experiences and activities, which is in line

with Domínguez-Gonzalez et al. (2018) theory, stating that learning by doing generates meaningful knowledge. This hands-on approach not only enhances the learning process but also fosters a deeper connection between students and the subject matter (Nikou, 2024).

The difficulties pointed out by Domínguez-González (2018), who mentions that public school teachers often face a lack of financial resources to acquire digital rapid prototyping tools, are not reflected in our study. The participating teachers expressed a high level of satisfaction, as all the schools involved were public and the project was supported with European funding. This financial support ensured the provision of the necessary resources and tools, allowing teachers to fully focus on learning and implementing maker education without the usual constraints of lack of technological equipment.

In this study, it is observed that there is a lack of training related to the adaptation of activities for pupils with special educational needs (SEN). Martínez and Bielous (2017) emphasize that, in order to be inclusive and effective, maker education trainings must take into account the specificities of each pupil. At the same time, Gutiérrez-Esteban and Jaramillo-Sánchez (2022) highlight the benefits for pupils with disabilities, as they foster the development of skills that would be difficult to achieve through less hands-on and practical methodologies.This aspect represents an essential area of improvement for future educational initiatives.

Despite this shortcoming, the importance of considering the socio-emotional aspects of pupils in their different contexts has been promoted among teachers. In this sense, we agree with Carrasco and Valls (2023), who emphasise that the teacher should act as a facilitator of learning, also playing the role of a reference and support figure during the educational intervention, as well as a companion in the socio-emotional sphere.

5. CONCLUSIONS

This study aimed to assess the development of training for primary school teachers to implement Maker Education in the classroom. Overall, once the training program was completed, the interviews and observations confirmed that the centres received good support. It is important to note that training itself has been positively evaluated, partly due to the use of a framework (Marshall & Harron, 2018) that provides clear guidance on the content to be covered. Although not all of the elements in the rubric were covered to the same depth, they were all addressed, some to a greater extent than others. We recommend that frameworks continue to be used as a support in future studies, as they provide a coherent and facilitating structure for the design and delivery of training programs.

Indeed, some contents are treated in a transversal way in several sessions, such as maintaining the pupils' interest or linking the activities carried out in class with the pupils' daily life. There are also other aspects, such as designing or evaluating maker activities in the classroom, that are not cross-curricular, but are dealt with in depth in specific sessions. This combination provides a balanced approach to teacher training, as it allows for in-depth exploration of key aspects, while continuously reinforcing essential content that needs to be considered in most sessions of maker activities.

Teachers with more experience in maker education find it easier to link activities to pupils' everyday lives. However, their prior knowledge can also present challenges, as established practices may need to be re-thought, which can be complex due to the inertia of existing trends. On the other hand, teachers with less experience are more open to incorporating new ideas, as they don't have to unlearn previous practices. Parallel to that, it is essential that teacher training programs include guidance on adapting Maker Education activities to meet the needs of pupils with SEN. Furthermore, it is vital for teaching staff to develop confidence and proficiency in using technological tools effectively. This will make maker activities easy to use, useful, satisfying, enjoyable, and ultimately motivating for students (Nikou, 2024).

This study contributes to the field of maker education by identifying key points for teacher training, in line with current needs around the lack of information on how to effectively prepare teachers (Ioannou & Gravel, 2025; Stevenson et al., 2019). These findings highlight the importance of further developing training models to support teachers. Ultimately, it is beneficial to also consider hands-on activities that provide a more holistic perspective for both, teachers and pupils. Maker education represents an opportunity for the holistic development of pupils, in line with the demands and challenges of the 21st century.

5.1. Limitations and future lines of research

As a limitation of this study, the analysis has been confined to two schools due to difficulties in obtaining permissions, which limits the generalisability of the results. In addition, the teachers interviewed are part of the team behind the educational project, so the inclusion of other teachers' perspectives could enrich the findings.

6. AUTHOR CONTRIBUTION

Conceptualization: Oriol Nadal, Mireia Usart, Cristina Valls; Data curation: Mireia Usart; Formal analysis: Cristina Valls; Funding acquisition: Mireia Usart, Cristina Valls; Investigation: Oriol Nadal, Mireia Usart, Cristina Valls; Methodology: Mireia Usart; Project administration: Mireia Usart, Cristina Valls; Software: Oriol Nadal; Resources: Oriol Nadal; Supervision: Mireia Usart, Cristina Valls; Validation: Oriol Nadal; Visualization: Oriol Nadal; Writing – original draft: Oriol Nadal; Writing – review & editing: Oriol Nadal, Mireia Usart, Cristina Valls.

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8. ANNEXES

1. Nadal, O., Usart, M., Valls, C. (2025), "Questions for Teacher Interviews on the Maker Project", https://doi.org/10.34810/data1970, CORA.Repositori de Dades de Recerca, DRAFT VERSION
2. Nadal, O., Usart, M., Valls, C. (2025), "Maker training evaluation rubric", https://doi.org/10.34810/data1968, CORA.Repositori de Dades de Recerca, DRAFT VERSION

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Preschool Teachers' Intentions to Use Digital Storytelling in Early Childhood Education: An Analysis through the UTAUT2 Model

Las intenciones de los maestros de preescolar de utilizar la narración digital en la educación infantil: Un análisis a través del modelo UTAUT2

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Ayşegül Şakir
ORCID: 0000-0002-2979-7899
Kırşehir Ahi Evran University, Turkey
aselimhocaoglu@ahievran.edu.tr

ABSTRACT

This study investigates the factors influencing preschool teachers' intention to adopt digital storytelling (DST) in early childhood education, using the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) framework. A quantitative research design was employed, collecting data from 550 in-service preschool teachers in Turkey through a structured questionnaire. Constructs from UTAUT2—including performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit—were measured to assess their impact on behavioral intention. The results of the structural equation modeling (SEM) confirmed that all seven constructs significantly and positively predicted teachers' intentions to integrate DST. Performance expectancy and habit emerged as the strongest predictors, highlighting the importance of perceived pedagogical value and routine technology use. Facilitating conditions and effort expectancy also had notable effects, suggesting that institutional support and ease of use are crucial for adoption. Additionally, hedonic motivation and price value demonstrated that emotional engagement and cost-effectiveness play meaningful roles in shaping acceptance. These findings offer theoretical support for UTAUT2's application in early childhood education and provide practical insights for improving DST integration. The study emphasizes the need for teacher training, institutional support, and access to cost-effective tools to foster the adoption of innovative pedagogical practices in preschool classrooms.

KEYWORDS Digital Storytelling, UTAUT2, Early Childhood Education, Technology Adoption, Preschool Teachers

RESUMEN

Este estudio investiga los factores que influyen en la intención de los docentes de educación infantil para adoptar la narración digital (DST) en el aula. Para ello, se utilizó el marco teórico del Modelo Unificado de Aceptación y Uso de Tecnología 2 (UTAUT2). Se empleó un diseño de investigación cuantitativa y se recopilaron datos de 550 maestros en ejercicio en Turquía mediante un cuestionario estructurado. Se midieron los constructos de UTAUT2: expectativa de rendimiento, expectativa de esfuerzo, influencia social, condiciones facilitadoras, motivación hedónica, valor percibido y hábito, con

el fin de evaluar su impacto sobre la intención conductual. Los resultados del modelo de ecuaciones estructurales (SEM) confirmaron que los siete constructos predijeron de manera significativa y positiva la intención de los maestros de integrar DST. La expectativa de rendimiento y el hábito fueron los predictores más fuertes. Esto destaca la importancia del valor pedagógico percibido y la familiaridad con la tecnología. Las condiciones facilitadoras y la expectativa de esfuerzo también influyeron notablemente, lo que sugiere que el apoyo institucional y la facilidad de uso son fundamentales. Asimismo, la motivación hedónica y el valor percibido demostraron que el compromiso emocional y la rentabilidad desempeñan un papel relevante en la aceptación. Estos hallazgos respaldan teóricamente la aplicabilidad del modelo UTAUT2 en la educación infantil y proporcionan implicaciones prácticas para fomentar la integración de DST. El estudio subraya la importancia de la formación docente, el apoyo institucional y el acceso a herramientas accesibles para promover prácticas pedagógicas innovadoras en la educación preescolar.

PALABRAS CLAVE narración digital, UTAUT2, educación infantil, adopción tecnológica, maestros de preescolar

1. INTRODUCTION

The rapid advancement of digital technology has significantly transformed the landscape of education, including early childhood learning environments (Al-khresheh et al., 2024; Bethencourt-Aguilar et al., 2021; López-Marí et al., 2021; Şakir, 2024). One of the emerging pedagogical tools in this context is digital storytelling (DST), which integrates multimedia elements such as text, images, audio, and animation to create engaging and interactive learning experiences (Chang & Chu, 2022). DST supports children's cognitive, language, and socio-emotional development by fostering creativity, engagement, and a deeper understanding of concepts (Addone et al., 2021). In early childhood education, where storytelling plays a crucial role in learning and development, the integration of DST can enhance traditional teaching methods and provide children with a more dynamic and interactive learning experience (Jalongo, 2021).

Despite these potential benefits, the adoption of DST in preschool education remains limited. Research suggests that teachers' acceptance and willingness to use technology are key factors in the successful integration of digital tools in classrooms (Ateş & Kölemen, 2025). However, while numerous studies have examined teachers' technology adoption in general, there is a lack of research specifically focusing on preschool teachers' intentions to use DST. Moreover, existing studies on DST in education primarily focus on its impact on students' learning outcomes rather than the factors influencing teachers' adoption of this tool (Yang et al., 2022). This gap in research suggests that more attention is needed to understand the specific challenges, motivations, and facilitating conditions that influence preschool teachers' use of DST in their teaching practices.

To address this gap, the present study employs the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) framework (Venkatesh et al., 2012) to investigate preschool teachers' intentions to integrate DST into their teaching practices. UTAUT2 is a comprehensive model that explains technology acceptance by examining factors including performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit. While UTAUT2 has been widely applied in higher education and workplace settings, its application in early childhood education—particularly in relation to DST—remains underexplored. By utilizing this model, the study aims to provide a deeper understanding of the factors that encourage or hinder preschool teachers from adopting DST in their classrooms.

This study is particularly significant as it contributes to both theoretical and practical aspects of early childhood education. From a theoretical perspective, it expands the application of UTAUT2 in the context of preschool education, offering empirical evidence on how teachers perceive and adopt DST. By identifying the key factors that influence technology acceptance among preschool teachers, this study provides a nuanced understanding of how DST can be successfully integrated into early childhood curricula. From a practical perspective, the findings can inform teacher training programs, helping educators develop the necessary skills and confidence to use DST effectively. The study also provides valuable insights for policymakers and curriculum developers to design strategies that promote DST as a meaningful pedagogical tool in preschool settings.

Given the increasing emphasis on technology integration in early childhood education, it is essential to explore how teachers perceive DST and what factors influence their willingness to use it. Therefore, this study seeks to answer the following research question: What factors influence preschool teachers' intention to use DST in their classrooms based on the UTAUT2 model?

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1. Digital Storytelling in Early Childhood Education

Digital storytelling in early childhood education represents an innovative pedagogical approach that combines traditional narrative techniques with digital media tools to create engaging and meaningful learning experiences for young children (Catalano & Catalano, 2022; Hoa & Minh, 2023). By integrating multimedia elements such as images, text, audio, video, and animation, digital storytelling enriches the narrative experience while also supporting the development of digital literacy skills from an early age (Hartsell, 2017). This method allows educators to tailor stories to children's interests and cultural contexts, thereby creating a more personalized and relevant learning environment (Catalano & Catalano, 2022; Hoa & Minh, 2023).

Empirical research indicates that digital storytelling can significantly enhance both cognitive and socio-emotional learning. For example, studies conducted in Vietnam have shown that early childhood educators perceive digital storytelling as a means to bridge real-life experiences with curriculum content, fostering active engagement and critical thinking (Hoa & Minh, 2023; Purnama, 2021). Similarly, research from Indonesia highlights that digital storytelling enhances children's storytelling competence, imagination, and early literacy development (Purnama, 2021; Purnama et al., 2022). Rahiem (2021), in an in-depth case study of a storytelling–art–science club in Indonesia, showed that teachers use DST because it makes storytelling more entertaining, captivating, communicative, and theatrical. Observations with over 70 children revealed that simple digital technologies—combined with traditional storytelling—engaged children more deeply and promoted active participation. Rahiem's findings underscore the necessity of improving teachers' technological competencies, enhancing school ICT infrastructure, and updating curricula to integrate DST effectively. Similarly, Catalano and Catalano (2022) found that digital storytelling is increasingly being adopted as a means to promote child-centred pedagogy in kindergartens. Their mixed-methods study involving 160 educators revealed that DST allows teachers to select and design digital stories aligned with children's unique experiences and interests. The approach fosters opportunities for children to make

sense of their own lives and for teachers to better understand their students, thereby enhancing empathy, emotional intelligence, and classroom relationships. The adaptability and novelty of DST also make it highly impactful in both online and onsite learning contexts. From a developmental perspective, the model of "early childhood Imagineering" developed by Jitsupa et al. (2022) provides a structured framework for integrating DST in ECE in Thailand. Their research synthesized and evaluated a four-stage model: Leading to Learn (imagination), Active Learning (design and development), Opinion Sharing (presentation), and Reflective Thinking (improvement and evaluation). The implementation of this model, which incorporates stop-motion animation and collaborative storytelling, was strongly endorsed by educational experts. Their results highlight that DST, when embedded within systematic, creative processes, promotes imagination, self-expression, and reflective thinking—crucial competencies for holistic early childhood development. Direct classroom evidence of DST's practical benefits has also been documented by Yuksel-Arslan et al. (2016), who employed a phenomenological approach to explore Turkish kindergarten teachers' experiences with DST after specialized workshops. The study revealed that teachers effectively used DST to enrich learning activities, improve student engagement, and scaffold complex concepts through digital narrative formats. The teachers reported several successes—including heightened motivation, improved collaboration, and enhanced creativity among children—but also highlighted challenges such as technical difficulties, time constraints, and the need for ongoing professional development. These findings suggest that the integration of digital storytelling not only supports academic domains such as reading and language acquisition but also nurtures creativity and socio-cultural awareness (Adara, 2020; Purnama et al., 2022).

An additional benefit of digital storytelling is its ability to promote child-centered learning environments. The adaptability of digital stories enables educators to design narratives that reflect children's individual experiences, interests, and cultural backgrounds, thus fostering empathy, emotional intelligence, and interpersonal skills (Catalano & Catalano, 2022; Maranatha et al., 2024). In this context, digital storytelling serves as an engaging pedagogical tool that draws on students' prior knowledge and lived experiences, enabling deeper connections between instructional content and personal learning journeys (Kisno et al., 2022; Maranatha et al., 2024). Furthermore, the interactive nature of digital storytelling encourages active participation and collaboration, which are essential for developing higher-order thinking skills and building a sense of classroom community (Purnama et al., 2022; Sunar et al., 2022).

Digital storytelling also extends classroom learning beyond traditional boundaries by incorporating alternative modes of communication and expression. Educators can utilize digital media to develop stories that are accessible, culturally responsive, and aligned with educational goals, such as enhancing literacy and fostering digital competence (Adara, 2020; Sabari & Hashim, 2023). As children engage with these multimodal narratives, they are exposed to new vocabulary and language structures, while also learning to appreciate diverse storytelling forms and techniques (Losi et al., 2022; Purnama, 2021). Such engagement plays a critical role in laying the foundation for both linguistic and digital literacy development (Hartsell, 2017; Hoa & Minh, 2023).

In summary, digital storytelling in early childhood education is a multifaceted instructional tool that enhances learning by integrating technology with narrative practices. It facilitates content delivery that is connected to children's lived experiences, supports culturally responsive and child-centered pedagogy, and strengthens language and literacy skills. As an emerging field in early childhood education, digital story-

telling presents promising opportunities for fostering creativity, digital fluency, and holistic development among young learners (Hoa & Minh, 2023; Purnama, 2021; Purnama et al., 2022).

2.2. Hypothesis Development

The adoption of digital storytelling (DST) in early childhood education is shaped by psychological, social, and institutional factors. Grounded in the UTAUT2 model (Venkatesh et al., 2012), this study explores seven constructs—performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit—as predictors of preschool teachers' intention to adopt DST (Tang et al., 2025).

Performance expectancy refers to teachers' beliefs about DST's effectiveness in enhancing instructional quality and learning outcomes. Prior studies show that tools perceived as beneficial for engagement, comprehension, and skill development are more readily adopted (Hu et al., 2025). DST's multimodal features support creativity, language development, and digital literacy, increasing its perceived instructional value. Thus, it is hypothesized that performance expectancy positively influences intention to use DST. Effort expectancy captures the perceived ease of learning and applying DST. Teachers are more likely to adopt tools that are intuitive and require minimal training (Ateş & Gündüzalp, 2025). Given preschool teachers' multifaceted responsibilities, user-friendly interfaces and integration with existing practices can reduce cognitive load and increase adoption likelihood. Social influence reflects the extent to which teachers feel encouraged by peers, administrators, and parents to use DST (Şimşek & Ateş, 2022). In collaborative preschool environments, perceived professional or policy-level support can strengthen adoption intentions. Facilitating conditions, such as access to technology, institutional backing, and training, play a critical role in technology use (Sungur-Gül & Ateş, 2021). Teachers are more likely to adopt DST when they have the tools and support needed to use it confidently. Hedonic motivation refers to the enjoyment teachers derive from using DST. Studies indicate that when digital tools are fun and creatively engaging, educators are more motivated to use them (Berkovich & Hassan, 2024). DST's narrative and multimedia elements can make the teaching process more personally rewarding. Price value involves the perceived cost-effectiveness of DST, especially in resource-limited settings. Teachers are more inclined to adopt technologies they view as affordable and pedagogically beneficial (Duer & Jenkins, 2023). Open-access platforms and low-cost tools can enhance DST's appeal. Habit captures the influence of prior experience with digital tools. Teachers with a background in multimedia instruction or frequent use of technology are more likely to integrate DST routinely (Venkatesh et al., 2012; Şimşek & Ateş, 2022). Familiarity reduces resistance and supports long-term engagement.

Based on the UTAUT2 framework and its application to preschool teachers' adoption of DST, the following hypotheses are proposed. The relationships among the constructs are depicted in Figure 1:

H1: Performance expectancy positively influences preschool teachers' intention to use digital storytelling in their classrooms.

H2: Effort expectancy positively influences preschool teachers' intention to use digital storytelling in their classrooms.

H3: Social influence positively influences preschool teachers' intention to use digital storytelling in their classrooms.

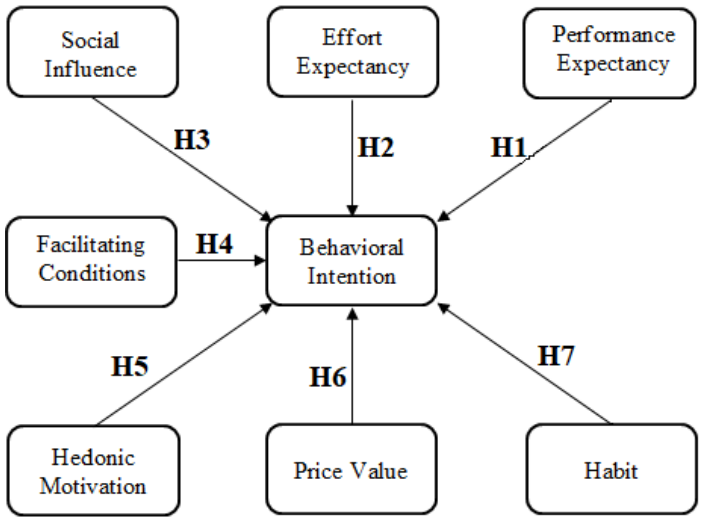
H4: Facilitating conditions positively influence preschool teachers' intention to use digital storytelling in their classrooms.

H5: Hedonic motivation positively influences preschool teachers' intention to use digital storytelling in their classrooms.

H6: Price value positively influences preschool teachers' intention to use digital storytelling in their classrooms.

H7: Habit positively influences preschool teachers' intention to use digital storytelling in their classrooms.

FIGURE 1. **UTAUT2 Model for Digital Storytelling Adoption.** This figure illustrates the theoretical framework and hypothesized relationships among the seven UTAUT2 constructs and teachers' intention to use digital storytelling in early childhood education.



3. MATERIAL AND METHOD

3.1. Data Collection Process

To prepare participants for the integration of DST into early childhood education, we first provided an overview highlighting its pedagogical benefits, such as fostering creativity, language development, and digital literacy in preschool settings. Teachers were introduced to the purpose, features, and educational relevance of DST to ensure a clear understanding of its potential.

We then offered a technical introduction to DST tools, including descriptions of software platforms, multimedia integration options, and hardware requirements. Step-by-step user guidelines were developed, supported by visuals and video tutorials, to accommodate varying levels of technological proficiency among teachers.

Hands-on workshops and training sessions were organized to guide teachers through key DST processes, such as storyboarding, multimedia editing, and voice narration. Participants had the opportunity to create digital stories, troubleshoot issues, and explore classroom applications in collaborative settings.

To support ongoing adoption, a help desk, online forums, and regular Q&A sessions were established. Teachers were encouraged to share experiences and seek assistance, fostering a supportive learning community. Feedback was collected through surveys and informal reflections to refine training content and support systems.

Updates on DST technologies were periodically shared, and case studies showcasing successful classroom implementations were included to inspire and motivate participants. This structured approach—combining technical knowledge, practical training, and continuous support—aimed to ensure confident, sustainable integration of DST in preschool education.

3.2. Participants

The participants of this study consisted of in-service preschool teachers actively employed in public and private early childhood education institutions across various metropolitan cities in Turkey. Data collection was conducted through a self-administered questionnaire, distributed at the beginning of the spring semester (January to May 2024). We used convenience sampling to recruit teachers with diverse levels of technological proficiency and teaching experience, ensuring a representative sample for analyzing DST adoption in preschool education.

Before participating, all teachers received informed consent forms outlining the study's objectives, the voluntary nature of participation, and the confidentiality of their responses. Ethical guidelines were strictly followed to ensure participant autonomy and data protection. The teachers were given adequate time to review the information before proceeding with the survey.

A total of 600 questionnaires were distributed, and 550 completed responses were collected, resulting in a 91.6% response rate. After screening for incomplete or inconsistent answers, all 550 responses were deemed valid for inclusion in the final analysis. According to Kline (2011), a minimum of 10 cases per survey item is necessary for statistical reliability. Given that the questionnaire contained 35 items, a minimum of 350 responses was required; therefore, our sample of 550 participants exceeded this threshold, ensuring robust and reliable data analysis.

The demographic distribution of the participants reflected a diverse range of experiences and backgrounds. Among the teachers, 73% were female and 27% were male, which aligns with the general gender distribution in early childhood education. The majority of participants were between the ages of 30 and 45 (67%), with 64% being married. Regarding educational qualifications, 29% of teachers held postgraduate degrees, indicating a high level of professional development.

In terms of technology experience and DST familiarity, 18% of teachers reported having previously integrated DST into their classroom activities, while an additional 52% expressed interest in using DST for storytelling and instructional purposes. Teachers with prior DST experience reported using it mainly for language development, creative expression, and student engagement, while those new to DST cited the need

for additional training and institutional support before full implementation. The remaining 30% of teachers were unfamiliar with DST but were open to exploring its potential benefits in early childhood education.

3.3. Measures

The data collection instruments used in this study were developed through a systematic and rigorous process, beginning with a comprehensive review of literature on UTAUT2 and its application in educational technology adoption (Ateş & Polat, 2025; Venkatesh et al., 2012). The initial scale items were designed based on UTAUT2 constructs, including performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit, ensuring that each construct aligned with the theoretical framework guiding this study. To validate the relevance and clarity of these items, a panel of four experts in early childhood education, educational technology, and psychology evaluated their face and content validity, following the recommendations of Gravetter and Forzano (2012). This evaluation ensured that the items were clearly worded, culturally appropriate, and accurately measured the constructs under investigation.

Following expert validation, a pilot study was conducted with 255 in-service preschool teachers to assess the reliability and validity of the instrument. This preliminary phase allowed for the identification of potential ambiguities, redundancies, and response biases in the measurement scales, ensuring that the final version accurately captured preschool teachers' perceptions and intentions regarding DST adoption. Considering the Turkish educational context, the questionnaire was translated from English to Turkish using a blind translation-back-translation method, as recommended by Esfandiar et al. (2020). This process was crucial in maintaining semantic and conceptual equivalence, minimizing language-related distortions that could affect the validity of responses.

The final survey instrument was structured around the UTAUT2 model to systematically assess the factors influencing preschool teachers' adoption of DST. The instrument included eight constructs, each measured with three or four items, allowing for a comprehensive analysis of their influence on teachers' behavioral intentions.

Performance Expectancy (PE) was measured using three items that assessed teachers' beliefs regarding the extent to which DST would enhance instructional quality and learning outcomes. Effort Expectancy (EE) included three items evaluating the perceived ease of learning and applying DST in preschool education. Social Influence (SI) was measured through three items capturing the perceived encouragement and expectations from colleagues, school administrators, and other influential figures regarding the use of DST. Facilitating Conditions (FC) consisted of four items assessing access to technological infrastructure, institutional support, training opportunities, and the compatibility of DST with existing teaching tools. Hedonic Motivation (HM) was captured using three items that measured the degree of enjoyment and intrinsic satisfaction teachers derived from using DST. Price Value (PV) was assessed through three items focusing on teachers' evaluations of the cost-effectiveness and perceived benefits of using DST. Habit (HT) was measured with three items reflecting the frequency and automaticity of technology use in teaching, including the likelihood of DST becoming a routine part of instructional practices. Finally, Behavioral Intention (INT) to use DST was measured using three items that examined teachers' future intentions, plans, and commitment to integrating DST into their classroom practices.

As seen in Table 1, all 30 items were rated on a 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree).

TABLE 1. Digital Storytelling Adoption Scale: Constructs and Item-Level Metrics

Construct	Item Statement	Factor Loading	Mean	SD	AVE	CR	α
Performance Expectancy (PE)	Using digital storytelling in my classroom will improve student engagement and learning outcomes.	0.84	5.21	0.82	0.69	0.88	0.85
	DST helps me teach more effectively.	0.81	5.18	0.79			
	DST enhances my productivity in planning and delivering lessons.	0.85	5.09	0.81			
Effort Expectancy (EE)	Learning to use DST in preschool education is easy for me.	0.82	4.88	0.89	0.70	0.89	0.84
	The interface of DST tools is user-friendly.	0.83	4.92	0.90			
	I can quickly learn how to create digital stories.	0.85	4.85	0.86			
Social Influence (SI)	My colleagues encourage me to use DST in my teaching.	0.78	4.75	0.91	0.66	0.86	0.83
	My school administrators support the use of DST.	0.81	4.80	0.87			
	Other teachers whose opinions I value think I should use DST.	0.80	4.85	0.85			
Facilitating Conditions (FC)	My school provides the necessary technology for DST.	0.84	4.61	0.94	0.68	0.87	0.86
	I have sufficient training to use DST effectively.	0.81	4.55	0.89			
	I can receive support when facing problems with DST.	0.83	4.66	0.91			
	DST is compatible with the other teaching tools I use.	0.80	4.58	0.88			
Hedonic Motivation (HM)	Using DST in class is enjoyable for me.	0.85	5.02	0.86	0.71	0.89	0.87
	I find DST fun and engaging to work with.	0.83	5.08	0.89			
	Creating digital stories makes teaching more enjoyable.	0.82	4.95	0.87			
Price Value (PV)	The educational benefits of DST outweigh its cost.	0.79	4.42	1.01	0.65	0.86	0.82
	DST is affordable considering its instructional value.	0.84	4.50	0.98			
	DST provides good value for the time and effort invested.	0.81	4.47	1.00			
Habit (HT)	Using digital tools like DST is part of my regular teaching practices.	0.83	4.85	0.94	0.68	0.88	0.85
	I often use similar technologies, so DST feels familiar.	0.82	4.78	0.92			
	I expect to routinely use DST once I begin.	0.80	4.75	0.91			
Intention to Use DST (INT)	I plan to use DST in my teaching regularly.	0.86	5.12	0.87	0.75	0.90	0.88
	I am committed to using DST in future classroom activities.	0.87	5.18	0.85			
	I will try to integrate DST into my teaching as much as possible.	0.85	5.10	0.83			

3.4. Data Analysis

The data analysis for this study was performed using SPSS version 21 for descriptive statistics and reliability analysis and AMOS version 20 for structural equation modeling (SEM), ensuring a rigorous statistical evaluation of the proposed model based on the UTAUT2. The analytical process followed a multi-step approach to examine the measurement structure, reliability, validity, and structural relationships among the key factors influencing preschool teachers' adoption of DST in early childhood education.

Initially, descriptive statistics were computed to summarize the means, standard deviations, and frequency distributions of the survey responses. This step provided an overview of general trends regarding teachers' perceptions, prior experiences, and intentions related to DST. Skewness and kurtosis values were examined to assess the normality of the data, ensuring that parametric statistical tests could be appropriately applied.

To validate the measurement model, confirmatory factor analysis (CFA) was conducted using AMOS 20. This analysis assessed the factor structure, reliability, and validity of the constructs in the study. Internal consistency was evaluated by calculating Cronbach's alpha coefficients for each construct, ensuring that all values met or exceeded the acceptable threshold of 0.70. Additionally, composite reliability (CR) values were calculated to verify the internal consistency of each latent variable.

To establish convergent validity, we examined whether factor loadings (FL) exceeded 0.60, ensuring that each item contributed significantly to its respective construct. The average variance extracted (AVE) was also assessed, with all values exceeding the minimum criterion of 0.50, indicating that the constructs captured sufficient variance from their indicators. Discriminant validity was confirmed by verifying that the square roots of the AVE values for each construct were greater than the inter-construct correlations, as recommended by Byrne (2016) and Fornell and Larcker (1981), and Hair et al. (2010). This test ensured that the constructs in the model were theoretically and statistically distinct from one another.

TABLE 2. Interrelations of UTAUT2 Constructs with Discriminant Validity Indicators

Constructs	PE	EE	SI	FC	HM	PV	HT	INT
PE	**0.83**							
EE	0.45	**0.84**						
SI	0.40	0.42	**0.81**					
FC	0.35	0.38	0.47	**0.82**				
HM	0.50	0.44	0.39	0.40	**0.84**			
PV	0.30	0.36	0.33	0.37	0.35	**0.81**		
HT	0.55	0.48	0.41	0.42	0.38	0.31	**0.82**	
INT	0.60	0.52	0.45	0.50	0.55	0.46	0.49	**0.87**

Note: Bolded diagonal elements indicate the square roots of the AVE values, providing evidence for discriminant validity among the constructs.

The structural model was evaluated through SEM to test the hypothesized relationships between the UTAUT2 constructs and preschool teachers' intention to use DST. Several model fit indices were examined to determine how well the theoretical model aligned with the observed data. The fit indices included the Chi-square to degrees of freedom ratio (χ^2/df), Goodness of Fit Index (GFI), Incremental Fit Index (IFI), Tucker-Lewis Index (TLI), Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). All indices met acceptable statistical thresholds, confirming a good model fit and supporting the validity of the theoretical framework used in this study.

The results of these analyses, including detailed factor loadings, reliability coefficients, and model fit statistics, are systematically presented in Tables 1 and 2.

4. RESULTS

4.1. Structural Model Analysis

Following the validation of the CFA, path analysis was conducted using SEM to evaluate the fit indices of the UTAUT2 model applied to preschool teachers' intentions to use DST in early childhood education. The results indicated that the structural model exhibited an acceptable fit, with all indices meeting the recommended thresholds for model adequacy. The fit indices for the model were as follows: χ^2/df = 2.85, Goodness of Fit Index (GFI) = 0.91, Incremental Fit Index (IFI) = 0.94, Tucker-Lewis Index (TLI) = 0.90, Comparative Fit Index (CFI) = 0.94, Root Mean Square Error of Approximation (RMSEA) = 0.04, and Standardized Root Mean Square Residual (SRMR) = 0.04. These values indicate that the model achieved a good fit with the observed data, supporting the theoretical structure proposed in this study. Additionally, the explanatory power of the model was assessed through the R^2 value, which measures the proportion of variance explained by the independent variables. The results demonstrated a strong explanatory power, with an R^2 value of 0.52, indicating that the UTAUT2 model accounted for 52% of the variance in preschool teachers' intentions to adopt DST in their classrooms.

4.2. Results of UTAUT2 Model

The findings from the structural path analysis provided important insights into the factors that influence preschool teachers' intentions to DST in early childhood classrooms. The results revealed statistically significant relationships among several UTAUT2 constructs and teachers' behavioral intentions, as summarized below.

Performance expectancy had a strong, significant positive effect on preschool teachers' intention to adopt DST ($\beta = 0.38$, $p < 0.001$). This indicates that teachers are more likely to use DST if they perceive it as an effective tool for enhancing student engagement, learning outcomes, and teaching productivity.

Effort Expectancy also emerged as a significant predictor of intention ($\beta = 0.34$, $p < 0.01$), indicating that perceived ease of use plays a central role in teachers' willingness to adopt DST. Teachers who found DST platforms intuitive and accessible were more likely to report stronger intentions to integrate it into their teaching practices.

Social Influence had a positive and statistically significant relationship with behavioral intention (β = 0.27, $p < 0.01$). This result suggests that encouragement and support from colleagues, administrators, and other influential stakeholders positively shape teachers' perceptions and readiness to adopt DST in the classroom.

Facilitating Conditions were also found to significantly influence teachers' intention to adopt DST (β = 0.30, $p < 0.01$). Access to necessary infrastructure, training opportunities, and institutional support was critical in supporting preschool teachers' adoption efforts.

Hedonic Motivation showed a meaningful and positive effect on behavioral intention (β = 0.29, $p < 0.05$). Teachers who found DST enjoyable and creatively fulfilling were more likely to express intentions to use it in their classrooms. The intrinsic pleasure derived from creating digital stories was an important motivational factor.

Price Value also emerged as a significant factor (β = 0.26, $p < 0.05$), suggesting that teachers' perceptions of DST as a cost-effective instructional tool influence their intention to adopt it. When teachers viewed the time, effort, and resources invested in DST as justified by its educational benefits, they were more inclined to adopt it.

Finally, Habit had a strong and statistically significant effect on intention (β = 0.35, $p < 0.001$). This indicates that teachers who were already familiar with digital tools or regularly engaged with technology-enhanced instruction were more likely to adopt DST as part of their routine teaching practice.

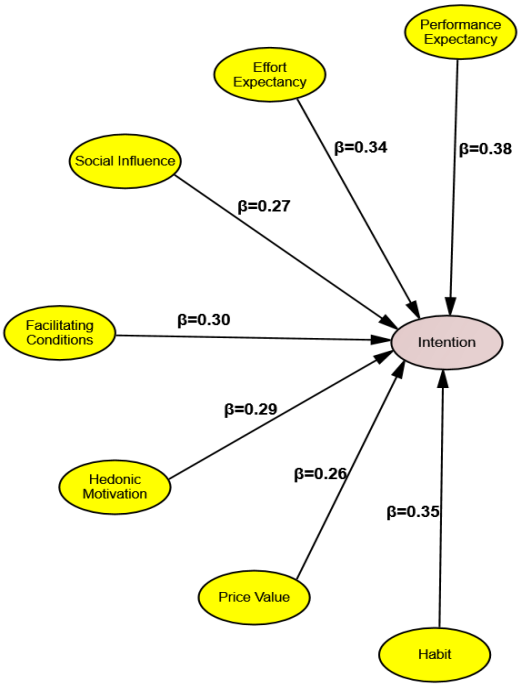
Collectively, these results underscore the multidimensional nature of technology acceptance and highlight the importance of both cognitive evaluations (e.g., usefulness, ease of use) and affective-motivational drivers (e.g., enjoyment, familiarity) in shaping early childhood educators' adoption of digital storytelling. The detailed standardized path coefficients illustrating these relationships within the UTAUT2 framework are visually presented in Table 3 and Figure 2.

TABLE 3. SEM Results of the UTAUT2 Model

Hypothesis Number	Path	Standardized Coefficient (β)	t-value	Hypothesis Outcome
H1	Performance Expectancy → Intention	0.38**	8.542	Supported
H2	Effort Expectancy → Intention	0.34**	7.926	Supported
H3	Social Influence → Intention	0.27*	5.842	Supported
H4	Facilitating Conditions → Intention	0.30*	6.489	Supported
H5	Hedonic Motivation → Intention	0.29*	6.103	Supported
H6	Price Value → Intention	0.26*	5.774	Supported
H7	Habit → Intention	0.35**	8.321	Supported

Note: $p < 0.001$, $p < 0.0001$.

FIGURE 2. Path Analysis Results of the UTAUT2 Model. The standardized coefficients indicate the strength and significance of relationships between the constructs based on structural equation modeling.



5. DISCUSSION

This study employed the UTAUT2 model to investigate the factors influencing preschool teachers' intention to adopt DST in early childhood education. The structural equation modeling results confirmed that all seven constructs—performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit—significantly and positively influenced behavioral intention. Among these, performance expectancy and habit were the strongest predictors, indicating that teachers are more likely to adopt DST when they see it as beneficial for teaching and are already familiar with digital tools. Effort expectancy and facilitating conditions also played key roles, suggesting that ease of use and institutional support are important for adoption. Additionally, hedonic motivation and price value contributed to teachers' intention by highlighting the importance of enjoyment and cost-effectiveness. Overall, the model explained a substantial portion of the variance in adoption intention, offering a validated framework for understanding technology acceptance in early childhood education and practical insights for promoting DST integration in preschool settings.

5.1. Implications

This study makes several important theoretical and practical contributions to the field of educational technology, particularly within the context of early childhood education. By employing UTAUT2 to examine preschool teachers' intention to adopt DST, the study provides a validated framework that captures how performance-related beliefs, social norms, intrinsic motivations, facilitating conditions, and habitual behaviors

influence technology acceptance in a foundational learning environment. This application is especially significant, as research on technology adoption models has primarily focused on secondary or higher education contexts (Al-Adwan & Al-Debei 2024; Ateş & Polat, 2025; Suhail et al., 2014), leaving early childhood education comparatively underexplored.

From a theoretical perspective, this study affirms and extends the validity of UTAUT2 by demonstrating its predictive power in early childhood settings, where pedagogical decisions are heavily influenced by developmentally appropriate practices and resource limitations. All seven hypothesized constructs—performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit—were found to significantly influence behavioral intention. This supports earlier studies that found UTAUT2 to be a robust model in educational settings (Ateş & Garzón, 2023; Cabero-Almenara et al., 2024; Zheng et al., 2025), while extending its relevance to preschool educators, a group often omitted in mainstream technology acceptance literature (Şakir, 2024). Notably, performance expectancy and habit emerged as the most influential predictors. These findings corroborate Davis's (1989) Technology Acceptance Model (TAM), which highlights perceived usefulness as a central determinant of behavioral intention. They also align with recent studies showing that when teachers perceive a tool as enhancing learning outcomes and instruction (e.g., Ateş & Polat, 2025), they are more likely to adopt it. The significance of habit emphasizes the role of prior exposure and routine use of technology, echoing Ajzen's (1991) Theory of Planned Behavior, which suggests that past behavior can strongly inform future intentions. For early childhood educators, who often operate in low-tech environments, the habitual use of digital tools may lower cognitive barriers and increase readiness to integrate DST. The importance of effort expectancy and facilitating conditions further reflects core UTAUT2 assumptions, showing that ease of use and supportive infrastructure are key drivers of technology adoption. These constructs are particularly salient in early childhood settings, where educators may lack consistent access to training or resources. Prior research by Cabellos et al. (2024) and Ogegbo et al. (2024) similarly found that teachers' technology integration is contingent upon the usability of tools and the availability of institutional support, such as hardware, software, and professional development. This study also advances theoretical understanding by validating the role of hedonic motivation and price value in shaping behavioral intention. The significant influence of hedonic motivation aligns with self-determination theory (Ryan & Deci, 2000), which emphasizes the importance of intrinsic enjoyment in sustaining engagement. Teachers who find DST enjoyable are more likely to use it—not only for pedagogical utility but also for the personal satisfaction derived from creative teaching. This complements studies by Ateş and Garzón (2022), who highlighted the emotional dimension of digital tool usage as a strong predictor of technology acceptance in education. Moreover, price value, reflecting the perceived trade-off between costs and benefits, reinforces earlier work by Venkatesh (2022), which found that affordability and perceived value strongly influence adoption. In the preschool context, where budgets are often constrained, a tool like DST must demonstrate both low operational cost and high pedagogical payoff to gain teacher acceptance. Collectively, these findings provide empirical support for UTAUT2's multidimensional structure while demonstrating its adaptability to early childhood education—an area often overlooked in technology acceptance research. This study enriches the literature by showing that technology adoption in early learning environments is influenced not only by rational judgments of utility and support, but also by emotional engagement and habitual practices.

On a practical level, the study offers actionable insights for educators, school leaders, policymakers, and teacher educators aiming to promote the adoption of DST in preschool education. First, professional development programs should focus on demonstrating the pedagogical effectiveness and ease of use of DST tools. Teachers are more likely to adopt such tools when they can clearly see how these resources improve lesson delivery and student engagement. Workshops and hands-on training sessions should include practical examples of classroom integration, highlighting both the instructional benefits and the user-friendly features of DST platforms. Second, institutional support must be enhanced. Schools should ensure that technological infrastructure is readily available, including devices, multimedia resources, and reliable internet access. Moreover, administrators should communicate a clear commitment to supporting innovative teaching practices and provide ongoing technical support and peer mentoring, allowing teachers to adopt DST with confidence and continuity. Additionally, enjoyment and creativity should be emphasized in teacher training, as the study found that hedonic motivation significantly influences adoption intention. Showcasing DST as a playful, expressive, and rewarding experience for teachers—as well as a powerful engagement tool for children—can increase its appeal. Further, cost-related concerns must be addressed. Schools and education departments can facilitate adoption by providing access to free or low-cost DST tools, offering subsidies for software licenses, or integrating DST into broader digital learning strategies. Lastly, policy-level support is essential for scaling DST adoption. Education ministries or local authorities could incorporate DST into early childhood curriculum guidelines, promote best practices through national digital education portals, and support teacher networks that share success stories and resources. Developing these collaborative platforms can foster a culture of innovation, where DST becomes a natural extension of preschool instruction. enhancing both teaching practices and learning experiences in the process.

6. CONCLUSIONS

This study investigated the factors influencing preschool teachers' intention to DST in early childhood education through the lens of the UTAUT2. The analysis confirmed that all seven hypothesized constructs—performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit—significantly and positively impacted teachers' behavioral intention to adopt DST. Among these factors, performance expectancy and habit emerged as particularly strong predictors, highlighting the importance of perceived pedagogical value and prior experience with technology in shaping teachers' intentions. Teachers were more inclined to adopt DST when they recognized its potential to improve student engagement, learning outcomes, and their own teaching efficiency. Similarly, teachers with greater familiarity and comfort with digital tools reported a higher likelihood of integrating DST into their routine practices. Effort expectancy and facilitating conditions were also important, indicating that ease of use and institutional support are essential for successfully implementing DST. Teachers who perceived DST tools as user-friendly and reported access to adequate resources, training, and technical support were more likely to express a strong intention to use them in their classrooms. Moreover, intrinsic enjoyment (hedonic motivation) and perceived cost-effectiveness (price value) were shown to be influential. These findings suggest that both emotional engagement and practical considerations contribute meaningfully to adoption decisions. Overall, the findings highlight the need to develop teacher-centered support systems that address

both technical and motivational needs. The study contributes to the theoretical understanding of technology acceptance in early childhood education and offers practical recommendations for designing professional development programs and institutional policies aimed at promoting DST adoption.

6.1. Limitations and future lines of research

While this study provides important insights, several limitations should be acknowledged. First, the sample consisted only of in-service preschool teachers in Turkey, which may limit the generalizability of the findings to other educational contexts or cultural settings. Future research could include comparative studies across different countries or regions to examine potential contextual differences in technology acceptance.

Second, the study relied on self-reported survey data, which may be subject to social desirability bias or inaccuracies in self-assessment. To address this, future studies could incorporate qualitative methods, such as interviews or classroom observations, to enrich the findings and provide a deeper understanding of teachers' experiences with DST.

Third, the cross-sectional design of the study does not allow for the examination of changes in intention or behavior over time. Longitudinal research would be valuable for investigating how teachers' perceptions and use of DST evolve with increased exposure and training.

Additionally, while this study focused on behavioral intention, it did not assess actual usage behavior. Future research could explore the gap between intention and behavior by tracking how frequently and in what ways DST is implemented in real classroom settings.

Finally, this study employed only the UTAUT2 framework. Although comprehensive, UTAUT2 may be complemented by other theoretical models, such as TPACK or TAM3, for a more holistic analysis of digital tool adoption in early childhood education.

Future research could also examine the impact of DST on student learning outcomes and engagement, providing a more complete picture of its effectiveness as a pedagogical innovation. Moreover, exploring how DST can be integrated into specific subject areas—such as language development or social-emotional learning—could further inform best practices in curriculum design and instructional strategy. Importantly, further studies should investigate the practical applications of DST in multicultural classrooms and with students who have diverse educational needs. As interest in inclusive education grows globally, understanding how DST can support engagement and learning among culturally and linguistically diverse students, as well as those with disabilities, represents a valuable direction for future research.

7. AUTHOR CONTRIBUTION

In accordance with the CRediT taxonomy, all aspects of this study were carried out solely by the author. This includes conceptualization, data curation, formal analysis, investigation, methodology, project administration, validation, and visualization. The author also wrote the original draft of the manuscript and completed all review and editing.

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Neither 1, nor 3, Are 7! Analysis of Technostress Profiles in University Students through a Mixed Method

Ni 1, ni 3, ison 7! Análisis de los perfiles de tecnoestrés en estudiantes universitarios a través de un método mixto

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Jonathan Peñalver
ORCID: 0000-0003-1339-7484
Equipo de investigación WANT, Universitat Jaume I, España
jpenalve@uji

Mercedes Ventura
ORCID: 0000-0001-5949-7144
Equipo de investigación WANT, Universitat Jaume I, España
mventura@uji.es

Alba Juan Alemany
ORCID: 0009-0008-3928-1272
Universitat Jaume I, España
al384728@uji.es

Mabel San Román-Niaves
ORCID: 0000-0003-3550-9088
Alma Mater Studiorum-Università di Bologna, Italia
mabel.sanromanniave2@unibo.it

ABSTRACT

While technostress can affect anyone who uses ICTs (including employees and students) individuals experience it differently through anxiety, fatigue, addiction. This study aims to advance technostress research among students by identifying distinct profiles and examining differences between them through a mixed-method approach. The sample consisted of 224 university students (68.5% female) from different Spanish universities. Our findings revealed seven technostress profiles: Profile 1, Techno-anxious, Profile 2, Techno-fatigued, Profile 3, Techno-addicted, Profile 4, Techno-anxious-fatigued, Profile 5, Techno-anxious-addicted, Profile 6, Techno-fatigued-addicted, Profile 7, Techno-anxious-fatigued-addicted. Although student burnout did not significantly differentiate between profiles, qualitative analysis showed that insufficient digital competencies and information overload contributed to increased anxiety and technology resistance. Furthermore, prolonged screen exposure without adequate management led to mental and visual fatigue. These results highlight the need for targeted interventions to enhance digital literacy and promote

healthier technology use habits. Our findings have important theoretical implications for understanding technostress complexity and practical applications for developing more precise diagnostic tools and personalized support strategies.

KEYWORDS Technostress, University Students, Profiles, Mixed Methods Research, Student Burnout

RESUMEN

Aunque el tecnoestrés puede afectar a cualquier persona que utilice las TIC (incluyendo empleados y estudiantes), los individuos lo experimentan de manera diferente a través de ansiedad, fatiga o adicción. Este estudio pretende avanzar en la investigación del tecnoestrés en estudiantes mediante la identificación de perfiles distintivos y el análisis de las diferencias entre ellos utilizando un enfoque de métodos mixtos. La muestra estuvo formada por 224 estudiantes universitarios (68,5 % mujeres) de diferentes universidades españolas. Los resultados revelaron siete perfiles de tecnoestrés: Perfil 1, Tecno-ansioso, Perfil 2, Tecno-fatigado, Perfil 3, Tecno-adicto, Perfil 4, Tecno-ansioso-fatigado, Perfil 5, Tecno-ansioso-adicto, Perfil 6, Tecno-fatigado-adicto, Perfil 7, Tecno-ansioso-fatigado-adicto. Aunque el burnout estudiantil no discrimina entre los perfiles, el análisis cualitativo mostró que las competencias digitales insuficientes y la sobrecarga de información contribuyeron a aumentar la ansiedad y la resistencia hacia la tecnología. Además, la exposición prolongada a pantallas sin una gestión adecuada provoca fatiga mental y visual. Estos resultados destacan la necesidad de intervenciones específicas para mejorar las competencias digitales y promover un uso más saludable de la tecnología. Los resultados tienen importantes implicaciones teóricas para comprender la complejidad del tecnoestrés y aplicaciones prácticas para desarrollar herramientas de diagnóstico más precisas y estrategias de apoyo personalizadas.

PALABRAS CLAVE tecnoestrés, estudiantes universitarios, perfiles, método mixto, agotamiento en estudiantes

1. INTRODUCTION

1.1. The shift of technostress from work to study environments

In an increasingly digitalised world, the impact of information and communication technologies (ICT) on the daily lives is undeniable. In fact, it can be argued that the use of digital tools has transformed the way people work, study, shop, and live, while also giving rise to different ways of interacting with Information and Communication Technologies (ICT; e.g., Hong et al., 2023). These experiences are often referred to as technoflow (a positive experience) or technostress (a negative experience; Salonova et al., 2014).

Initially proposed by Broad (1984) and later expanded by various authors (e.g., Ragu-Nathan et al., 2008; Salanova et al., 2014), technostress can be understood as a negative job experience (e.g., disease, kind of stress, psychological state) associated with the use of ICT. It is characterised by a perceived mismatch between different technological demands and users' skills or resources. Its consequences are diverse and well-documented, including physical and emotional symptoms (Sanjeeva-Kumar, 2024), as well as behavioural effects such as intention to quit (Harris et al., 2022).

Although technostress was originally identified in workplace settings (e.g., Muhametjanova et al. 2024), this psychosocial phenomenon has also been observed in academic environments, affecting students who rely heavily on technology for their learning process (Saleem et al. 2024). As early as 1989, Hudiburg suggested that students might also be vulnerable to technostress when using computers. Since then, research has increasingly highlighted this issue, pointing to the combination of high academic demands and intensive

use of digital technologies as key contributors to students' technostress (Asensio-Martínez et al., 2023). Over the years, the consequences of technostress among students have been found to mirror those observed in workers, including physical pain and emotional discomfort (Villavicencio-Ayub et al. 2024).

1.2. Profile of technostress

In the evolving field of technostress research (Sanjeeva Kumar, 2024), some models have focused on identifying its various causes and consequences (Ragu-Nathan et al., 2008), while others have aimed to better understand the subjective nature of the experience itself (Salanova et al., 2014). One influential line of work conceptualises technostress as a multi-dimensional construct, combining emotional (e.g., anxiety, fatigue), cognitive (e.g., self-efficacy), and behavioural (e.g., addiction) dimensions. Salanova and colleagues (2004, 2012) confirmed that individuals can experience these dimensions simultaneously, depending on their interaction with technology. Based on this, they identified three core technostress profiles: 1) Techno-anxiety: a negative emotional state characterised by anxiety during the use ICTs; 2) Techno-fatigue: physical and psychological exhaustion caused by information overload and persistent technological demands; and 3) Techno-addiction: excessive and compulsive use of ICTs, marked by a constant need to interact with them.

Although this classification has contributed to a more precise comprehension of technostress (Penado-Abilleira et al., 2021), it may not fully capture the complexity of real-life experiences. From a conceptual standpoint, individuals are likely to experience combinations of these profiles. This suggests the existence of mixed technostress profiles, such as techno-anxious-fatigued or techno-fatigued-addicted.

Some recent studies have attempted to explore this issue, yest most still rely on discrete classifications (i.e., techno-functional, techno-strained, and techno-addicted; Rosa et al., 2025), based on the intensity of technostressors (Ficapal-Cusí et al., 2024), or maladaptive ICT use (Díaz-López et al., 2020); However, these approaches often overlook the subjective combination of symptoms, the student perspective, and the potential value of qualitative insights.

To address this gap, our study is grounded in three key foundations: First, anxiety, fatigue and/or addiction can co-occur. Several studies have reported significant positive correlations between anxiety and fatigue (Kim & Kang, 2017; van Dam, 2016; Villanueva Ramírez et al., 2023). Moreover, Fekih-Romdhane et al. (2023) found that smartphone, internet and Facebook addiction can trigger or intensify anxiety symptoms.

Second, self-efficacy, defined as one's beliefs in their ability to organize and execute specific actions (Bandura, 1997), serves as a protective factor against technostress (Salanova et al., 2014). However, as highlighted by Social Cognitive Theory (Bandura, 1997), self-efficacy is domain-specific: a user may feel confident writing emails but feel uncapable of controlling their overall use of ICT. In line with this, studies that analyse the role of specific self-efficacy (e.g., self-efficacy for online teaching) have emerged, as did Levante et al. (2025). Also, Chang et al. (2024) found that technical self-efficacy modulated emotional reactions to AI-driven technostress, reducing anxiety and enhancing positive affect depending on whether the stressor was perceived as a challenge or a hindrance.

Thirdly, based on Lazarus and Folkman's transactional model of stress (1984), and its application to technostress (Salanova et al., 2014; Sharma & Gupta, 2023), stress occurs when perceived demands exceed one's coping reources. Individuals may use emotion-focused coping to manage anxiety or frustration from technological demands, while also engaging in problem-solving by continuing to use technology compulsively to meet academic or professional goals. This dynamic can generate contradictory experience within the same person.

In summary, constant interaction with multiple digital tools may lead to ambivalent states. For example, dependence on technology for studying or working may coexist with fatigue due to the overuse and frustration when outcomes do not meet expectations. Therefore, we formulated the first research question:

- **Research Question 1 (RQ1)**: Are there mixed profiles of technostress among university students?

1.3. Technostress and student burnout

The relationship between burnout and technostress among university students has received growing attention in recent research, particularly considering the increasing reliance on digital technologies for academic purposes. Burnout refers to a psychological state of prolonged response to chronic stress (Maslach & Jackson 1981), characterised by emotional exhaustion, cynicism or depersonalization, and reduced personal accomplishment. Approximately one-third of high-level students report symptoms that negative affective their academic performance and mental well-being (Rosales-Ricardo et al., 2021).

Research indicates that technostress contributes to burnout development. Galvin et al. (2022) found that excessive demands from technology-driven academic environments increase burnout risk by intensifying emotional exhaustion and reducing motivation. Similarly, Vallone et al. (2023) suggest that high technostress levels lead to burnout symptoms that hinder academic engagement and performance.

This relationship became particularly evident during the rapid transition to online learning, when studies identified several technostress creators as being positively correlated with both behavioural stress (Upadhyaya & Vrinda, 2021), and emotional exhaustion (Álvarez-Risco et al. 2021). Additionally, Zhao et al. (2022) reported that technostress negatively affects students' sleep quality and academic performance.

When considering the seven different technostress profiles identified in our study, it is possible to theorise distinct patterns of association with burnout dimensions. For instance, techno-anxious students may be more prone to emotional exhaustion, while techno-fatigued students might show higher levels of cynicism. In contrast, techno-addicted students may present a unique pattern in which high academic efficacy coexists with emotional exhaustion.

The mixed profiles suggest more complex interactions. Students experiencing both anxiety and fatigue may be vulnerable to emotional exhaustion and cynicism, whereas those combining addiction with either anxiety or fatigue might present patterns of high engagement coupled with psychological distress.

Based on these theoretical relationships, we propose that burnout dimensions can serve as discriminating factors across technostress profiles. Specifically, each profile may be characterised by distinct

patterns in: (1) Emotional exhaustion, as an indication of psychological strain; (2) Cynicism, as a potential coping mechanisms, and (3) Academic efficacy, reflecting different patterns of engagement with technology. This leads to our second research question:

- **Research Question 2 (RQ2):** Are there any significant differences in student burnout (emotional exhaustion, cynicism, and academic efficacy) across the seven identified technostress profiles?

1.4. Technostress and the use of ICT in the academic context

ICTs have become essential tools in the academic field, significantly transforming teaching and learning dynamics. In higher education, these technologies offer a wide range of possibilities, from access to online educational resources to digital platforms that facilitate collaborative and personalized processes. However, students' perception of ICT use can be both positive and negative, depending on the benefits or challenges students may experience.

Understanding how students perceive the use of ICT is essential for optimising their integration into educational processes, particularly in increasingly diverse contexts. Numerous studies have highlighted the benefits of ICT, including enhanced access to academic resources, improved collaboration between teachers and students, and the facilitation of personalised learning paths that support academic outcomes (Aguilar y Xiang, 2023; Agudelo-Velásquez y Salinas, 2020; Castro, 2023). Moreover, the development of digital competencies among university students is crucial for transforming ICT into inclusive learning tools (Parody-García et al., 2024). In this sense, ICT not only promote accessibility through the principles of Universal Design for Learning (Calle-Córdoba et al., 2024), but also contribute to the development of communication skills, student autonomy, and active participation, particularly among learners with functional diversity, thus fostering equitable and innovative pedagogical approaches (Parody-García et al., 2022).

Nonetheless, despite the numerous advantages, several studies have identified challenges associated with their implementation. On the one hand, a lack of adequate training or digital literacy within the academic community can hinder the effective use of these tools (Sangeeta & Tandon, 2020). On the other hand, unequal access to devices and connectivity remains a significant barrier, especially in socioeconomically vulnerable contexts (Villao & Matamoros, 2024). Furthermore, the intensive use of digital technologies may result in distractions and cognitive overload, negatively impacting students' well-being and academic performance. As such, the perception of ICT can vary depending on students' personal resources and their ability to cope with these demands (Llorens et al., 2007; Salanova et al., 2011).

Considering these complexities, this study aims to explore university students' perceptions of ICT use through a qualitative approach, with the goal of providing a more contextualised view of the role these tools play in their academic lives. Accordingly, the third research question is formulated as follows:

- **Research Question 3 (RQ3):** What are university students' perceptions of the use of technology during their studies?

2. METHOD

2.1. Sample and procedure

The sample consisted of 224 university students (68.5% female) from different Spanish universities (university 1, 70.1%; university 2, 15.6%; other universities, 14.3%), aged between 18 and 43 years (M = 22; SD = 3.75). They represented a variety of academic disciplines, including health sciences (40.6%), humanities (33.9%), natural sciences (18.9%), and social sciences (7.5%). Most participants (88.2%) were enrolled in undergraduate programs.

Data were collected through an online questionnaire developed using the Google Forms platform. A snowball sampling technique was employed to disseminate the questionnaire among university students. Participation was entirely voluntary and non-remunerated. In accordance with the ethical standards of the Declaration of Helsinki, all participants provided written informed consent. Anonymity and confidentiality were maintained throughout the research process.

In addition to standardized instruments, the questionnaire included two open-ended questions aimed at capturing students' subjective perceptions and experiences regarding the use of ICT in academic contexts.

2.2. Variables and instruments

Technostress in students was assessed using an adaptation of the RED-Technostress or RED-ICT for students (Eidman & Basualdo, 2021). Also, the five-factor structure of the RED-ICT scale has been confirmed through confirmatory factor analysis in prior research (e.g., Eidman & Basualdo, 2021). The RED-ICT is composed of 22 items divided into 5 subscales: Anxiety (4 items; e.g., "I feel tense and anxious when studying with technologies"); Fatigue (4 items; e.g., "I find it difficult to relax after a day of studying using them"); Scepticism (4 items; e.g., "I doubt the outcome of studying with these technologies"); Inefficacy with technologies (4 items; e.g., "In my opinion, I am ineffective using technologies"); and Addiction (6 items; e.g., "I think I over use technologies in my life"). All items rated on 7-point Likert scale ranging from 0 ("never") to 6 ("every day"; Salanova, et al., 2004).

Student burnout was measured using the Maslach Burnout Inventory-Student Survey (MBI-SS, Schaufeli et al., 2002). This scale includes three subscales: Emotional exhaustion (5 items; e.g., "I am emotionally drained from doing this grade"), Cynicism (4 items, e.g., "I have become more cynical about the usefulness of my studies"), and Efficacy with studies (6 items; e.g., "I can effectively solve problems related to my studies."). All the items had a 7-point Likert response format ranging from 0 ("never") to 6 ("every day").

Additionally, two open-ended questions were included to explore students' subjective perceptions of ICT use during their studies: 1) *"What is your opinion on the use of technology during your studies?"*; and 2) *"What do you think are the reasons for the difficulties in using technologies?"*.

2.3. Data analysis

Data were analysed using the SPSS 23.0 (IBM Corp, 2015) and ATLAS.ti version 24 software. Prior to the main analyses, data were screened for missing values, and descriptive statistics, reliability indices, and bivariate correlations were calculated for all dimensions included in the study.

Technostress profiles were constructed based on participants' scores in the five technostress dimensions: anxiety, fatigue, inefficacy, scepticism, and addiction. The classification criteria followed the framework established by Salanova et al. (2004), as well as the normative thresholds proposed by Peñalver and Ventura (2024). According to this classification, the techno-anxiety profile was assigned to students scoring high or very high on anxiety, inefficacy, and scepticism; the techno-fatigue profile to those scoring high or very high on fatigue, inefficacy, and scepticism; and the techno-addiction profile to students scoring high or very high on the addiction dimension.

To examine whether differences in student burnout levels emerged across the identified technostress profiles, an analysis of variance (ANOVA) was conducted. This allowed for the comparison of emotional exhaustion, cynicism, and academic efficacy among the seven technostress profiles.

The qualitative data, derived from two open-ended questions, were analysed using a content analysis approach that combined both deductive and inductive strategies (Saldaña, 2009). Deductive coding was based on pre-established thematic categories, while inductive coding allowed for the emergence of new, data-driven subcategories. This hybrid approach enabled a richer and more contextualised understanding of students' experiences with ICT in academic settings. To enhance the robustness of the analysis, triangulation techniques were applied, integrating the written responses, categorical descriptors, and technostress profiles to support a multi-faceted interpretation of the data (Flick, 2004). A critical-interpretative perspective was also adopted, allowing for deeper reflection on the contextual and theoretical dimensions of students' responses.

To ensure anonymity and confidentiality, an alphanumeric coding system was used. The letter "S" indicated a student, followed by a number representing their assigned participant ID (e.g., S6 refers to student number 6).

3. RESULTS

3.1. Quantitative results

Listwise deletion of missing data was applied, resulting in a data loss rate of less than 5% data (Fichman & Cummings, 2003), no participants were excluded from the analyses. Based on the recommendations of Finney and DiStefano (2006), the skewness and kurtosis values for all dimensions indicated that the assumption of normality was not violated. The results also revealed statistically significant correlations among the study dimensions, except for emotional exhaustion and efficacy with studies, which showed weaker associations with the rest of the dimensions. Regarding internal consistency, Cronbach's alpha coefficients indicated good reliability across all dimensions. Descriptive statistics, reliability indices, and intercorrelations are presented in Table 1.

TABLE 1. Descriptive, reliably and bivariate correlations

Variables	M	SD	S	K	α	2	3	4	5	6	7	8
1. Anxiety	2.07	1.48	.50	-.54	.83	.63**	.56**	.35**	.75**	.23**	.21**	-.06
2. Fatigue	2.68	1.65	.13	-1.05	.89		.43**	.43**	.48**	.33**	.22**	.02
3. Scepticism	1.92	1.26	.52	-.44	.78			.21**	.53**	0.12	.15*	.00
4. Addiction	3.26	1.35	-.15	-.56	.86				.34**	.26**	.30**	.04
5. Inefficiency with technologies	1.68	1.29	.89	.49	.80					.12	.16*	-.14*
6. Emotional exhaustion	2.77	1.51	.13	-.71	.92						.67**	.03
7. Cynicism	1.84	1.62	.80	-.14	.90							-.14*
8. Efficacy with studies	3.80	1.32	-.48	-.34	.86							

Note: M= Mean, SD= Std. deviation, S= Skewness, K= Kurtosis, α= Cronbach's index, *p<.05,**p<.01

The categorisation process identified seven technostress profiles based on students' levels of anxiety, fatigue, scepticism, inefficacy with technologies, and addiction: Profile 1, Techno-anxious; Profile 2, Techno-fatigued; Profile 3, Techno-addicted; Profile 4, Techno-anxious-fatigued; Profile 5, Techno-anxious-addicted; Profile 6, Techno-fatigued-addicted; Profile 7, Techno-anxious-fatigued-addicted. A total of 51.1% of students did not meet the criteria into any of the seven profiles.

To examine potential differences in burnout across these profiles, a one-way analysis of variance (ANOVA) was conducted. However, the results did not indicate any statistically significant differences in emotional exhaustion (F = 0.464, p = .802), cynicism (F = 0.325, p = .897), or academic efficacy (F = 0.658, p = .656) across the profiles. It should be noted that Profile 6 (Techno-fatigued-addicted) included only one participant; therefore, it was excluded from the ANOVA due to insufficient sample size.

TABLE 2. Descriptive analysis for student burnout in the 7 profiles of technostress

Variables		Emotional exhaustion		Cynicism		Efficacy with studies	
Profile	**%**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Profile 1, Techno-anxious	1.3	2.53	0.64	1.50	1.50	3.78	1.35
Profile 2, Techno-fatigued	.9	2.10	0.99	1.63	1.24	3.67	1.41
Profile 3, Techno-addicted	34.5	3.24	1.52	2.27	1.77	1.23	1.23
Profile 4, Techno-anxious-fatigued	3.6	2.85	1.41	1.63	1.41	4.21	0.75
Profile 5, Techno-anxious-addicted	1.8	1.52	1.52	2.31	2.59	3.21	1.33
Profile 6, Techno-fatigued-addicted	.4	3.00	-	1.75	-	3.5	-
Profile 7, Techno-anxious-fatigued-addicted	6.3	2.91	1.80	2.18	1.92	3.50	1.74

Note: M= Mean, SD= Std. deviation.

3.2. Qualitative results

As shown in Table 3, the different technostress profiles perceive both positive and negative aspects of using ICT. Students with a techno-fatigue profile view ICT as beneficial in areas such as calculations, teaching, and communication, while also highlighting challenges such as difficulties concentrating during digital reading and mental and visual fatigue caused by prolonged device use.

TABLE 3. Categories by technostress profiles. What is your opinion on the use of technology during your studies?

Profile	Category	Emerging Subcategory
Tecno-fatigued	Positive perceptions	• Usefulness in mathematical calculations • Facilitates academic work • Facilitates communication **Example:** "*I think they are necessary (...) for certain calculations. Also, for teaching and making video conferences.* (S5)
	Negative Perceptions	• Difficulty concentrating • Preference for physical format for studying • Mental and visual fatigue **Example:** *"When I read an article or a book, if I do it digitally, I am unable to keep my focus on what I am reading (...) After using technology for a while, when I want to refocus on my studies, I first need to rest, my eyes and mind. I need to have the article in physical form in order to study it well."* (S5)
Techno-addict	Positive perception	• Access to educational resources • Facilitation of collaboration • Optimisation of time management • Improvement in learning quality **Example:** *"Technologies are very useful (...) I have access to digital books and articles."* (S7); *"I believe they facilitate and optimise tasks. For me, it's all advantages because everything is very accessible."* (S33)
	Negative perception	• Mental and physical fatigue • Distractions and lack of concentration • Information overload • Privacy concerns • Concerns about excessive use **Example:** *"You spend a lot of time with electronic devices... and it ends up exhausting you mentally and physically."* (S11); *"They generate physical and mental exhaustion."* (S22);*"You can get distracted by looking at anything."* (S28); *"Technologies represent a work monitoring that can border on a lack of privacy."* (S39)
Techno-anxious-fatigued	Positive perceptions	• Facilitate academic work • Accessibility and flexibility **Example:** "*They make it much easier to create assignments."* (S87); *"It can be useful since it allows all students to have the same material at hand."* (S83)
	Negative perceptions	• Fatigue • Concern about replacing traditional methods • Lack of effort **Examples:** "*I feel more tired after using technology for so long."* (S85); *"It's useful, but it should never completely replace physical or in-person materials*." (S89)

Techno-anxious-addicted	**Positive perception**	• Necessary for professional development • Facilitate academic work **Example:** "*For my career, translation, they are completely necessary for our professional future.*" (S91); *"It's really a great help and makes the job easier..."* (S92)
	Negative perception	• Concern about future availability • Discomfort in use **Examples:** "*The impermanence and future availability*" (S94); *"(...) its use sometimes drives you a little crazy*" (S92)
Techno-anxious-fatigued-addicted	**Positive perception**	• Facilitate academic work • Accessibility and flexibility • Facilitate communication **Examples:** *"The use of technology during studies is very useful because it saves paper, space, and weight... It also allows quick* communication with professors and classmates." (S97); *"Technological resources are very good because they facilitate the work and are accessible."* (S102)
	Negative perceptions	• Physical and visual fatigue • Dependence on technology • Technical and connection issues • Anxiety • Frustration **Examples:** *"I feel that they take a lot of my energy and my eyes get tired, in fact, I've started wearing glasses because of it."* (S100); *"Creating dependency on technology is very easy, we literally just finished studying or taking notes, meaning 2 or 3 hours in front of the computer, and right after we pick up the phone..."* (S105)

Students with a techno-addict profile highlight the educational benefits of using ICT, such as increased accessibility to resources and improved communication and collaboration. However, they also acknowledge the negative aspects, such as privacy issues, information overload, excessive use of technology, mental and physical fatigue, distractions, and decreased concentration.

Students with a techno-anxious-fatigued profile combine positive perceptions, such as ease and efficiency, with concerns about technology replacing traditional methods and encouraging passive learning. They also report experiencing mental and physical fatigue due to excessive use.

Students with a techno-anxious-addicted profile recognise the usefulness of technology for academic and professional tasks, but express concerns about its impermanence, the constant need to adapt to new ICT, and the uncertainty regarding its future availability. Those students in the techno-anxious-fatigued-addicted profile appreciated the positive role of ICT in facilitating academic tasks, enhancing accessibility, and improving communication.

At the same time, they were aware of the potential negative impacts including performance disruption due to technical failures or connectivity issues, increased information overload, technological dependence, visual fatigue, anxiety, and frustration.

As shown in Table 4 (see next page), students' reported difficulties with technology vary according to their technostress profiles. Students with a techno-fatigued profile primarily emphasised the need for additional training, citing a lack of proficiency in specific software tools. They also reported experiencing information overload, which negatively affected their concentration. Similarly, students with a techno-addicted profile expressed frustration from not knowing how to use specific tools and being distracted by prolonged technology use. Additional difficulties included coping with constant system updates and restricted access to essential resources, often due to financial barriers or limited availability of devices.

TABLE 4. Categories by technostress profiles. What do you think are the reasons for the difficulties in using technologies?

Profile	Category	Description
Techno-fatigued	Training needs	• Lack of skills to use certain software programs. **Example:** *"I want everything done for me without having to read how to use a program correctly."* (S5)
	Information overload	• Feeling of saturation caused by excessive information. **Example:** "*Sometimes an excess of information causes me to lose focus."* (S5)
	Distractions	• Problems arising from lack of concentration due to technology. **Example:** *"Technologies cause me to lose focus."* (S5)
Techno-addict	Training needs	• Lack of knowledge to use specific technological tools. **Example:** *"We haven't been taught how to use them."* (S12); *"I lack training in specific programs, in general."* (S8); *"Little knowledge about their use, learning in a self-taught way."* (S66)
	Information overload	• Feeling of saturation caused by excessive information and excessive usage time. **Example:** *"Sometimes they overwhelm me a bit."* (S39); *"The distraction from the original focus as time goes on."* (S81).
	Constant updates	• Difficulty adapting to technological advancements, such as artificial intelligence. **Example:** *"The constant changes in technology, lately it happens to me with artificial intelligence."* (S40)
	Distractions	• Problems arising from lack of concentration or distraction when using technologies. **Example:** *"The distraction from the original focus as time passes."* (S81); *"I waste time with different platforms, etc."* (S63)
	Lack of access to specific resources	• Limitations due to the absence of programs, licenses, or necessary educational resources. **Example:** "*I need specific qualitative analysis programs, but I don't have access to them because the university doesn't pay for the license.*" (S34); *"Sometimes it's not easy to access them because they require subscriptions."* (S68)
Techno-anxious-fatigued	Training needs	• Lack of knowledge and skills to use software programs. **Example:** *"I struggle when I don't have a good grasp of programs."* (S84); *"The little training on programs that are constantly updated."* (S85); *"Anxiety due to insecurity about participating in something I don't know."* (S87)
	Constant updates	• Difficulty adapting to the constant technological evolution. **Example:** "*To the constant evolution of them."* (S88)
	Lack of interest in technology	• Lack of motivation to use technology. **Example:** *"Due to a lack of interest in technology and its use."* (S86); *"Low usage."* (S91)
Techno-anxious-addict	Technical problems	• Problems with the functionality of technological tools. **Example:** *"Sometimes, especially in career-specific apps, the interfaces* are very old and hard to understand." (S92)
	Technological distrust	• Technology facilitates academic work, but some users express distrust toward its use. **Example:** *"I feel distrust toward them, and it biases me when interacting with them."* (S95)
Techno-anxious-fatigued-addict	Training needs	• Lack of knowledge and skills to use technologies, and lack of information. **Example:** *"Lack of technological skills."* (S99); *Lack of formation."* (S110)
	Constant updates	• Difficulty adapting to rapid technological changes. **Example:** *"Lately everything moves so fast, and we can't fully adapt."* (S109)

Students classified under the techno-anxious-fatigued profile described increased anxiety when using unfamiliar programs and difficulties in adapting to frequent updates. This, combined with a lack of interest, leaded to reduced motivation to use technology.

Students within the techno-anxious-addicted profile reported technical issues, such as software malfunctions and outdated interfaces, along with a general mistrust of technology.

Finally, those in the techno-anxious-fatigued-addicted profile identify a lack of digital knowledge and skills as the main source of difficulty, further intensified by the ongoing need to adapt to constant technological updates.

4. DISCUSSION

This study adopted a mixed-method approach to provide a comprehensive understanding of the impact of technology on Spanish university students, addressing three research questions.

Regarding RQ1, our findings lead to a twofold conclusion. On the one hand, approximately half of the sample met the full criteria for at least one technostress profile, indicating that one in two students experienced some form of technostress. It is worth noting that this figure only includes those who fully met the criteria and does not account for the students who scored high or moderately high on individual dimensions and may be a risk. These prevalence results are consistent with previous studies. For instance, Suria (2023) reported that 53.9% of student presented high levels of technostress.

On the other hand, although previous research has attempted to classify technostress profiles (Díaz-López et al., 2020; Ficapal-Cusí et al., 2024; Rosa et al., 2025), none have proposed a categorisation as comprehensive as the one presented here, which conceptualises technostress as a mixed experience from the student perspective. Our study identified seven different profiles: three "pure" types (Techno-anxious, Techno-fatigued, and Techno-addicted) and four mixed types (Techno-anxious-fatigued, Techno-anxious-addicted, Techno-fatigued-addicted, and Techno-anxious-fatigued-addicted).

These results are in line with the three theoretical premises guiding this research. First, the identification of mixed profiles reinforces the idea that technostress is not a unidimensional phenomenon but rather a co-occurrence of states such as anxiety, fatigue, and compulsive technology use. This is supported by previous findings showing significant correlations between anxiety and fatigue (Kim & Kang, 2017; van Dam, 2016; Villanueva Ramírez et al., 2023) and by evidence suggesting a reciprocal relationship between anxiety and technology-related addictions (Fekih-Romdhane et al., 2023).

Second, the diversity of profiles may reflect differences in domain-specific self-efficacy, which, according to Social Cognitive Theory (Bandura, 1997), shapes how individuals perceive and respond to technological demands. As shown by Levante et al. (2025) and Chang et al. (2024), specific types of self-efficacy, such as efficacy for online teaching or technical problem-solving, can buffer the emotional impact of technostress and influence whether stressors are interpreted as challenges or hindrances.

Third, the coexistence of emotional and behavioural patterns within profiles is consistent with the transactional model of stress (Lazarus & Folkman, 1984), which posits that stress results from the interaction

between perceived demands and coping resources. This framework helps explain how students may simultaneously engage in emotion-focused coping (e.g., avoidance, frustration) and problem-focused coping (e.g., compulsive use to meet academic requirements), supporting the notion of technostress as a dynamic and multidimensional experience (Sharma & Gupta, 2023).

Concerning RQ2, although the literature consistently reports a positive association between technostress and burnout (Galvin et al., 2022), our data showed that burnout did not significantly differentiate between the identified technostress profiles. This may be because burnout reflects a broader and more long-term outcome of technostress (Li, 2025; Llorens et al., 2007). As noted by Nastjuk et al. (2023), psychological responses to technostress tend to emerge earlier, while behavioural outcomes such as burnout require prolonged exposure. From a methodological perspective, the instrument used (MBI-SS) may have lacked the sensitivity to detect subtle profile differences, particularly in a sample with low variability. Recent work has shown that broader tools like the Burnout Assessment Tool (BAT) provide more comprehensive coverage of burnout dimensions (Schaufeli et al., 2020). While recent studies have explored technostress (Ficapal-Cusí et al., 2024; Rosa et al., 2025) and burnout profiles (Boone et al., 2022), integrated approaches remain rare. Finally, individual factors such as digital self-regulation (Hromalik & Koszalka, 2018) or personality traits (Pflügner et al., 2021) may further shape how technostress and burnout are experienced.

Finally, RQ3 revealed varied perceptions regarding ICT use across different techno-stress profiles. Although the more integrative profiles (i.e., those including multiple dimensions of technostress) shared some perceptions, students' views showed meaningful differences. Those with a techno-fatigue recognised technology benefits in areas such as mathematical calculations, teaching, and communication, but highlighted difficulties including lack of software training and information overload. Prolonged digital device exposure caused mental and visual fatigue along with concentration difficulties. These findings align with research showing that information overload can induce "information fatigue," affecting cognitive processing and potentially leading to anxiety and reduced decision-making quality (Ji, 2023), while negatively impacting academic performance and creating burnout (Subramanyam et al., 2013).

Students with techno-anxious-fatigued profiles expressed exhaustion from constant ICT use and concerns about technology replacing traditional teaching methods, potentially fostering passive learning attitudes. Their lack of interest combined with insecurity from unfamiliarity with certain programs aligns with research highlighting digital skills deficiency as a key obstacle to digital transformation (Ala-Mutka, 2011). Mental fatigue further affects willingness to learn new digital tools (Müller et al., 2021).

In contrast, techno-addiction students expressed a more negative view of excessive technology use. While acknowledging ICT benefits in education, they identified problems like information overload leading to mental and physical fatigue, and distractions (Aziz et al., 2024). Students with a techno-anxious-addicted profile perceived that excessive ICT use and adaptation to technological innovations causes anxiety. This constant need for updates and compulsive technology use aligns with the techno-addict profile characteristics (Llorens et al., 2011). Similarly, research with higher education teachers found excessive classroom technology led to technological fatigue and stress from adapting to constant digital tool changes (Halupa & Bolliger, 2020).

Lastly, students with a combined profile of techno-fatigued-addicted perceived both positive and negative aspects, as seen in the previous profiles, with particular emphasis on visual fatigue caused by excessive

ICT use. Previous studies have shown that prolonged digital screen exposure can trigger symptoms including eye strain, dry eyes, and headaches (Halim et al., 2024).

5. CONCLUSIONS

This study provides an innovative perspective on technostress among university students by identifying seven distinct profiles based on combinations of anxiety, fatigue, and technological addiction. These profiles reflect not only varying degrees of discomfort but also differences in emotional appraisal and coping processes, suggesting that technostress is not a homogeneous experience but rather a diverse and context-dependent phenomenon (Lazarus & Folkman, 1984; Sharma & Gupta, 2023).

Unlike previous studies that have focused on more general approaches (Díaz-López et al., 2020; Ficapal-Cusí et al., 2024; Rosa et al., 2025), this work adopts a person-centered approach by combining quantitative analysis with a qualitative exploration that directly incorporates students' voices. This mixed-methods strategy allows for a deeper understanding not only of the impact of technostress but also of how students perceive and experience it, thereby enhancing both the ecological validity and practical relevance of the findings.

From an applied perspective, the results underscore the importance of designing targeted interventions tailored to each identified profile. For instance, students with techno-anxious or techno-fatigued profiles may benefit from socio-emotional development programs, while those with a techno-addicted profile may require interventions focused on digital time management and the promotion of healthy digital habits (Llorens et al., 2011).

At the institutional level, these findings may inform the design of personalised training strategies and support policies aimed at mitigating the effects of technostress on students' academic experiences. In this regard, the literature supports the implementation of a comprehensive techno-pedagogical approach that not only facilitates the effective integration of technology into educational settings but also promotes robust digital competence training. Such interventions have been shown to enhance academic performance and significantly reduce levels of techno-anxiety (Martínez-Márquez et al., 2025; Muñoz et al., 2017).

Moreover, the need to foster a more conscious, balanced, and healthy use of digital technologies is emphasised. This includes practices such as taking regular breaks, limiting screen time, and engaging in critical reflection on digital habits. Adopting these practices may help prevent mental and visual fatigue and contribute to students' overall well-being. These findings could inform the implementation of concrete actions within university psychological and academic counselling services, aimed at creating more sustainable and student-centred learning environments.

Taken together, this study reinforces the importance of addressing technostress through a comprehensive and multidimensional lens that simultaneously considers personal, emotional, and contextual factors. The implications of this research open new avenues for the development of more inclusive, preventive, and responsive educational policies, aligned with the evolving demands of increasingly digitalised academic environments.

5.1. Limitations and Future Research

Some limitations of the present study should be noted. First, a convenience sample was used, which might restrict the generalisability of these findings. However, the sample is heterogeneous because it includes students from different universities, fields of study, and degrees. Second, sample size could be considered small, especially when participants need to be classified into profiles; therefore, future research should use larger sample to replicate the findings. Third, data were collected from self-report measures, which might have caused common method variance bias. However, considering the nature of the psychological experiences evaluated (i.e., technostress, student burnout), it is difficult to employ other measures (e.g., objective). Finally, although our research focused on documenting technostress profiles and the relation with student burnout and perceptions of the use of ICT during their studies, future research should examine other discriminant variables such as sociodemographic (e.g., age differences, Tomczyk et al., 2023), psychological (e.g., Psycap, Peñalver et al., 2024), and physical (e.g., biomarkers, Mishra & Rašticová, 2024).

6. AUTHOR CONTRIBUTION

Author 1: Conceptualization, Data curation, Supervision, Formal analysis, Methodology, Investigation, Writing – original draft, Writing – review & editing. Author 2: Data curation, Formal analysis, Writing – original draft, Writing – review & editing. Author 3: Data curation, Investigation. Author 4: Data curation, Writing – original draft, Writing – review & editing.

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Efectos de un entorno de aprendizaje de programación de computadores basado en el desarrollo de videojuegos sobre la motivación por aprender de los estudiantes

Effects of a Computer Programming Learning Environment Based on Video Game Development on Student's Learning Motivation

RECIBIDO 07/02/2025 ACEPTADO 09/04/2025 PUBLICADO 01/12/2025

Manuel Alejandro Peña Vargas
ORCID: 0009-0009-4961-4605
Universidad Nacional de Colombia, Colombia
mapenav@unal.edu.co

Luis Alejandro Mongua López
ORCID: 0009-0006-3652-0958
Universidad Nacional de Colombia, Colombia
lamongual@unal.edu.co

Jhon Jairo Ramírez-Echeverry
ORCID: 0000-0002-6499-1785
Universidad Nacional de Colombia, Colombia
jjramireze@unal.edu.co

Felipe Restrepo-Calle
ORCID: 0000-0003-4226-1324
Universidad Nacional de Colombia, Colombia
ferestrepoca@unal.edu.co

Jairo Hernán Aponte Melo
ORCID: 0000-0002-5339-896X
Universidad Nacional de Colombia, Colombia
jhapontem@unal.edu.co

RESUMEN

El presente estudio aborda la evaluación de los efectos del aprendizaje basado en el desarrollo de videojuegos (Game Development-Based Learning, GDBL) en la motivación de los estudiantes para aprender programación de computadores en un curso de Programación Orientada a Objetos (POO). Inicialmente, se llevó a cabo un proceso de selección de un Game Development Framework (GDF) que tuviera un enfoque académico y un rendimiento adecuado, seleccionando Python Arcade. Posteriormente, se diseñó una intervención educativa adaptando el cronograma y los materiales del curso para

implementar un ambiente de aprendizaje basado en GDBL. El estudio se realizó mediante un enfoque explicativo secuencial mixto, con la participación de 33 estudiantes. La motivación de los estudiantes se caracterizó cuantitativamente mediante el cuestionario MSLQ-Colombia antes y después de la intervención, y cualitativamente a través de una encuesta de percepción aplicada al final del curso. Aunque el análisis cuantitativo no mostró cambios significativos en la motivación, el análisis cualitativo reveló efectos en la motivación intrínseca, el control del aprendizaje, las expectativas de autoeficacia y una reducción de la ansiedad. No obstante, algunos participantes indicaron limitaciones del GDBL, entre ellas, que no lograron percibir su aplicabilidad en diversos ámbitos de la programación de computadores. Los estudiantes otorgaron una valoración positiva en lo que respecta al diseño del juego, la personalización y el producto final. Estos hallazgos apuntan a la potencialidad del GDBL en el fortalecimiento de los aspectos motivacionales y la promoción de la autonomía en el proceso de aprendizaje. Se recomienda que en futuras investigaciones se ponga especial cuidado a la integración que se haga del GDBL dentro del currículo y se compare con métodos tradicionales para evaluar su eficacia.

PALABRAS CLAVE aprendizaje basado en el desarrollo de videojuegos, motivación en el aprendizaje, aprendizaje de la programación de computadores, aprendizaje autorregulado

ABSTRACT

The present study assesses the effects of Game Development-Based Learning (GDBL) on students' motivation to learn computer programming in an Object-Oriented Programming (OOP) course. Initially, a selection process of a Game Development Framework (GDF) that had an academic focus and adequate performance was carried out, selecting Python Arcade. Subsequently, an educational intervention was designed by adapting the course schedule and materials to implement a GDBL-based learning environment. The study employed a mixed sequential explanatory approach, with the participation of 33 students. The quantitative analysis of student motivation was conducted using the MSLQ-Colombia questionnaire, administered before and after the intervention, while the qualitative analysis was facilitated through a perception survey administered at the conclusion of the course. While the quantitative analysis revealed no significant changes in motivation, the qualitative analysis indicated effects on intrinsic motivation, learning control, self-efficacy expectations, and a reduction in anxiety. However, some participants indicated limitations of the GDBL, including a perceived lack of applicability in various areas of computer programming. Conversely, students expressed satisfaction with aspects such as game design, customization, and the final product. These findings suggest that GDBL has the potential to enhance motivational aspects and promote autonomy in the learning process. It is recommended that future research attention be paid to the integration of GDBL within the curriculum and compare it with traditional methods to evaluate its effectiveness.

KEYWORDS Game Development-Based Learning (GDBL), Learning Motivation, Computer Programming Learning, Self-Regulated Learning

1. INTRODUCCIÓN

La programación de computadores es esencial en múltiples disciplinas, aumentando la demanda de profesionales en este campo. Esta tendencia ha llevado a que diversos programas universitarios, incluso fuera de la ingeniería de computación, incluyan cursos de programación (Abidin & Zaman, 2017; Otake & Uetake, 2017). En estos cursos, los estudiantes enfrentan desafíos como la comprensión de problemas, la aplicación de conocimientos teóricos, la descomposición de tareas, la codificación y el ajuste de soluciones (Martins et al., 2018). Sin embargo, la complejidad de este proceso y las competencias requeridas generan dificultades que reducen la motivación, incrementan la frustración y pueden afectar el rendimiento académico o provocar el abandono (Azmi et al., 2017; Waweru et al., 2020). En particular, la desmotivación limita la

adquisición de habilidades clave como lógica de programación, pensamiento algorítmico, resolución de problemas y comprensión de conceptos abstractos, reflejándose en resultados insatisfactorios (Otake & Uetake, 2017).

Para abordar estos desafíos, la investigación educativa en ingeniería ha adoptado estrategias didácticas y entornos de aprendizaje que mejoren la enseñanza de la programación (Amro & Romli, 2019; Malik et al., 2020; Piteira et al., 2017). Destaca el uso de herramientas cercanas a los estudiantes, como los videojuegos, adoptando el desarrollo o modificación de éstos como recurso didáctico. Esta estrategia es conocida como Game Development-Based Learning (GDBL) (Wu & Wang, 2012). Algunos estudios indican que el GDBL mejora la motivación estudiantil (Torres-Toukoumidis et al., 2020), facilita la visualización de beneficios a largo plazo de la programación, incluso en términos profesionales (Kafai & Burke, 2015), y fomenta competencias transversales como pensamiento crítico, trabajo en equipo y conocimiento interdisciplinario (Sevilla et al., 2012). En contextos educativos de otras áreas de conocimiento también se ha encontrado que el desarrollo de videojuegos tiene efectos positivos en diversas competencias transversales relevantes para el aprendizaje integral de los estudiantes. La creatividad se ve significativamente impulsada, ya que el diseño de juegos exige la generación de ideas originales en la narrativa, la mecánica y los elementos visuales y sonoros (Pala, 2024). Asimismo, el proceso de creación involucra el desarrollo del pensamiento crítico al requerir la resolución de problemas técnicos y de diseño, la toma de decisiones y la evaluación constante del prototipo (González & Álvarez, 2022; Pala, 2024). La alfabetización tecnológica también se fortalece de manera inherente, abarcando desde la comprensión de principios digitales hasta el manejo de herramientas de desarrollo, incluyendo potencialmente aplicaciones de video y escritura (Pala, 2024). Además, el trabajo colaborativo que a menudo implica el desarrollo de videojuegos fomenta la comunicación y la colaboración entre los participantes (González & Álvarez, 2022; Kapoor & Sohi, 2024; Pala, 2024). Finalmente, la necesidad de planificar, ejecutar y probar el videojuego contribuye al desarrollo de la autonomía y la capacidad de gestión de proyectos (Pala, 2024).

Sin embargo, a pesar del potencial de GDBL falta evidencia empírica sobre su impacto en el aprendizaje de programación de computadores (Bewer & Gladkaya, 2022). La literatura es aún limitada, dificultando una comprensión completa de sus beneficios y limitaciones (de A. Souza et al., 2018; Kafai & Burke, 2015). En este sentido, de A. Souza et al. (2018) subrayan la necesidad de más estudios sobre sus efectos educativos y Kafai y Burke (2015) advierten que la escasez de investigaciones empíricas limita los hallazgos disponibles y la fundamentación de enfoques específicos. En consecuencia, consolidar el GDBL como estrategia de enseñanza requiere más estudios que optimicen sus técnicas de aplicación (Bewer & Gladkaya, 2022). Kafai y Burke (2015) destacan la importancia de investigar el diseño de juegos, el trabajo colaborativo, las aplicaciones en línea y el impacto del GDBL en distintos contextos, considerando factores como motivación, edad de los estudiantes y tiempo de uso de las herramientas.

Para contribuir con evidencia empírica sobre el GDBL, este estudio analiza sus efectos en la motivación estudiantil dentro de un entorno de aprendizaje de programación basado en la construcción de videojuegos. La motivación es clave en el aprendizaje, pues influye en el compromiso, la persistencia, la confianza y el rendimiento académico (Fincher & Robins, 2019). No obstante, los métodos tradicionales han mostrado un impacto limitado en la motivación (Sugano & Manolo, 2021). Se espera que un entorno basado en GDBL

fomente la motivación en el aprendizaje de la programación (Corvalán et al., 2020). A partir de ello, surge la pregunta de investigación: ¿Cuál es el efecto de un entorno de aprendizaje de programación de computadores basado en la construcción de videojuegos (GDBL) sobre la motivación de los estudiantes?

2. MARCO CONCEPTUAL

2.1. Motivación por aprender

La teoría constructivista del aprendizaje enfatiza la construcción y refinamiento de modelos mentales a través de la experiencia, promoviendo un aprendizaje activo y autónomo mediante la observación, repetición y práctica (Kafai & Burke, 2015). Este enfoque sostiene que la motivación del estudiante es clave para lograr la autorregulación del aprendizaje (Self-Regulated Learning, SRL). Aunque establecer metas y monitorear el progreso es responsabilidad del estudiante (Zimmerman, 2002), la autorregulación depende de entornos que fomenten la motivación para activar este proceso autónomo (Sugano & Manolo, 2021).

La motivación para aprender comprende factores psicológicos que favorecen el compromiso y la perseverancia (Fincher & Robins, 2019). Es central en el aprendizaje, pues integra la autoeficacia percibida, el valor asignado a las tareas y aspectos afectivos, como la ansiedad ante evaluaciones (Gopalan et al., 2020). Por lo tanto, no es un elemento aislado, sino un conjunto de metas, deseos y creencias personales que interactúan en el aprendizaje. La teoría de la autorregulación (Pintrich & de Groot, 1990) define sus componentes: (i) valoración de la tarea (importancia, utilidad e interés atribuidos); (ii) orientación hacia metas intrínsecas (deseo genuino de aprender); (iii) orientación hacia metas extrínsecas (aprendizaje por razones externas); (iv) expectativas de autoeficacia en el aprendizaje (confianza en la capacidad de aprender); (v) expectativas de autoeficacia en el rendimiento (confianza en el éxito en evaluaciones); (vi) creencias de control sobre el aprendizaje (atribución del éxito al esfuerzo personal); y (vii) ansiedad ante evaluaciones (grado de nerviosismo o preocupación) (Pintrich & de Groot, 1990).

Además, investigaciones recientes sugieren una estrecha relación entre el pensamiento crítico y el aprendizaje autorregulado en entornos digitales. Denoni Buján y Cebollero Salinas (2025) encontraron que las competencias en línea pueden favorecer la disposición al pensamiento crítico de los estudiantes universitarios. Dado que el aprendizaje autorregulado implica la capacidad de evaluar y seleccionar información relevante, así como de interactuar con otros de manera efectiva, el desarrollo del pensamiento crítico se convierte en un componente esencial para promover un aprendizaje autónomo y motivado en entornos de aprendizaje basado en el desarrollo de juegos.

2.2. Game Development-Based Learning (GDBL)

La estrategia educativa basada en videojuegos se fundamenta en el constructivismo, considerando que la participación activa del estudiante en la creación de recursos facilita el aprendizaje y profundiza la comprensión de las herramientas tecnológicas, sus propósitos y aplicaciones (Kafai, 2006). Desde esta perspectiva surge el aprendizaje basado en desarrollo de juegos (GDBL, Game Development Based Learning), cuyo

objetivo es que los estudiantes adquieran habilidades mediante la creación o modificación de videojuegos en entornos audiovisuales (Wu & Wang, 2012). El GDBL emplea herramientas visuales, dinámicas y elementos narrativos para fomentar la formulación de problemas y el desarrollo de soluciones (Chiazzese et al., 2018), permitiendo abordar múltiples temáticas y brindando exposición directa a los ciclos de desarrollo en programación (de A. Souza et al., 2018). Además, sitúa a los estudiantes en un rol activo en la ejecución de proyectos, lo que facilita el aprendizaje de programación, especialmente en principiantes (Serrano-Laguna et al., 2015). Estudios señalan que el GDBL promueve estudiantes más activos, favoreciendo la autorregulación del aprendizaje, con una gestión del tiempo más eficiente, mayor interacción social y mejores resultados académicos (Mayo, 2007; Kafai, 2006; Kafai & Burke, 2015; Wang & Wu, 2009).

Investigaciones adicionales evidencian que la construcción de videojuegos potencia la motivación, la exploración y la expresión personal (Bewer & Gladkaya, 2022; Torres-Toukoumidis et al., 2020; Wu & Wang, 2012). Específicamente, se ha encontrado que el GDBL influencia positivamente los diferentes elementos constitutivos de la motivación por aprender: la valoración de la tarea por el interés que suscita el diseño y desarrollo de videojuegos, así como por la utilidad percibida al adquirir conocimientos y habilidades de manera práctica y creativa (Wu & Wang, 2012). La naturaleza motivadora de los juegos digitales (González & Álvarez, 2022) debido al entusiasmo que despiertan en los estudiantes fomentan una orientación hacia metas intrínsecas, impulsando un deseo genuino de aprender a través de la creación de videojuegos (Wu & Wang, 2012). Aunque la orientación hacia metas extrínsecas no es el foco principal, la posibilidad de obtener resultados tangibles y la presentación de proyectos pueden generar motivación externa. Las expectativas de autoeficacia en el aprendizaje se fortalecen al permitir a los estudiantes construir productos significativos y experimentar el aprendizaje de forma activa y autodirigida (Wu & Wang, 2012), mientras que las expectativas de autoeficacia en el rendimiento pueden aumentar al visualizar los juegos desarrollados como evidencia concreta de sus capacidades (Wu & Wang, 2012). Las creencias de control sobre el aprendizaje se ven favorecidas por la participación activa en el diseño y la capacidad de tomar decisiones durante el proceso de desarrollo (Pala, 2024). Finalmente, el enfoque lúdico y creativo del GDBL podría potencialmente disminuir la tensión asociada a los procesos de evaluación del aprendizaje tradicional.

En la discusión sobre los beneficios del GDBL, es importante considerar las ventajas que los videojuegos aportan a la educación en diferentes niveles. Mielgo-Conde et al. (2022) realizaron una revisión sistemática que destaca cómo los videojuegos en la educación primaria favorecen la atención, la concentración y la resolución de problemas. Además, Pala (2024) examinó el impacto del uso de juegos digitales en el aprendizaje de historia en la educación secundaria. Su estudio enfatiza la influencia positiva de los juegos en el éxito académico y el pensamiento creativo. Estos trabajos contextualizan aún más el impacto del GDBL, mostrando cómo los juegos pueden ser una herramienta efectiva para aumentar la motivación de los estudiantes.

3. MATERIALES Y MÉTODOS

Este estudio analizó los efectos de un entorno de aprendizaje de programación basado en el desarrollo de videojuegos (variable independiente) sobre la motivación por aprender de los estudiantes (variable dependiente). Para ello, se diseñó un estudio de caso con estudiantes de una asignatura centrada en la enseñanza y aplicación de fundamentos de programación, incorporando GDBL en la metodología.

3.1. Participantes

El estudio involucró a 33 estudiantes de la asignatura Programación Orientada a Objetos (POO), impartida en modalidad remota en el periodo 2023-2 en la Universidad Nacional de Colombia - Sede Bogotá. La asignatura se desarrolló en dos sesiones semanales de 6:00 a 8:00 a.m. durante 16 semanas. Este curso teórico-práctico aborda temáticas básicas de programación de computadores que pueden aplicarse, entre otras, al diseño y desarrollo de videojuegos. La selección de los participantes de este estudio se realizó mediante un muestreo no aleatorio por conveniencia, debido a que los estudiantes que participaron inscribieron la asignatura de manera autónoma en función de sus intereses particulares, por ejemplo, la conveniencia de horario. Además, se adoptó un diseño de estudio de caso debido a la imposibilidad de contar con una muestra más amplia que permitiera, por ejemplo, un diseño cuasiexperimental con grupos de control y experimental. A pesar de que este tipo de diseño de investigación limita la posibilidad de extrapolar los resultados a otros contextos, los hallazgos aportan evidencia empírica relevante y establecen bases para futuras investigaciones.

Los participantes se distribuyeron en: 14 de ingeniería industrial (42.4 %), 9 de ingeniería de sistemas y computación (27.3 %), 5 de ingeniería mecatrónica (15.2 %) y 5 de ingeniería electrónica (15.2 %). La edad promedio fue de 22 años; 26 eran hombres (79 %) y 7 mujeres (21 %).

3.2. Instrumentos de caracterización

El estudio siguió un diseño mixto secuencial explicativo [QUAN → qual]. Se recolectaron datos cuantitativos (QUAN) mediante el cuestionario de autoinforme MSLQ-Colombia para caracterizar la motivación por aprender (Ramírez-Echeverry et al., 2016). Luego, se obtuvieron datos cualitativos (qual) a través de una encuesta con preguntas abiertas, enfocadas en explorar la motivación, la experiencia educativa de los estudiantes en el ambiente de aprendizaje basado en GDBL y la retroalimentación sobre dicho entorno.

3.2.1. MSLQ-Colombia

El *Motivated Strategies for Learning Questionnaire (MSLQ),* desarrollado por Pintrich et al. (1991) y validado para Colombia por Ramírez-Echeverry (2017), es una herramienta ampliamente utilizada para evaluar la motivación y las estrategias de aprendizaje. Su versión colombiana, MSLQ-Colombia, consta de 75 ítems organizados en dos escalas: motivación y estrategias de aprendizaje, con respuestas en una escala Likert de siete puntos (1-7), que reflejan el nivel de competencia en cada estrategia. Este estudio empleó los 30 ítems de la escala de motivación, definida en el marco de la teoría de autorregulación del aprendizaje.

El MSLQ-Colombia evalúa siete aspectos de la motivación: (1) Valoración de la tarea: percepción de utilidad, importancia e interés del contenido; (2) Metas intrínsecas: motivación impulsada por curiosidad y deseo de aprender; (3) Metas extrínsecas: enfoque en logros externos como calificaciones o reconocimientos; (4) Autoeficacia en el rendimiento: confianza en el éxito en evaluaciones; (5) Autoeficacia en el aprendizaje: percepción de competencias para aprender; (6) Control de aprendizaje: reconocimiento del esfuerzo personal en el aprendizaje; y (7) Ansiedad: niveles de preocupación y nerviosismo en evaluaciones.

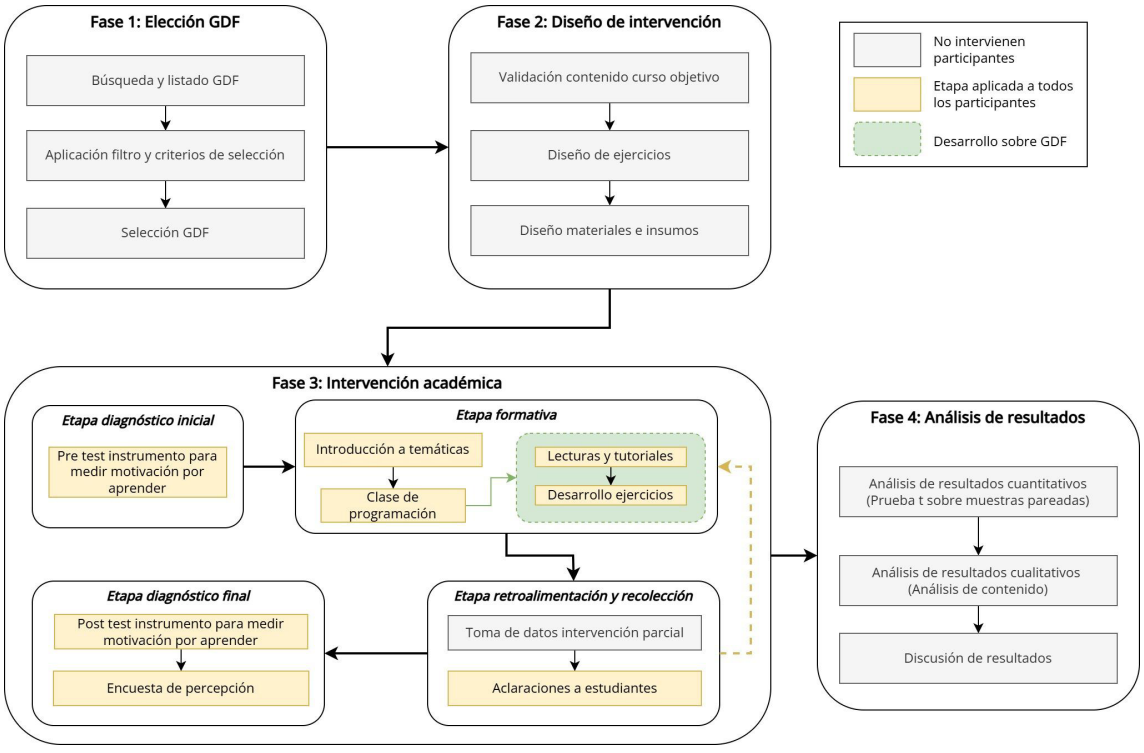
3.2.2. Encuesta de percepción

La encuesta abordó tres áreas: (1) Motivación por aprender, con 14 preguntas: 7 en escala Likert sobre los mismos aspectos motivacionales del MSLQ y 7 abiertas para justificar las respuestas; (2) Elementos del desarrollo de videojuegos, donde los estudiantes evaluaron diseño gráfico, narrativa, personalización, mecánicas de juego y el producto final; y (3) Retroalimentación, solicitando sugerencias para mejorar la estrategia educativa. Antes de responder, los estudiantes recibieron información sobre el propósito del estudio, firmaron un consentimiento informado y se garantizaron acuerdos de confidencialidad. Las preguntas específicas pueden consultarse en este enlace.

3.3. Metodología del estudio

Con base en Wang y Wu (2009) y Wu y Wang (2012), se plantearon cuatro fases para realizar este estudio (ver Figura 1).

FIGURA 1. Metodología del diseño del estudio



3.3.1. Fase 1: elección del Game Development Framework (GDF)

Los entornos de desarrollo de videojuegos (Game Development Framework, GDF) son herramientas para crear videojuegos, cuya complejidad varía desde bibliotecas y paquetes en lenguajes de programación hasta entornos multipropósito que soportan animaciones, gráficos y audio para desarrollo profesional. Los enfoques GDBL suelen emplear GDF existentes (Bewer & Gladkaya, 2022; Kafai & Burke, 2015; Serrano-Laguna

et al., 2015). Bewer y Gladkaya (2022) clasifican los GDF en tres tipos según su complejidad: sin código (e.g., Construct 2), basados en bloques (e.g., Scratch, Blocky, Game Salad) y basados en texto (e.g., Unity, libGDX, Java ME SDK). Además, indican que los estudiantes de secundaria rinden mejor en entornos basados en bloques, mientras que, en educación superior, algunos destacan con lenguajes basados en texto, dependiendo de su experiencia previa y la complejidad del curso.

Dado lo anterior, la selección del GDF requiere un análisis riguroso para implementar estrategias GDBL efectivas. Wu y Wang (2012) proponen tres pasos: (1) identificación de herramientas candidatas, (2) análisis de características y (3) aplicación de criterios de selección. En este estudio, se identificaron 16 herramientas con las características mostradas en la Tabla 1 y, con base en Bewer y Gladkaya (2022), se definieron ocho criterios para la selección del GDF más adecuado:

1. **Tipología:** basado en texto.
2. **Entorno de desarrollo:** flexible para múltiples géneros de videojuegos.
3. **Lenguaje de programación:** compatible con Python.
4. **Dificultad/conocimiento:** dificultad media-baja de aprendizaje y/o conocimiento requerido, orientado a PC.
5. **Restricciones:** alineado con objetivos académicos, sin limitaciones de género de videojuego.
6. **Versión:** versiones recientes con soporte activo.
7. **Documentación:** calidad evaluada en una escala de 0 a 4, considerando detalle de métodos, guías de implementación, ejemplos y enfoque académico.
8. **Acceso:** gratuito y funcional en hardware de gama baja.

TABLA 1. Matriz comparativa de los GDF candidatos para usar en el estudio

GDF	Tipología	Entorno de desarrollo	Lenguaje	Dificultad/ Conocimiento	Restricciones	Versión	Documentación	Acceso
Unity	Text-based	IDE	C#	Avanzado/ Alta	-	2023	3	Gratuito
Unreal engine	Text-based	IDE	C++	Avanzado/ Alta	-	2023	3	Gratuito
Cryengine	Text-based	IDE	C++	Avanzado/ Alta	-	2020	3	Gratuito
Arduino	Text-based	IDE	C	Básico/Media	Dispositivos arduino	2023	2	Gratuito
Java ME SDK	Text-based	SDK	Java	Básico/Media	-	2023	2	Gratuito
SFML	Text-based	Librería	Java, Ruby, Python, GO, C++, C, .net	Básico/Baja	-	2022	3	Gratuito
libGDX	Text-based	Librería	Java	Básico/Baja	-	2022	3	Gratuito
Impact.js	Text-based	Librería	Javascript	Básico/Baja	-	2014	3	Gratuito

GDF	Tipología	Entorno de desarrollo	Lenguaje	Dificultad/ Conocimiento	Restricciones	Versión	Documentación	Acceso
Phaser	Text-based	Librería	Javascript	Básico/Baja	-	2023	3	Gratuito
Python Arcade	Text-based	Librería	Python	Básico/Bajo	-	2023	4	Gratuito
Construct 2	Code-free	IDE	N/A	Básico/Media	-	2021	3	Pago
Blocky	Block-based	Web	N/A	Básico/Baja	Entorno web con solo 5 ejercicios	2023	2	Gratuito
Game Salad	Block-based	Web	N/A	Básico/Baja	-	2023	4	Pago
Scratch	Block-based	Web	N/A	Básico/Baja	-	2023	4	Gratuito
Alice	Block-based	IDE	Java	Básico/Baja	--	2014	3	Gratuito
Pygame	Text-based	Librería	Python	Básico/Baja	-	2023	3	Gratuito

Como resultado, se seleccionaron tres candidatos: Python Arcade, PyGame y SFML. Python Arcade mostró mejor rendimiento en pruebas de estrés (Craven, 2023), superando a PyGame en eficiencia de renderizado y destacando por su documentación educativa, como “Arcade Academy”. SFML fue descartado por su dependencia de C++ y escasa documentación educativa. Así, Python Arcade fue elegido por cumplir con los criterios establecidos, ofrecer un enfoque académico y garantizar alto rendimiento en el desarrollo de videojuegos. Python Arcade fue diseñado para crear juegos 2D en Python (Craven, 2023), usa Pyglet (Holkner, 2006) y OpenGL (Woo et al., 1999) para gráficos, sonido, entrada de usuario y colisiones, permitiendo crear juegos completos de forma eficiente. Su simplicidad, enfoque académico y accesibilidad consolidan su elección. En los siguientes enlaces se puede consultar más información: Python Arcade Library y Arcade Academy.

3.3.2. Fase 2: diseño de la intervención

En esta fase se diseñaron los ejercicios, materiales e insumos entregados a los estudiantes durante la intervención educativa, siguiendo las recomendaciones de Wu y Wang (2012) para implementar GDBL en el aula. Consta de tres pasos: (1) validación del contenido del curso, (2) diseño de ejercicios y (3) diseño de materiales e insumos. La intervención educativa se desarrolló en la asignatura POO de la Universidad Nacional de Colombia, estructurada en cinco módulos: (1) transición de lo imperativo a lo orientado a objetos, (2) introducción a la programación orientada a objetos, (3) relación entre clases, (4) herencia y polimorfismo e (5) interfaces gráficas de usuario. Se enfocó en los módulos 2, 3 y 4, que abarcan los fundamentos de la programación orientada a objetos, sin intervenir en el módulo 1 y con ajustes mínimos en el módulo 5. La implementación de GDBL se basó en talleres para la construcción progresiva de videojuegos. El diseño de la intervención educativa integró los contenidos de la asignatura y los talleres GDBL sin alterar la estructura académica original del curso. El cronograma aplicando GDBL estuvo alineado con las 16 semanas del curso, inició en la semana 3, tras completar el módulo 1, y se extendió hasta la semana 16 en

la que los estudiantes sustentaron sus proyectos finales. Las duraciones aplicando GDBL en cada módulo fueron: cinco semanas en el módulo 2, tres semanas en el módulo 3, cuatro semanas en el módulo 4 y tres semanas en el módulo 5.

El diseño de ejercicios y materiales se orientó a facilitar el aprendizaje y la implementación de GDBL, organizándose en dos categorías: (1) presentaciones y guías de clase y (2) recursos adicionales. Las presentaciones y guías abordaron semanalmente conceptos clave de programación orientada a objetos, como clases, objetos, abstracción, encapsulamiento, herencia y polimorfismo, con ejemplos prácticos y talleres. Estos progresaron desde la manipulación de elementos en Python Arcade hasta interacciones avanzadas de juego. También se incluyeron guías sobre buenas prácticas en Python y fundamentos de desarrollo de videojuegos, siempre vinculadas al aprendizaje de POO bajo GDBL. Además, se ofrecieron recursos para enriquecer el aprendizaje y facilitar el diseño de videojuegos: gráficos, audio, herramientas de apoyo y documentación/tutoriales. Los recursos gráficos y de audio permitieron animaciones y efectos, mientras que los de apoyo incluyeron constructores de mapas y selectores de color. La documentación y tutoriales contenían APIs, ejemplos y guías prácticas, ampliando las posibilidades creativas y fomentando un aprendizaje experiencial. Finalmente, se creó un repositorio en GitHub con ejemplos de POO aplicados al desarrollo de videojuegos con Python Arcade, facilitando el acceso a conceptos clave y herramientas prácticas. Los recursos diseñados están disponibles en este repositorio.

3.3.3. Fase 3: intervención académica

La intervención educativa, núcleo de la metodología, abarcó la recopilación de datos y la aplicación de instrumentos al grupo objetivo en cuatro etapas:

- **Caracterización inicial:** se aplicó el cuestionario MSLQ-Colombia como pre-test para evaluar la motivación estudiantil antes de la intervención. Se presentó el proyecto, destacando la importancia de mediciones pre y post intervención para garantizar objetividad. Se aclaró que las respuestas no influirían en las calificaciones y los estudiantes firmaron un consentimiento informado para garantizar la confidencialidad.
- **Formativa:** bajo un modelo incremental, se desarrollaron actividades en la asignatura de POO. Los estudiantes iniciaron modificando juegos existentes y progresaron hasta crear nuevos, tras una introducción a los conceptos de desarrollo de videojuegos y al GDF. La metodología combinó clases magistrales, prácticas, lecturas, tutoriales y ejercicios de cada tema.
- **Retroalimentación y recolección:** paralela a la etapa formativa, esta fase brindó seguimiento y retroalimentación para facilitar el uso del GDF y la adaptación al GDBL. Se recopilaron entregas y observaciones semanales, permitiendo ajustes continuos en el curso.
- **Diagnóstico final:** durante las semanas 13 y 14, se aplicó nuevamente el cuestionario MSLQ-Colombia como pos-test para evaluar la motivación tras la intervención, junto con una encuesta de percepción para recolectar datos cualitativos. Se reiteró la confidencialidad y la neutralidad de las encuestas respecto a las calificaciones.

3.3.4. Fase 4: análisis de resultados

El análisis de datos combinó enfoques cuantitativo y cualitativo. En el primero, se evaluaron cambios en la motivación de los estudiantes mediante la prueba de Wilcoxon en las siete subescalas del cuestionario MSLQ-Colombia, comparando pre y post intervención. De 33 estudiantes que completaron el pre-test, 26 participaron en el post-test.

Los datos cualitativos se estructuraron mediante análisis de contenido, en tres etapas: codificación abierta, axial y selectiva. La codificación abierta identificó conceptos y categorías iniciales; la axial estableció relaciones entre categorías y subcategorías, revelando patrones; y la selectiva integró y refinó las categorías en torno a un núcleo central. Este proceso iterativo garantizó rigor y precisión, proporcionando una comprensión profunda del fenómeno estudiado (Bryman, 2012; Gibbs, 2012). Con el propósito de conferir confiabilidad y consistencia a los análisis de los datos cualitativos, uno de los investigadores de este estudio llevó a cabo el primer ejercicio de codificación abierta y axial. Posteriormente, los otros dos investigadores realizaron una revisión con el objetivo de lograr un chequeo inter-codificador en los dos tipos de codificación mencionados. Finalmente, la codificación selectiva fue realizada en conjunto por los tres investigadores.

4. RESULTADOS

Los resultados se presentan en tres secciones: el análisis estadístico de las encuestas Pre y Post Test MSLQ-Colombia (sección 3.1), que examina variaciones en la motivación estudiantil tras la intervención educativa (datos cuantitativos); las percepciones de los estudiantes sobre los elementos de desarrollo de videojuegos (datos cuantitativos) en la sección 3.2; y, finalmente, un análisis cualitativo de sus experiencias de aprendizaje con GDBL (sección 3.3).

4.1. Motivación por Aprender - MSLQ-Colombia

Se aplicó la prueba de Wilcoxon con un nivel de significancia del 5 % (0.05) para evaluar cambios significativos, positivos o negativos, en los siete aspectos motivacionales caracterizados con el MSLQ-Colombia en el Pre-test y Post-test. La Tabla 2 (en pág. sig.) resume los promedios de las respuestas en ambos tests, las diferencias entre ellos y los p-valores correspondientes.

Ningún aspecto de la motivación mostró cambios estadísticamente significativos; el menor p-valor (0.190) correspondió a “Expectativas de autoeficacia en el rendimiento”, lo que indica la ausencia de variaciones relevantes en los factores motivacionales evaluados.

4.2. Percepciones de los estudiantes sobre los elementos de desarrollo de videojuegos

Los estudiantes evaluaron los componentes del desarrollo de videojuegos, como diseño gráfico, narrativa, personalización, mecánicas de juego y producto final. La estadística descriptiva de la Tabla 3 (en pág. sig.) muestra una opinión muy positiva en todos los aspectos, con promedios superiores a 5.00 en la escala Likert (1.00 a 7.00). Las desviaciones estándar, entre 1.20 y 1.47, indican consistencia en las preferencias estudiantiles.

TABLA 2. Estadísticas sobre la motivación en el aprendizaje basadas en el Pre-Test y Post-Test del MSLQ-Colombia

Sub-escala motivacional	Etapa	Promedio	Diferencia	p-valor Wilcoxon
Valoración de la tarea	Pre	5.64	-0.23	0.212
	Pos	5.41		
Metas intrínsecas	Pre	4.88	-0.36	0.212
	Pos	4.52		
Metas extrínsecas	Pre	5.16	-0.21	0.616
	Pos	4.95		
Expectativas de autoeficacia en el rendimiento	Pre	5.79	-0.42	0.190
	Pos	5.37		
Expectativas de autoeficacia en el aprendizaje	Pre	5.52	0.04	0.903
	Pos	5.56		
Control de aprendizaje	Pre	5.95	-0.06	0.456
	Pos	5.89		
Ansiedad	Pre	4.67	0.15	0.607
	Pos	4.82		

TABLA 3. Estadísticas descriptivas de las percepciones de los estudiantes sobre los componentes del GDBL

Componente GDBL	Promedio	Desviación estándar	Percentil 25 %	Percentil 50 %	Percentil 75 %
Componente gráfico	5.19	1.47	4	5	7
Diseño de juego	5.38	1.35	4	5	7
Narrativa	5.14	1.35	4	5	6
Personalización de los juegos	5.38	1.24	4	6	6
Diseño de lógicas y mecánicas de juego	5.19	1.20	5	5	6
Producto final	5.61	1.43	5	6	7

Aunque las percepciones generales son similares entre los componentes, el percentil 75 destaca 'Producto final', 'Diseño de juego' y 'Personalización de los juegos' como los más valorados. En contraste, 'Componente gráfico', 'Narrativa' y 'Diseño de lógicas y mecánicas de juego' presentan percentiles 75 más bajos, reflejando menor relevancia en ese nivel.

4.3. Percepciones de los estudiantes sobre la experiencia de aprendizaje usando GDBL

Las respuestas de la encuesta de percepción se analizaron mediante análisis de contenido. Primero, los datos se etiquetaron y agruparon según los aspectos motivacionales evaluados con el MSLQ-Colombia. Luego, se identificaron categorías emergentes no directamente relacionadas con estos aspectos, pero relevantes para el estudio. En síntesis, se hallaron tres temas: motivación en el aprendizaje, GDBL en el proceso de aprendizaje y aspectos generales de la experiencia educativa.

4.3.1. Tema: Motivación en el Aprendizaje

El análisis de 137 opiniones reveló que el 55 % (76 opiniones) se relaciona con motivación en el aprendizaje. En general, el enfoque GDBL tuvo un efecto positivo en la motivación y el aprendizaje de los estudiantes, destacándose los aspectos de interés intrínseco por aprender, control del aprendizaje, valoración de la tarea y expectativas de autoeficacia en el aprendizaje. Los resultados se detallan en la Tabla 4.

TABLA 4. Tema: Motivación en el Aprendizaje

Categoría	Descripción	Opinión destacada	Cantidad opiniones
Metas intrínsecas	Las opiniones resaltan que el GDBL proporcionó dinamismo, motivación y un enfoque práctico, incrementando el interés de los estudiantes por la programación de computadores.	"Si bien la programación no es general mi actividad favorita, si considero que el hecho de que haya estado enfocado a juegos ayudó a que mi interés en ésta aumentara." (sic)	23
Control del aprendizaje	Los estudiantes destacaron el trabajo autodidacta durante la experiencia y señalaron que la metodología les mostró la importancia de la proactividad y el autodescubrimiento para su aprendizaje.	"...siento que también tengo que esforzarme y dar más de mi para poder avanzar en la clase."	14
Valoración de la tarea	Las opiniones destacaron la utilidad profesional de la programación (9 opiniones), aunque algunos percibieron una desconexión del GDBL con su futuro laboral (4 opiniones).	"Si, pues a través del desarrollo de juegos se puede evidenciar el uso de los conceptos y pilares clave de la programación orientada a objetos, los cuales serán muy útiles en el futuro sin duda." (sic)	13
Expectativas de autoeficacia en el aprendizaje	Los estudiantes desarrollaron confianza y persistencia en su aprendizaje, incluso ante dificultades. El GDBL mejoró la comprensión de conceptos complejos.	"El hecho de que sea basado en videojuegos ayuda a que los conceptos no se queden tan abstractos, de modo que sí pude entender mayoritariamente los temas de programación orientada a objetos."	13
Metas extrínsecas	Algunos estudiantes señalaron que el enfoque los motivó para obtener mejores calificaciones.	"Los buenos resultados obtenidos me motivaron a seguir aprendiendo y esforzándome."	7
Ansiedad	De las 4 opiniones registradas, la mitad atribuidas al estrés de la entrega final, mientras que las demás fueron positivas, señalando una menor percepción de rigidez en la evaluación.	"Al ser de videojuegos, se siente menos rígido."	4
Expectativas de autoeficacia en el rendimiento	Las opiniones resaltaron la confianza en alcanzar buenos resultados académicos mediante el esfuerzo en la creación de videojuegos.	"El hecho de crear nuestro propio videojuego nos motivó a esforzarnos por lograr el objetivo en mente, y el producto de ese esfuerzo nos fue reconocido adecuadamente."	2

4.3.2. Tema: GDBL en el proceso de aprendizaje

Este tema reúne 71 percepciones sobre el enfoque educativo basado en GDBL, abarcando aplicaciones generales y específicas, con énfasis en sus implicaciones profesionales. También se consideran sus efectos en el aprendizaje y el interés por los videojuegos dentro del curso. La Tabla 5 resume las categorías y descripciones asociadas.

TABLA 5. Tema: GDBL en el proceso de aprendizaje

Categoría	Descripción	Opinión destacada	Cantidad opiniones
Valoración positiva de GDBL frente a métodos tradicionales	Percepciones que resaltan el interés y la efectividad del enfoque GDBL frente a métodos tradicionales. No obstante, algunos estudiantes señalaron dificultades, particularmente con herramientas como Python Arcade.	"Siento que mezclar esta materia con la temática de videojuegos fue interesante y genial."	15
Percepción de GDBL como enfoque de enseñanza didáctico	Los estudiantes resaltaron que el método facilita la comprensión y aplicación estructurada de conceptos de programación, aunque una minoría expresó confusión durante el aprendizaje.	"hay conceptos que son mas fáciles de entender con este enfoque". (sic)	18
Enfoque GDBL no genera efectos significativos en el aprendizaje	Algunos estudiantes indicaron que el enfoque no influyó significativamente en su aprendizaje ni motivación, considerándolo una herramienta similar a los métodos tradicionales.	"No creo que haya diferencia con el enfoque normal."	20
Dudas sobre la aplicabilidad de GDBL para el ámbito profesional	Algunos estudiantes percibieron el enfoque como un objetivo final de la clase, no como una herramienta de aprendizaje, y no lo consideraron útil para su futuro. Además, señalaron que los temas estaban excesivamente orientados al desarrollo de videojuegos.	"No creo que me ayude en mi desarrollo profesional, pero lo puedo ver más como un hobbie."	13
Perspectiva de la temática de videojuegos como impulsora de la creatividad y la participación	Los estudiantes valoraron los videojuegos por fomentar la creatividad y facilitar su participación en la asignatura.	"Los videojuegos siempre son de mi interés personal, luego diseñar uno fue muy entretenido."	5

4.3.3. Tema: Experiencia educativa

Este tema reúne las opiniones estudiantiles sobre aspectos clave de la intervención educativa, incluyendo su compromiso, dificultades en el aprendizaje y valoración de la retroalimentación individual, el acompañamiento docente y el aprendizaje en general. La Tabla 6 muestra los resultados, que comprenden 22 opiniones, equivalentes al 16 % del total analizado.

TABLA 6. Tema: experiencia educativa

Categoría	Descripción	Opinión destacada	Cantidad opiniones
Dificultades en el aprendizaje y resolución de dudas	La asignatura fue percibida como exigente, y los estudiantes enfrentaron obstáculos como dudas no resueltas e incomprensión de ciertos conceptos.	"...requiere bastante tiempo de investigación ..." "...hay puntos en los que no sé por dónde continuar"	10
Valoración del apoyo docente	Los estudiantes valoraron el rol de la realimentación del docente y asistentes docentes para el aprendizaje.	"...el apoyo de los monitores fue de mucha ayuda."	7
Aprendizaje a través de proyectos prácticos	Los estudiantes valoraron los proyectos como una estrategia innovadora y motivadora para aplicar y evaluar conocimientos, en contraste con los métodos tradicionales.	"Me gusta demostrar conocimiento a través de proyectos más que con pruebas." (sic)	5

5. DISCUSIÓN

El diseño metodológico implementado y los resultados mixtos obtenidos permitieron responder la pregunta de investigación sobre los efectos de un entorno de aprendizaje basado en la construcción de videojuegos (GDBL) en la motivación de los estudiantes para aprender programación. Los resultados cuantitativos mostraron niveles medios o altos en todos los aspectos motivacionales, excepto en 'Ansiedad', donde los estudiantes expresaron preocupación generalizada. Las variaciones entre pre-test y pos-test no fueron estadísticamente significativas, sugiriendo que el GDBL no influyó en la motivación. Sin embargo, estos hallazgos no pueden generalizarse debido al carácter de estudio de caso, lo que limita la identificación de un efecto cuantitativo concluyente.

El análisis cualitativo complementó los resultados al sugerir que la experiencia con GDBL fue, en general, positiva. Con respecto a la motivación por aprender, las percepciones de los estudiantes evidenciaron los mayores efectos favorables en la orientación a metas intrínsecas, control del aprendizaje, valoración de la tarea y expectativas de autoeficacia por aprender. Estudios previos (Rugelj & Lapina, 2019; Torres-Toukoumidis et al., 2020) destacan que los videojuegos facilitan el aprendizaje, y este estudio confirmó que el GDBL aumentó el interés por la programación, incluso en estudiantes inicialmente desinteresados. Además, se destacó la mejora en autonomía, gestión del tiempo y control del aprendizaje, en línea con investigaciones previas (Mayo, 2007; Wang & Wu, 2009). Algunos participantes indicaron que la estrategia incentivó el deseo de mejorar sus calificaciones, lo que sugiere un posible efecto en la motivación extrínseca, aspecto no reportado en la literatura. Asimismo, el GDBL mostró potencial para reducir la ansiedad, coincidiendo con estudios que indican que la familiaridad con este enfoque facilita el aprendizaje y puede hacer los cursos más accesibles y menos estresantes (Bewer & Gladkaya, 2022; Rugelj & Lapina, 2019; Wu & Wang, 2012).

Por otro lado, la diferencia entre los resultados cuantitativos y cualitativos podría obedecer principalmente al tamaño de la muestra. La potencia estadística de pruebas como Wilcoxon se incrementa con muestras más amplias (Wiedermann & von Eye, 2013). Por lo tanto, esta situación podría haber limitado la capacidad de identificar cambios estadísticamente significativos con los datos cuantitativos del presente estudio. Además, se plantea la posibilidad de que factores no contemplados en los análisis de este estudio, tales como la carga académica en otras asignaturas, las condiciones laborales, las socioeconómicas y las familiares, hayan podido enmascarar los efectos del GDBL. Asimismo, la implementación del enfoque GDBL a partir de la tercera semana, en lugar de la primera, podría haber generado incertidumbre y afectado la respuesta motivacional.

Adicionalmente, el análisis cualitativo generó categorías emergentes. Un grupo amplio de estudiantes (33 opiniones) percibió el GDBL como interesante, efectivo y didáctico, destacando su capacidad para facilitar la comprensión de conceptos de programación de manera dinámica y estructurada. Se resaltó que este enfoque no sólo hace el aprendizaje más accesible y atractivo, sino que fomenta la creatividad y participación. Además, la retroalimentación docente se identificó como un factor motivador, lo que coincide con los hallazgos de Torres-Toukoumidis et al. (2020) y Rugelj y Lapina (2019). Por otra parte, el GDBL podría estimular el pensamiento crítico al requerir que los estudiantes evalúen información, resuelvan problemas complejos y justifiquen sus decisiones durante el diseño y la programación. Este proceso es crucial, ya que,

como destacan Denoni Buján y Cebollero Salinas (2025), este tipo de actividades favorece la disposición al pensamiento crítico de los estudiantes universitarios.

Si bien este estudio se centra en la educación superior, es útil considerar los efectos de los videojuegos en otros niveles educativos. Mielgo-Conde et al. (2022) destacan los beneficios de los videojuegos en la educación primaria, mientras que Pala (2024) también encontró un impacto positivo en el aprendizaje de historia en la educación secundaria. Junto con los resultados del presente estudio, estos trabajos indican que los beneficios motivacionales y cognitivos de los videojuegos pueden extenderse a través de diferentes niveles educativos. Es posible que los efectos observados en la educación primaria y secundaria, como el aumento de la motivación intrínseca y el desarrollo de habilidades, también contribuyan a los resultados positivos observados en la educación superior en el contexto del GDBL.

No obstante, 20 estudiantes no percibieron un efecto significativo en su aprendizaje, sugiriendo que el GDBL no difiere sustancialmente de métodos tradicionales. Algunos señalaron dificultades para comprender los temas y materializar sus ideas, lo que indica que la estrategia no es igualmente accesible para todos. También mencionaron una mayor inversión de tiempo y esfuerzo, a pesar del contenido habitual del curso. Se identificaron desafíos en el manejo de herramientas como Python Arcade, evidenciando la necesidad de integrarlas mejor en el currículo. Además, los estudiantes con experiencia en videojuegos mostraron mayor facilidad para comprender conceptos complejos, en coherencia con la teoría constructivista de Kafai y Burke (2015). Estas percepciones divergentes resaltan la importancia de ajustar la implementación del GDBL para mejorar su efecto educativo. Como sugieren Bewer y Gladkaya (2022), Kafai y Burke (2015) y Rugelj y Lapina (2019), es fundamental ampliar experiencias empíricas para refinar esta estrategia educativa.

En lo que respecta a la percepción de relevancia profesional, la mitad de los participantes consideró que el curso no se vinculaba con sus metas laborales, percibiéndolo más como una actividad recreativa que como una experiencia formativa con aplicación en su futuro profesional. Los estudiantes expresaron que el enfoque estaba demasiado centrado en el desarrollo de videojuegos como un fin en sí mismo, en lugar de una herramienta para el aprendizaje de la programación de computadores en un contexto más amplio. Sin embargo, una minoría destacó que la metodología facilitó una mejor comprensión de los ciclos de desarrollo de un programa y los elementos cruciales del trabajo de un programador. Estos hallazgos apuntan a la necesidad de hacer ajustes cuidadosos cuando se hagan futuras integraciones del GDBL dentro del currículo. Esto con el fin de hacer más evidente su aplicabilidad en diversos ámbitos de la programación de computadores, no sólo para el desarrollo de videojuegos, y de alinearlo más con los intereses y expectativas profesionales de los estudiantes.

Los estudiantes valoraron los componentes ‘Producto final’, ‘Diseño de juego’ y ‘Personalización de los juegos’, en línea con De Sousa et al. (2014), quienes destacan el enfoque en proyectos y el ciclo de desarrollo. El ‘Producto final’ fue el más relevante, al representar un logro tangible. ‘Diseño de juego’ y ‘Personalización de los juegos’ permitieron a los estudiantes aplicar su estilo personal y explorar la programación a través de la creación de videojuegos. En contraste, los componentes ‘Componente gráfico’, ‘Narrativa’ y ‘Diseño de lógicas y mecánicas de juego’ fueron los menos preferidos, posiblemente por su enfoque creativo y narrativo, menos relacionado con la programación. Aunque estos elementos son esenciales al diseñar videojuegos porque afectan la experiencia del jugador, los participantes los consideran secundarios frente

a la codificación directa. Este hallazgo sugiere que futuras implementaciones de GDBL deberían explorar si estos aspectos afectan la motivación en el aprendizaje.

Finalmente, el estudio abordó la falta de modelos para seleccionar marcos de desarrollo de juegos (GDF) en entornos GDBL. Aunque existen modelos generales (Bewer & Gladkaya, 2022; Wang & Wu, 2009), este trabajo propuso una estrategia integral basada en criterios adicionales como tipo, funcionalidad, dificultad y documentación. Aunque aplicable a este estudio, el modelo propuesto requiere validación para adaptarlo a diversos contextos educativos.

6. CONCLUSIONES

Este estudio respondió la pregunta de investigación sobre los efectos de un entorno de aprendizaje basado en la construcción de videojuegos (GDBL) en la motivación por aprender programación. Se empleó un enfoque metodológico en el que, inicialmente, se llevó a cabo un proceso de elección de un Game Development Framework (GDF), seleccionando Python Arcade. Luego se realizó una intervención educativa en una asignatura de Programación Orientada a Objetos recolectando datos cuantitativos y cualitativos sobre la motivación por aprender de los estudiantes participantes. Aunque los análisis cuantitativos mostraron niveles medios o altos de motivación en la mayoría de las dimensiones evaluadas, los cambios entre el pre-test y el pos-test no fueron estadísticamente significativos. Esto indica que, en este estudio, el GDBL no generó un efecto cuantitativamente concluyente en la motivación por aprender.

Por otro lado, los participantes expresaron cualitativamente efectos positivos en componentes específicos de su motivación por aprender, tales como la orientación a metas intrínsecas, el control del aprendizaje, la valoración de la tarea y las expectativas de autoeficacia en el aprendizaje. Estos hallazgos confirman que el GDBL propició, entre los participantes de este estudio, el interés y el agrado por la programación, les permitió activar su proactividad y el autodescubrimiento en sus procesos de aprendizaje, generó un ambiente que facilitó percibir utilidades de la programación de computadores y, adicionalmente, propició la confianza y persistencia de los estudiantes en su aprendizaje, incluso ante dificultades. Adicionalmente, el GDBL demostró ser eficaz para mejorar la comprensión de conceptos complejos y también se identificó su potencial para reducir la ansiedad asociada a los procesos de evaluación, ofreciendo un entorno más accesible y menos estresante.

No obstante, el análisis cualitativo reveló desafíos significativos: muchos estudiantes no percibieron diferencias sustanciales con los enfoques de enseñanza tradicionales, mencionando dificultades conceptuales, mayor carga de trabajo y la necesidad de aprender herramientas como Python Arcade. Estas limitaciones subrayan la importancia de mejorar la integración curricular del GDBL para mejorar su accesibilidad y eficacia. Con respecto a la percepción profesional, si bien algunos participantes valoraron el GDBL por su contribución al desarrollo de competencias, muchos lo interpretaron como una actividad recreativa ajena a sus metas profesionales. Estos hallazgos indican que es necesario ajustar la implementación del GDBL para que los estudiantes no lo vean como un fin en sí mismo, sino como un ambiente que les permite aprender bases de programación de computadores que luego pueden aplicar en los diversos ámbitos de su vida académica y profesional.

En conjunto, este estudio destaca tanto el potencial del GDBL para fortalecer la motivación y el aprendizaje de la programación como las limitaciones que deben abordarse para maximizar su efecto en futuras aplicaciones educativas.

6.1. Trabajos Futuros

Los resultados indican la necesidad de ampliar la muestra en futuras investigaciones para mejorar la representatividad y comprensión del efecto del GDBL. En cuanto a aspectos metodológicos de la investigación, es crucial realizar estudios cuasi-experimentales con grupos control y experimental que comparen el GDBL con métodos tradicionales para validar sus efectos en la motivación y el aprendizaje. También, se recomienda incluir y analizar datos sobre carga académica, empleo y situación socioeconómica y familiar, ya que estos factores podrían influir en la motivación de los estudiantes. Adicionalmente, es importante replicar el estudio en distintos contextos y niveles educativos para evaluar la consistencia de los beneficios del GDBL. Además, se sugiere evaluar si la integración de estrategias de pensamiento crítico en el diseño de los videojuegos mejora la motivación y el aprendizaje.

En cuanto a la implementación de la metodología GDBL en cursos futuros de programación, es crucial comunicar de manera explícita a los estudiantes que GDBL es un medio para enseñar conceptos de programación y no un fin en sí mismo, evitando asunciones erróneas sobre la naturaleza y aplicabilidad del curso. Asimismo, es imperativo resaltar la aplicabilidad de los conceptos de programación más allá del desarrollo de videojuegos, ilustrando su relevancia en diversos campos de la ingeniería y la industria del software. Además, dada la carga de trabajo que puede generar el ambiente GDBL, se recomienda proporcionar orientación sobre la gestión del tiempo y estrategias de aprendizaje, así como facilitar herramientas para planificar y distribuir mejor las tareas. Finalmente, se recomienda un acompañamiento más frecuente por parte del docente cuando los estudiantes se encuentran en los primeros semestres, pues es posible que los estudiantes requieran un mayor apoyo para adaptarse a metodologías innovadoras. Se sugiere, por tanto, implementar tutorías, espacios de resolución de dudas y materiales complementarios que faciliten el aprendizaje.

6.2. Limitaciones

Este estudio enfrentó varias amenazas que pudieron afectar los resultados. La ausencia de un grupo control limitó la comparación entre el enfoque GDBL y una metodología tradicional. Además, la modalidad 100 % remota restringió la interacción estudiante-docente y el acceso a recursos pedagógicos disponibles en entornos presenciales. Por último, las condiciones socioeconómicas de algunos estudiantes, quienes combinaban trabajo y estudio, pudieron afectar su disponibilidad y desempeño en el curso.

7. CONTRIBUCIÓN DE LOS AUTORES

Todos los autores contribuyeron equitativamente en las siguientes actividades: conceptualización, curaduría de datos, análisis formal, investigación, metodología, administración del proyecto, desarrollo de software, recursos, supervisión, validación, visualización, redacción del borrador original y revisión y edición del manuscrito.

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La investigación en educación para la ciudadanía mundial: análisis de relevancia y estudio bibliométrico tematizado

Research in Global Citizenship Education: Relevance Analysis and Thematic Bibliometric Study

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Jacobo Roda-Segarra
ORCID: 0000-0002-4717-6295
Universitat de València, España
jacobo.roda@uv.es

Santiago Mengual-Andrés
ORCID: 0000-0002-1588-9741
Universitat de València, España
santiago.mengual@uv.es

Andrés Payà Rico
ORCID: 0000-0001-7646-4539
Universitat de València, España
andres.paya@uv.es

RESUMEN

La presente investigación desarrolla un análisis bibliométrico tematizado de la producción científica más relevante en el campo de la Educación para la Ciudadanía Mundial, diferenciando entre investigaciones históricas (más citadas desde que existen registros en Scopus) y recientes (más citadas en el último lustro). El análisis ha permitido visibilizar los estudios más relevantes en el primer cuarto del siglo XXI. La muestra estuvo compuesta por 500 trabajos (2000-2024) que fueron clasificados en cinco subtemas. Los resultados evidencian una concentración de artículos relevantes publicados entre 2011 y 2016, coincidiendo con la adopción de los Objetivos de Desarrollo Sostenible de la Agenda 2030. Se identificó un nivel bajo de colaboración (1,63 autores por artículo) y una alta especialización en autores y fuentes. España, Chile e Italia han emergido como países clave en las afiliaciones de la producción reciente, aunque con bajos índices de colaboración entre países. En el análisis de palabras clave identificaron cuatro bloques principales de categorías, destacando la relevancia del enfoque estratégico en educación y su orientación a la población joven. Este estudio ofrece una visión integral del campo de la Educación para la Ciudadanía Mundial, proporcionando una base para futuras investigaciones sobre su desarrollo, desafíos y tendencias.

PALABRAS CLAVE educación para la ciudadanía mundial, objetivos de desarrollo sostenible, bibliometría, investigación educativa

ABSTRACT

This study presents a thematized bibliometric analysis of the most relevant scientific output in the field of Global Citizenship Education, distinguishing between historical research (those most cited since records began in Scopus) and recent research (those most cited in the last five years). This analysis has made it possible to highlight the most significant studies in the first quarter of the 21st century. The sample comprised 500 works (2000–2024), classified into five subthemes. The findings reveal a concentration of influential articles published between 2011 and 2016, coinciding with the adoption of the Sustainable Development Goals of the 2030 Agenda. A low level of collaboration was identified (1.63 authors per article), along with a high degree of specialization among authors and sources. Spain, Chile, and Italy have emerged as affiliation key countries in recent research production, albeit with low levels of international collaboration. The keyword analysis identified four main category clusters, highlighting the significance of the strategic approach to education and its focus on young populations. This study provides a comprehensive overview of the field of Global Citizenship Education, offering a foundation for future research on its development, challenges, and trends.

KEYWORDS Global Citizenship Education, Sustainable Development Goals, Bibliometrics, Educational Research

1. INTRODUCCIÓN

En la actualidad, la Educación para la Ciudadanía Mundial (ECM) establece un marco de referencia educativo. Este marco gira alrededor de la noción de la conciencia global, la pertenencia a una humanidad común, la interdependencia política, económica, social y cultural, o la relación entre los aspectos más cercanos y locales con aquellos nacionales o mundiales (UNESCO, 2014). Este marco, que ha evolucionado desde una primigenia acción para impulsar la "Educación para la Comprensión Internacional" en los años 20 del siglo XX por parte de la Sociedad de las Naciones (Renoliet, 2000), se articula según la UNESCO (2015) a través de las dimensiones cognitiva, socioemocional y conductual. La primera de ellas se centra en la comprensión de los desafíos globales y su relación con la realidad local. La dimensión socioemocional busca el desarrollo de valores solidarios y tolerantes, mientras que la conductual promueve las acciones responsables. Con todo esto, la ECM persigue el objetivo de ser un elemento clave en la transformación de las personas para que puedan "contribuir a un mundo más inclusivo, justo y pacífico" (UNESCO, 2015, p.5).

Además, la ECM está vinculada de una manera muy relevante con el Objetivo de Desarrollo Sostenible 4 de la Agenda 2030, que busca una educación inclusiva, equitativa y de calidad a lo largo de toda la vida para todas las personas (Payà, 2020; 2022). En concreto se centra en la meta 4.7, donde se explicita la promoción de la ciudadanía mundial junto con la valoración de la diversidad cultural, la sostenibilidad, la igualdad o la promoción de la paz y la no violencia (ONU, 2015).

Esta amplitud de retos se ha reflejado en la literatura científica que se ha centrado en alguno de los aspectos que se englobaban dentro del marco de la ECM, dando como resultado una prolija cantidad de investigaciones en las últimas décadas (Damiani & Fraillon, 2025). La cantidad de las mismas y su diversidad temática hacen necesario un análisis global, que permita obtener un panorama general de la producción científica sobre ECM, pero sin dejar de lado la riqueza temática que se engloba dentro de este marco de referencia educativo.

En este sentido, los estudios bibliométricos permiten ofrecer esta perspectiva global sobre un campo de investigación, identificando el corpus de la literatura dentro del mismo (Ellegaard & Wallin, 2015), así como

los fundamentos, primeros trabajos y cánones metodológicos (Zupic & Čater, 2015). Sin embargo, este tipo de estudios ofrecen una visión unificada y restringida de la literatura científica, lo que simplificaría demasiado el estudio de un campo tan rico y variado, con tantas perspectivas diferentes, como es el de la ECM.

Así pues, la presente investigación se ha centrado en un análisis bibliométrico alrededor de la producción científica de la ECM en un análisis multinivel, sin perder la complejidad y la perspectiva de los diferentes temas que la conforman. Esto ha permitido tener, al mismo tiempo, una visión global sobre la producción científica de la ECM y, a la vez, individualizada en cada una de las temáticas abordadas. Además, el estudio se ha realizado tanto con la producción más relevante desde que existen registros, como con la producción más relevante del último lustro, lo que ha permitido visibilizar estudios recientes muy influentes y que demuestran las tendencias de investigación, que de otra manera hubieran pasado desapercibidos en un campo de estudio educativo con un ya largo recorrido como es el de la ECM.

2. MATERIAL Y MÉTODO

El objetivo de la presente investigación se ha analizado desde una aproximación bibliométrica de la producción científica (Colomo et al., 2025; Gil-Fernández & Calderón-Garrido, 2023; Piazza & Mengual-Andrés, 2020; Zhang et al., 2023). en el campo de la ECM. A través de una aproximación cuantitativa y mediante estadística descriptiva —análisis de tendencia central y dispersión— se pretendió identificar, desde una perspectiva global, la literatura científica sobre ECM. Dada la extensión del concepto de la ECM, se optó por concretar qué aspectos principales o grandes áreas temáticas estaban contenidos dentro de la definición de ECM. En dicho sentido, el primer paso de la investigación fue identificar los diferentes subtemas que se podían incluir dentro del concepto más genérico de ECM. Se configuró un grupo focal que pretendió reunir una serie de expertos para debatir sobre un tema concreto, dirigidos en mayor o menor medida por uno o varios moderadores (Wilkinson, 1998). El desarrollo del grupo focal tuvo lugar el día 26 de noviembre de 2024 en la Facultad de Filosofía y Ciencias de la Educación de la Universidad de Valencia. En la técnica participaron 18 miembros del equipo de investigación del proyecto "PID2023-151908NB-I00 Educación para la Ciudadanía Mundial y la formación del profesorado (EDCIMU)" financiado por el Ministerio de Ciencia, Innovación y Universidades todo ellos expertos en el campo de la ECM de las universidades de Valencia, UNED, Complutense de Madrid, Pablo de Olavide de Sevilla y Granada. El resultado de este *focus group* dio lugar al consenso sobre los subtemas, todos ellos incluidos dentro del campo de la ECM: (1) educación para el desarrollo sostenible, (2) educación en derechos humanos, (3) educación para la ciudadanía mundial, (4) educación para la paz y (5) educación intercultural.

Esta primera selección de subtemas se empleó para la configuración y desarrollo del estudio bibliométrico, de tal forma que posibilitara un análisis de la producción segmentada por cada uno de estos subtemas.

Aunque los análisis de tipo bibliométrico comparten ciertos aspectos generales y metodológicos basados en la estadística descriptiva, podemos encontrar, sin embargo, diferentes aproximaciones procedimentales. Zupic y Čater (2015) proponen seguir un procedimiento en 5 pasos, consistentes en: (1) diseñar la investigación, (2) compilar los datos bibliométricos, (3) analizar, (4) visualizar e (5) interpretar. Por su parte, Donthu et al. (2021) simplificaron el método reduciéndolo a 4 pasos: (1) definir el alcance y propósito, (2) seleccionar las técnicas de análisis, (3) recopilar los datos para la realización del análisis bibliométrico y (4) documentar los

resultados. Para el presente estudio se ha optado por la aproximación de Donthu et al. (2021), puesto que simplifica el procedimiento de Zupic y Čater (2015), compendiando algunos de sus pasos.

En lo que se refiere al primer paso, el propósito consiste en el análisis bibliométrico de la producción científica más relevante del campo de la ECM que esté indexada en la base de datos generalista Scopus en función de los 5 subtemas seleccionados en el *focus group* de expertos. Su alcance cubre los artículos, libros y publicaciones que han sido más influyentes en el campo de la ECM lo que, según los principios cienciométricos establecidos por Garfield (1970) y Price (1965), se corresponde con aquellos que más citas han recibido en otros trabajos. Se seleccionó, por tanto, la base de datos Scopus como principal fuente de información bibliométrica, dado que indexa las fuentes con mayor índice de reconocimiento internacional en su Scopus Content Coverage. Adicionalmente, sus datos permiten ser exportados a formatos fácilmente interoperables mediante herramientas de análisis bibliométrico.

Para el siguiente paso, la selección de las técnicas de análisis de datos, se ha optado por aquellas que han ayudado a identificar en términos globales el corpus de la literatura más relevante sobre ECM. Se ha realizado un análisis de la evolución de la producción científica de las investigaciones más citadas, así como los autores y autoras de las mismas, las citas, fuentes donde han sido publicados los trabajos y los países de procedencia de las autoras y autores. Por su parte se ha realizado un análisis de la evolución de las palabras clave en el periodo de publicación de la muestra. Los datos anteriores, además se presentan agrupados por los 5 subtemas emergidos en el grupo focal, lo que permite tener una visión más precisa de aquellos aspectos que han suscitado mayor interés desde el punto de vista de la producción científica, tal como se detalla a continuación.

En el tercer paso, que consiste en la recopilación de los datos para la realización del estudio bibliométrico, se planificaron 10 estrategias de búsqueda que se llevaron a cabo el 1 de febrero de 2025 con el siguiente procedimiento: por cada uno de los 5 subtemas seleccionados se realizaron dos búsquedas, la primera referida a todos los documentos indexados por Scopus, y la segunda de ellas limitada a los documentos publicados entre el 1 de enero de 2020 y el 31 de diciembre de 2024. Las cadenas de búsqueda se limitaron al título, resumen y palabras clave, así como al *subject area* de "social sciences". A continuación, se seleccionaron los 50 documentos más citados por cada uno de los subtemas, que fueron revisados individualmente por los autores de este artículo mediante un proceso de triangulación, excluyendo aquellos que no se ajustaban en su contenido al subtema correspondiente. Cuando se excluía un documento, se añadía el siguiente más citado al listado de documentos para revisar, de tal forma que la muestra final siempre contuviera las 50 investigaciones más citadas por cada uno de los subtemas. Este procedimiento dio lugar a dos submuestras:

- **Submuestra histórica:** los 50 documentos más citados para cada uno de los 5 subtemas desde que se tienen registros en Scopus (n=250).
- **Submuestra reciente:** los 50 documentos más citados para cada uno de los 5 subtemas, publicados entre el 1 de enero de 2020 y el 31 de diciembre de 2024 (n=250).

En la Tabla A1 del Anexo A se detallan las cadenas de búsqueda utilizadas, el número de registros devueltos y la cantidad de documentos que fueron excluidos en el proceso de triangulación.

La separación entre la submuestra histórica y la submuestra más reciente ha permitido analizar las últimas investigaciones del campo de la ECM que han sido más relevantes para la comunidad científica por su número elevado de citas, pero que hubieran pasado desapercibidos con un análisis exclusivamente histórico.

Los registros resultantes fueron importados en la herramienta Hecumen (Roda-Segarra y Mengual-Andrés, 2023) y empleando el paquete R Bibliometrix (Aria & Cuccurullo, 2017) para el desarrollo del cuarto paso, la documentación de resultados, que se expone a continuación.

3. RESULTADOS

3.1. Producción científica

En la muestra global, formada por la submuestra histórica y la submuestra más reciente, encontramos documentos de tipo *article* (n=405; 81 %), *book* (n=35; 7 %), *review* (n=35; 7 %), *book chapter* (n=19; 3,8 %), *conference paper* (n=3; 0,6 %) y *editorial* (n=3; 0,6 %), según la nomenclatura de Scopus.

El primer registro de la submuestra histórica que aparece en Scopus fue publicado en el año 2000, siendo 2011 el año con más documentos (n=28), seguidos de 2015 (n=22) y 2016 (n=19). Desde 2022 no aparece ningún documento, es decir, que ninguno de los documentos publicados desde 2022 en el campo de la ECM está entre los 250 más citados a nivel histórico; tampoco hay ninguno publicado antes del año 2000. La distribución completa por años de la submuestra histórica se puede ver en la Figura A1 del Anexo A, junto al modelo polinómico de tercer grado obtenido mediante una regresión lineal múltiple de mínimos cuadrados ordinarios, con la finalidad de identificar la evolución a lo largo del tiempo de los 250 documentos más citados históricamente.

Sin embargo, la aportación de cada subtema a la producción científica de la submuestra histórica es dispar, tal como se puede analizar en la Figura A2 del Anexo A, donde se ha representado la aportación porcentual de los 50 artículos más citados de cada uno de los 5 subtemas a la submuestra histórica. El subtema que más documentos aportó a la submuestra histórica en un único año fue "educación intercultural", con 8 documentos en 2011, seguido con 7 aportaciones en un año por "educación para el desarrollo sostenible" (2019), "educación en derechos humanos" (2011), "educación para la paz" (2011) y "educación intercultural" (2015). El resto de los años las aportaciones por cada subtema fueron bajas, con 5 o menos artículos por año, con excepción de "educación intercultural" en 2014 y "educación para la ciudadanía mundial" en 2016, ambos con n=6. La media fue similar en todos los subtemas puesto que todos los subtemas aportan 50 artículos en total (M=2); la mediana también es 2, a excepción de "educación para el desarrollo sostenible", que es 1. La moda en todos los subtemas fue 0. En cuanto a la dispersión, la varianza oscila entre 3,33 y 5, mientras que la desviación típica (SD) tiene un mínimo de 1,83 y un máximo de 2,24.

Por cuanto respecta a la submuestra más reciente, la mayor concentración de documentos más citados la encontramos en 2020 (n=100), primer año del intervalo temporal analizado y va decreciendo progresivamente hasta la cota inferior en 2024 (n=6). Esto es lo previsible, puesto que los artículos del primer año de la muestra han tenido más tiempo para ser citados. Sin embargo, si lo contrastamos con la submuestra histórica expuesta anteriormente, los artículos más citados no se encontraron en los primeros años de la muestra, sino en el intervalo 2011-2016. En la Figura A3 del Anexo A se ha representado la distribución temporal de la submuestra reciente junto con su modelo de evolución.

En este caso, la aportación de cada subtema a la submuestra se puede observar en la Figura A4 del Anexo A. Los subtemas con más documentos en un único año fueron "educación para el desarrollo sostenible" (n=30; 30 %), "educación para la ciudadanía mundial" (n=19; 19 %) y "educación para la paz" (n=18; 18 %), todos ellos

en 2020, el primer año del intervalo temporal en esta submuestra reciente (2020-2024). A partir de 2022 la cifra desciende a 10 artículos o menos por subtema y año. La media siempre es la misma (M=10; SD entre 5,87 y 12,19) puesto que cada subtema aporta 50 artículos, pero en la mediana encontramos diferencias. El menor valor lo encontramos en "educación para el desarrollo sostenible" (Mdn=4) y el mayor en "educación para la paz" (Mdn=10). En las medidas de dispersión, los valores más elevados los encontramos en "educación para el desarrollo sostenible" (SD2=148,50; SD=12,19), mientras que la menor se ha identificado en "educación en derechos humanos" (SD2=34,5; SD=5,87).

3.2. Autoras y autores

En lo que respecta a las autoras y autores de las investigaciones sobre ECM, la muestra conjunta está constituida por 814 personas, que han aparecido como firmantes en un total de 1103 ocasiones. Desde esta perspectiva, 153 firmaron investigaciones en solitario (18,80 %), mientras que este valor asciende a 661 (81,20 %) cuando hablamos de artículos firmados por más de una persona; la tasa de autores/as por artículo es de 1,63. Desde la óptica de las investigaciones, 191 documentos (38,20 %) fueron elaborados por una única persona, mientras que 309 (61,80 %) fueron realizados por más de una persona; la tasa de artículos por autor es de 0,614. Por su parte, la tasa de coautoría (aparición de autores dividido entre el total de artículos) asciende a 2,21.

Los 5 autores con mayor producción en cada uno de los 5 subtemas analizados, con el desglose de los artículos que han escrito en solitario o en colaboración con otras personas, su posición en el orden de firmas de estos, así como el Índice de Dominancia, que es el cociente de los artículos en los que ha firmado en primer lugar entre el número de artículos en los que ha colaborado con otras personas (Kumar & Kumar, 2008). Estos resultados se pueden analizar en la Tabla 1.

TABLA 1. Autores/as más productivos/as por submuestra y subtema

Submuestra	Subtema	Autor/a	Artículos totales	Autor/a único/a	Varios/as autores/as	Artículos como primer firmante	Índice de dominancia
Histórica	Educación para el desarrollo sostenible	Lozano, R.	3	0	3	2	0,67
		Olsson, D.	3	0	3	2	0,67
		Barth, M.	2	0	2	1	0,50
		Cebrián, G.	2	2	1	1	0,50
		Mochizuki, Y.	2	0	2	1	0,50
	Educación en derecho humanos	Osler, A.	3	1	2	1	0,50
		Covell, K.	2	0	2	2	1,00
		Stellmacher, J.	2	0	2	2	1,00
		Al-Daraweesh, F.	1	0	1	1	1,00
		Arthur, J.	1	0	1	1	1,00
	Educación para la ciudadanía mundial	Torres, C.A.	5	2	3	1	0,33
		Pashby, K.	4	3	1	1	1,00
		Goren, H.	4	0	4	3	0,75
		Yemini, M.	4	0	4	1	0,25
		Andreotti, V.	3	1	2	1	0,50

Submuestra	Subtema	Autor/a	Artículos totales	Autor/a único/a	Varios/as autores/as	Artículos como primer firmante	Índice de dominancia
Histórica	Educación para la paz	Zembylas, M.	4	1	3	2	0,67
		Bekerman, Z.	4	0	4	2	0,50
		Bajaj, M.	3	1	2	2	1,00
		Bar-Tal, D.	2	0	2	2	1,00
		Bickmore, K.	2	1	1	1	1,00
	Educación intercultural	Hajisoteriou, C.	3	0	3	1	0,33
		Elliot, D.L.	2	0	2	2	1,00
		Faas, D.	2	1	1	1	1,00
		Hornberger, N.H.	2	1	1	1	1,00
		Karousiou, C.	2	0	2	1	0,50
Reciente	Educación para el desarrollo sostenible	Cebrián, G.	3	0	3	2	0,67
		Ferguson, T.	2	0	2	2	1,00
		Filho, W.L.	2	0	2	1	0,50
		Sund, P.	2	0	2	1	0,50
		Acosta Castellanos, P.M.	1	0	1	1	1,00
	Educación en derechos humanos	Perry-Hazan, L.	3	2	1	1	1,00
		Giliomee, C.	2	1	1	1	1,00
		Ahmed, A.K.	1	0	1	1	1,00
		Ammert, N.	1	0	1	1	1,00
		Bean, T.W.	1	0	1	1	1,00
	Educación para la ciudadanía mundial	Bosio, E.	11	4	7	2	0,29
		Pashby, K.	5	0	5	3	0,60
		Akkari, A.	3	0	3	3	1,00
		Torres, C.A.	3	0	3	3	1,00
		Stein, S.	3	1	2	1	0,50
	Educación para la paz	Zembylas, M.	4	0	4	2	0,50
		Kester, K.	3	1	2	1	0,50
		Saputra, W.N.E.	2	0	2	2	1,00
		Kapshuk, Y.	2	0	2	1	0,50
		Ahmed, Z.S.	1	0	1	1	1,00
	Educación intercultural	Akkari, A.	2	0	2	2	1,00
		Arias-Ortega, K.	2	0	2	2	1,00
		Biasutti, M.	2	0	2	2	1,00
		Shadiev, R.	2	0	2	2	1,00
		Sommier, M.	2	0	2	1	0,50

Fuente: elaboración propia

3.3. Análisis de citas recibidas

Para el análisis de citas, se ha revisado de forma independiente los 5 subtemas estudiados, identificando los 5 documentos que más citas globales han recibido en cada uno de ellos, así como la fuente de procedencia. También se han identificado las editoriales o grupos editoriales que publican las fuentes correspondientes. En el caso de la submuestra histórica, aquellas editoriales cuya frecuencia de aparición es mayor de 1 son Routledge

(n=6; 24 %), Taylor and Francis (n=5; 20 %), SAGE (n=4; 16 %), Elsevier (n=3; 12 %) y Springer (n=2; 8 %). En lo que respecta a la submuestra reciente, Routledge sigue liderando el mayor número de investigaciones más citadas en el campo de la ECM (n=7; 28 %), seguido de Springer (n=4; 16 %), SAGE (n=3; 12 %), Taylor and Francis (n=2; 8 %), MDPI (n=2; 8 %) y Elsevier (n=2; 8 %). Las 5 editoriales que han publicado los artículos más citados sobre ECM, y que se han mantenido de una manera constante tanto en la submuestra histórica como en la reciente son Routledge, SAGE, Springer, Taylor and Francis y Elsevier. Los resultados se describen en la Tabla 2, mientras que las referencias a estos artículos se enumeran en el Anexo B.

TABLA 2. Investigaciones más citadas por submuestra y subtema

SUBMUESTRA HISTÓRICA				
Subtema	**Título**	**Citas globales**	**Fuente**	**Editorial**
Educación para el desarrollo sostenible	*Key competencies in sustainability: A reference framework for academic program development* (Wiek et al., 2011)	1624	*Sustainability science*	Springer
	Future-oriented higher education: Which key competencies should be fostered through university teaching and learning? (Rieckmann, 2012)	587	*Futures*	Elsevier
	Globalization and environmental education: Looking beyond sustainable development (Jickling y Wals, 2008)	428	*Journal of curriculum studies*	Taylor and Francis
	Connecting competences and pedagogical approaches for sustainable development in higher education: A literature review and framework proposal (Lozano et al., 2017)	427	*Sustainability (Switzerland)*	MDPI
	Dissonance in students' perceptions of sustainable development and sustainability: Implications for curriculum change (Kagawa, 2007)	396	*International Journal of Sustainability in Higher Education*	Emerald Group Publishing
Educación en derechos humanos	*South Africa's treatment action campaign: Combining law and social mobilization to realize the right to health* (Heywood, 2009)	185	*Journal of Human Rights Practice*	Oxford University Press
	Human rights in social science textbooks: Cross-national analyses, 1970-2008 (Meyer et al., 2010)	166	*Sociology of education*	SAGE
	Understanding what we do: Emerging models for human rights education (Tibbits, 2002)	156	*International Review of Education*	Springer
	Human rights education: Ideology, location, and approaches (Bajaj, 2011)	139	*Human Rights Quarterly*	Johns Hopkings
	Participatory niches for emergent citizenship in early adolescence: An international perspective (Torney-Purta y Amadeo, 2011)	85	*The annals of the American academy of political and social science*	SAGE
Educación para la ciudadanía mundial	*Global Citizenship: A Typology for Distinguishing its Multiple Conceptions* (Oxley y Morris, 2013)	304	*British journal of educational studies*	Taylor and Francis
	Global citizenship: Abstraction or framework for action? (Davies, 2006)	273	*Educational Review*	Routledge
	Citizenship education redefined – A systematic review of empirical studies on global citizenship education (Goren y Yemini, 2017)	256	*International Journal of Educational Research*	Elsevier
	(Towards) decoloniality and diversality in global citizenship education (Andreotti, 2011)	195	*Globalization, societies and education*	Taylor and Francis
	Globalising citizenship education? A critique of 'global education and 'citizenship education' (Davies et al., 2005)	184	*British journal of educational studies*	Taylor and Francis

SUBMUESTRA HISTÓRICA				
Subtema	**Título**	**Citas globales**	**Fuente**	**Editorial**
Educación para la paz	*Education and conflict: Complexity and chaos* (Davies, 2003)	243	*Education and Conflict: Complexity and Chaos*	Routledge
	'Pedagogies of resistance' and critical peace education praxis (Bajaj, 2015)	128	*Journal of Peace Education*	Routledge
	Peace education in societies involved in intractable conflicts: Direct and indirect models (Bar-Tal y Rosen, 2009)	128	*Review of Educational research*	SAGE
	An experiment in peace: Reconciliation-aimed workshops of Jewish-Israeli and Palestinian youth (Maoz, 2000)	116	*Journal of Peace Research*	SAGE
	Does peace education make a difference in the context of an intractable conflict? (Salomon, 2004)	106	*Peace and Conflict*	Routledge
Educación intercultural	*Slicing the onion ethnographically: Layers and spaces in multilingual language education policy and practice* (Hornberger y Johnson, 2007)	489	*TESOL Quarterly*	Wiley-Blackwell
	Developing intercultural understanding and skills: models and approaches (Perry y Southwell, 2011)	220	*Intercultural education*	Routledge
	A plea for change in research on intercultural discourses: A 'liquid' approach to the study of the acculturation of Chinese students (Dervin, 2011)	205	*Journal of multicultural discourses*	Routledge
	Language awareness and (critical) cultural awareness - relationships, comparisons and contrasts (Byram, 2012)	143	*Language awareness*	Taylor and Francis
	Assessing intercultural sensitivity: An empirical analysis of the Hammer and Bennett Intercultural Development Inventory (Paige et al., 2003)	127	*International journal of intercultural relations*	Elsevier
SUBMUESTRA RECIENTE				
Subtema	**Título**	**Citas globales**	**Fuente**	**Editorial**
Educación para el desarrollo sostenible	*Key competencies in sustainability in higher education—toward an agreed-upon reference framework* (Brundiers et al., 2021)	356	Sustainability Science	Springer
	Education for the future? Critical evaluation of education for sustainable development goals (Kopnina, 2020)	273	Journal of Environmental Education	Taylor and Francis
	Five trends of education and technology in a sustainable future (Burbules et al., 2020)	143	Geography and Sustainability	Beijing Normal University Press
	Synergizing education, research, campus operations, and community engagements (Menon y Suresh, 2020)	131	International Journal of Sustainability in Higher Education	Emerald Group Publishing
	Competencies in education for sustainable development: Emerging teaching and research developments (Cebrián et al., 2020)	125	Sustainability (Switzerland)	MDPI
Educación en derechos humanos	*The council of Europe's reference framework of competences for democratic culture: Policy context, content and impact* (Barrett, 2020)	36	London Review of Education	Routledge
	Conceptualising conflicts between student participation and other rights and interests (Perry-Hazan, 2021)	22	Discourse	Routledge
	Human rights education: developing a theoretical understanding of teachers' responsibilities (Robinson et al., 2020)	22	Educational Review	Routledge
	Students' Perceptions of Their Rights in School: A Systematic Review of the International Literature (Perry-Hazan, 2021)	21	Review of Educational Research	SAGE
	Students' Understanding of Institutional Practices: The Missing Dimension in Human Rights Education (Barton, 2020)	19	American Educational Research Journal	SAGE

SUBMUESTRA RECIENTE				
Subtema	**Título**	**Citas globales**	**Fuente**	**Editorial**
Educación para la ciudadanía mundial	*A meta-review of typologies of global citizenship education* (Pashby et al., 2020)	184	*Comparative Education*	Routledge
	An ideology critique of global citizenship education (Pais y Costa, 2020)	132	*Critical Studies in Education*	Taylor and Francis
	Global citizenship education at the crossroads: Globalization, global commons, common good, and critical consciousness (Torres y Bosio, 2020)	89	*Prospects*	Springer
	A transnational model of virtual exchange for global citizenship education (O'Dowd, 2020)	72	*Language Teaching*	Cambridge University Press
	Who Needs Global Citizenship Education? A Review of the Literature on Teacher Education (Estellés y Fischman, 2021)	66	*Journal of Teacher Education*	SAGE
Educación para la paz	*Toward a Decolonial Praxis in Critical Peace Education: Postcolonial Insights and Pedagogic Possibilities* (Hajir y Kester, 2020)	42	*Studies in Philosophy and Education*	Springer
	Achieving and monitoring education for sustainable development and global citizenship: A systematic review of the literature (Edwards et al., 2020)	37	*Sustainability (Switzerland)*	MDPI
	Academic mobility: Bridging tourism and peace education (Monteiro et al., 2020)	35	*Role and Impact of Tourism in Peacebuilding and Conflict Transformation*	IGI Global
	Rethinking peace education: A cultural political economy approach (Higgins y Novelli, 2020)	29	*Comparative Education Review*	University of Chicago Press
	Affective practices, difficult histories and peace education An analysis of teachers' affective dilemmas in ethnically divided Cyprus (Zembylas y Loukaidis, 2021)	29	*Teaching and Teacher Education*	Elsevier
Educación intercultural	*Teacher Education for Critical and Reflexive Interculturality* (Dervin y Jacobsson, 2021)	38	*Teacher Education for Critical and Reflexive Interculturality*	Springer
	Sustainable intercultural and inclusive education: teachers' efforts on promoting a combining paradigm (Sorkos y Hajisoteriou, 2021)	38	*Pedagogy, Culture and Society*	Routledge
	A review of research on intercultural learning supported by technology (Shadiev y Sintawati, 2020)	37	*Educational Research Review*	Elsevier
	Supporting Critical Multicultural Teacher Educators: Transformative teaching, social justice education, and perceptions of institutional support (Gorski y Parekh, 2020)	36	*Intercultural Education*	Routledge
	Working in the classroom with migrant and refugee students: the practices and needs of Italian primary and middle school teachers (Biasutti et al., 2020)	36	*Pedagogy, Culture and Society*	Routledge

Fuente: elaboración propia

3.4. Fuentes

Para el análisis de las fuentes se ha recurrido a identificar cuáles han sido las 5 fuentes con mayor frecuencia de aparición, calculando el porcentaje que ha copado de las 50 publicaciones más citadas en el subtema. Este análisis se ha realizado tanto de la submuestra histórica como de la submuestra reciente, y se puede analizar en la Tabla 3.

También se han incluido en el análisis las editoriales o grupos editoriales que publican la fuente. En la submuestra histórica, las editoriales que han publicado más de una fuente son Routledge (n=12; 48 %), Taylor and Francis (n=5; 20 %), Elsevier (n=2; 8 %) y Springer (n=2; 8 %). En la submuestra reciente encontramos a Routledge de nuevo (n=10; 40 %), Springer (n=4; 16 %) y Taylor and Francis (n=2; 8 %). Las tres editoriales que se han mantenido en ambas submuestras han sido Routledge, Taylor and Francis y Springer. Como fuente cabe destacar los resultados obtenidos por la revista Sustainability, que ha publicado el 50 % de los artículos en el último lustro referentes al subtema "educación para el desarrollo sostenible".

TABLA 3. Principales revistas que han publicado las submuestras por subtema

SUBMUESTRA HISTÓRICA				
Subtema	**Fuente**	**Artículos**	**%**	**Editorial**
Educación para el desarrollo sostenible	*Environmental Education Research*	11	22 %	Carfax Publishing
	International Journal Of Sustainability In Higher Education	11	22 %	Emerald Group Publishing
	Sustainability (Switzerland)	9	18 %	MDPI
	Sustainability Science	4	8 %	Springer
	Journal Of Environmental Education	2	4 %	Taylor and Francis
Educación en derechos humanos	*Educational Research*	3	6 %	Routledge
	Human Rights Quarterly	3	6 %	Johns Hopkings
	Cambridge Journal of Education	2	4 %	Routledge
	Educational Philosophy and Theory	2	4 %	Taylor and Francis
	Educational Review	2	4 %	Routledge
Educación para la ciudadanía mundial	*Globalisation Societies and Education*	7	14 %	Routledge
	Compare	4	8 %	Routledge
	Educational Review	3	6 %	Routledge
	Teaching and Teacher Education	3	6 %	Elsevier
	British Journal of Educational Studies	2	4 %	Taylor and Francis
Educación para la paz	*Journal of Peace Education*	12	24 %	Routledge
	International Review of Education	3	6 %	Springer
	Peace and Conflict	3	6 %	Routledge
	Theory into Practice	3	6 %	Routledge
	Compare	2	4 %	Routledge
Educación intercultural	*Intercultural Education*	5	10 %	Routledge
	Compare	2	4 %	Routledge
	Higher Education Research and Development	2	4 %	Taylor and Francis
	International Journal of Intercultural Relations	2	4 %	Elsevier
	Language and Intercultural Communication	2	4 %	Taylor and Francis

SUBMUESTRA RECIENTE				
Subtema	**Fuente**	**Artículos**	**%**	**Editorial**
Educación para el desarrollo sostenible	*Sustainability (Switzerland)*	25	50 %	MDPI
	International Journal of Sustainability in Higher Education	7	14 %	Emerald Group Publishing
	Environmental Education Research	4	8 %	Carfax Publishing
	Sustainability Science	3	6 %	Springer
	Comparative Education Review	1	0,50 %	University of Chicago Press
Educación en derechos humanos	*American Educational Research Journal*	2	4 %	SAGE
	Educational Review	2	4 %	Routledge
	International Journal of Children's Rights	2	4 %	Martinus Nijhoff Publishers
	International Journal of Human Rights	2	4 %	Routledge
	Journal of Human Rights and Social Work	2	4 %	Springer Science + Business Media
Educación para la ciudadanía mundial	*Globalisation Societies and Education*	9	18 %	Routledge
	Conversations on Global Citizenship Education: Perspectives on Research Teaching and Learning in Higher Education	4	8 %	Routledge
	Prospects	4	8 %	Springer
	Citizenship Teaching and Learning	3	6 %	Intellect
	Global Citizenship Education: Critical and International Perspectives	3	6 %	Springer
Educación para la paz	*Journal of Peace Education*	14	28 %	Routledge
	Peace and Conflict	5	10 %	Routledge
	Journal of Social Studies Education Research	2	4 %	ASSE
	Art Education	1	0,50 %	Routledge
	British Journal of Sociology of Education	1	0,50 %	Taylor and Francis
Educación intercultural	*Intercultural Education*	5	10 %	Routledge
	Globalisation Societies and Education	2	4 %	Routledge
	Journal of Multilingual and Multicultural Development	2	4 %	Routledge
	Journal of New Approaches in Educational Research	2	4 %	Springer
	Language and Intercultural Communication	2	4 %	Taylor and Francis

Fuente: elaboración propia

3.5. Países de correspondencia

A continuación, se ha realizado un análisis de los 5 países de las universidades o centros de investigación (filiación institucional) a los que pertenecen las autoras y autores de correspondencia de las investigaciones que más han aparecido en cada uno de los subtemas. El número de artículos por país se ha desglosado entre aquellos artículos cuyos firmantes provenían de instituciones del mismo país (SCP), y los artículos

que tenían firmantes de diferentes países (MCP), calculando consecuentemente la ratio de artículos MCP (MCP/total artículos del país). El análisis SCP indica una colaboración intra-país, mientras que el MCP reflejaría una colaboración inter-país (Alzard et al., 2022). Así pues, una ratio MCP cercana a 1 indica una alta colaboración inter-país, mientras que una cifra más próxima a 0 indica una alta colaboración intra-país. Los resultados por submuestra y subtema pueden observarse en la Tabla 4.

TABLA 4. Países de correspondencia y colaboración entre países por submuestra y subtema

SUBMUESTRA HISTÓRICA						
Subtema	**País**	**Artículos**	**Frecuencia**	**SCP**	**MCP**	**MCP ratio**
Educación para el desarrollo sostenible	Suecia	8	0,1818	4	4	0,500
	Reino Unido	7	0,1591	7	0	0,000
	Alemania	5	0,1136	3	2	0,400
	Países Bajos	3	0,0682	2	1	0,333
	Estados Unidos	3	0,0682	1	2	0,667
Educación en derechos humanos	Reino Unido	8	0,2353	7	1	0,125
	Estados Unidos	8	0,2353	8	0	0,000
	Alemania	3	0,0882	3	0	0,000
	Canadá	2	0,0588	2	0	0,000
	Chipre	2	0,0588	2	0	0,000
Educación para la ciudadanía mundial	Reino Unido	14	0,3889	10	4	0,286
	Canadá	6	0,1667	6	0	0,000
	Israel	4	0,1111	3	1	0,250
	Estados Unidos	3	0,0833	2	1	0,333
	Irlanda	2	0,0556	2	0	0,000
Educación para la paz	Estados Unidos	10	0,3125	7	3	0,300
	Israel	7	0,2188	6	1	0,143
	Reino Unido	7	0,2188	7	0	0,000
	Chipre	3	0,0938	2	1	0,333
	Corea	2	0,0625	0	2	1,000
Educación intercultural	Reino Unido	7	0,2000	6	1	0,143
	Estados Unidos	4	0,1143	4	0	0,000
	Alemania	3	0,0857	2	1	0,333
	Brasil	2	0,0571	2	0	0,000
	Canadá	2	0,0571	2	0	0,000

SUBMUESTRA RECIENTE						
Subtema	**País**	**Artículos**	**Frecuencia**	**SCP**	**MCP**	**MCP ratio**
Educación para el desarrollo sostenible	España	13	0,2889	10	3	0,231
	Alemania	6	0,1333	4	2	0,333
	China	4	0,0889	4	0	0,000
	Suecia	4	0,0889	3	1	0,250
	Brasil	2	0,0444	0	2	1,000
Educación en derechos humanos	Reino Unido	7	0,1795	6	1	0,143
	Estados Unidos	7	0,1795	7	0	0,000
	Sudáfrica	4	0,1026	3	1	0,250
	Suecia	3	0,0769	2	1	0,333
	Chile	2	0,0513	2	0	0,000
Educación para la ciudadanía mundial	Reino Unido	7	0,1944	4	3	0,429
	Japón	5	0,1389	2	3	0,600
	Canadá	4	0,1111	4	0	0,000
	Corea	4	0,1111	2	2	0,500
	España	3	0,0833	2	1	0,333
Educación para la paz	Estados Unidos	11	0,2683	9	2	0,182
	Chipre	4	0,0976	4	0	0,000
	Reino Unido	4	0,0976	4	0	0,000
	Israel	3	0,0732	3	0	0,000
	Corea	3	0,0732	1	2	0,667
Educación intercultural	Chile	6	0,150	4	2	0,333
	Italia	6	0,150	3	3	0,500
	Finlandia	4	0,100	0	4	1,000
	Reino Unido	4	0,100	3	1	0,250
	Australia	3	0,075	3	0	0,000

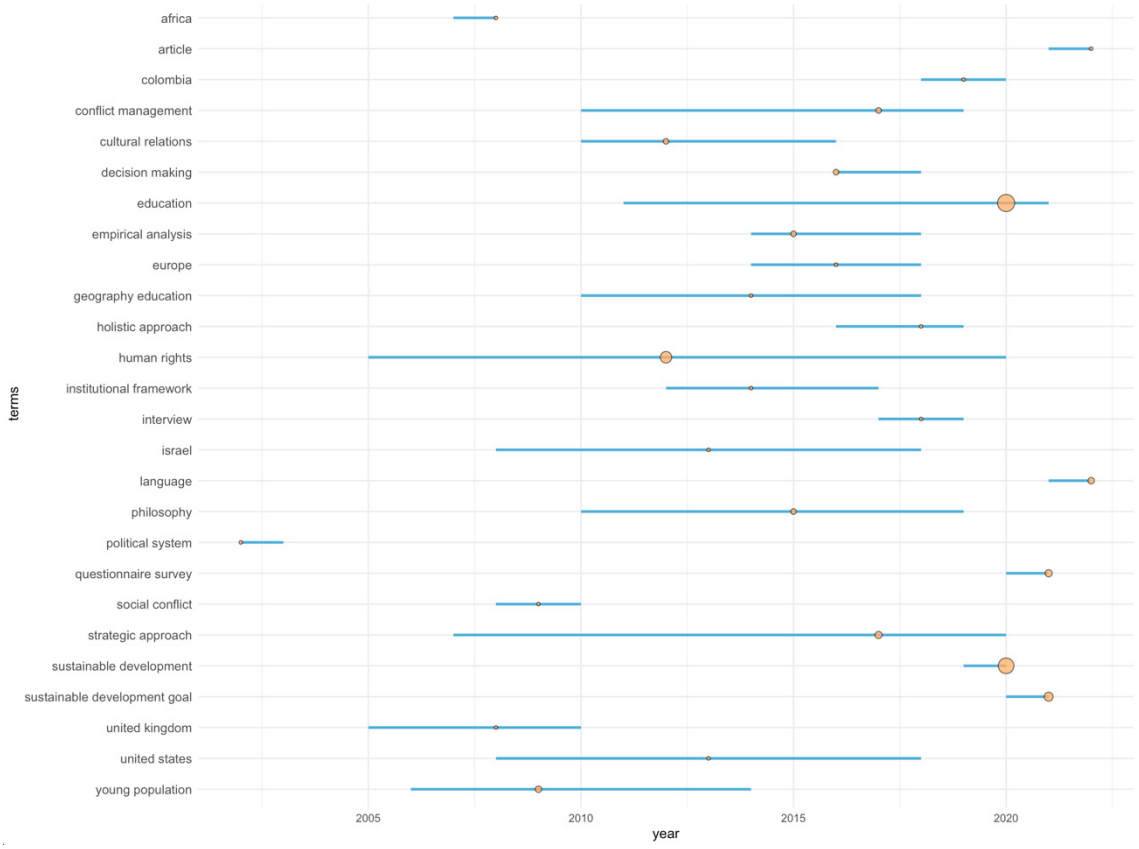
Fuente: elaboración propia

3.6. Análisis de las palabras clave

Para el análisis de las palabras clave se han identificado los términos más frecuentes en la muestra global (submuestra histórica junto con la submuestra reciente con todos los subtemas sin diferenciación). Para la selección de palabras clave se estableció un criterio de frecuencia mínima de aparición de 2 palabras clave por año, así como una aparición mínima global de 2, para poder considerarla en el análisis temático; esto implica que, para poder ser considerada, al menos debía haber aparecido un año en dos ocasiones. La aplicación de estos criterios en la muestra global ha dado lugar a la selección de 26 términos. Estas palabras clave se han representado gráficamente para mostrar la evolución de su interés en las investigaciones

científicas más citadas. El segmento tiene su inicio en el primer cuartil y finaliza en el tercer cuartil de la distribución de cada una de las palabras clave. La circunferencia representada sobre el segmento corresponde al tercer cuartil, y su diámetro se correlaciona con la frecuencia de aparición del término. Esta información queda representada en la Figura 1.

FIGURA 1. Evolución de las palabras clave en la muestra global



Fuente: elaboración propia

4. DISCUSIÓN

El objetivo del presente estudio ha sido realizar un análisis bibliométrico de la producción científica más relevante en el campo de la ECM a través de dos análisis complementarios: la producción científica más citada desde que se tienen registros en Scopus y la producción científica más citada en el último lustro correspondiente al intervalo 2020-2024. Adicionalmente, cada una de las dos submuestras (histórica y más reciente) ha sido obtenida mediante la búsqueda de documentos en 5 subtemáticas relacionadas con la ECM. Cada una de las subtemáticas por cada uno de las dos submuestras contaba con los 50 documentos más citados, lo que ha conformado una muestra global de 500 documentos.

El tipo de documento más frecuente en la muestra global ha sido el artículo (81 %), destacando que son más frecuentes los libros completos (7 %) frente a los capítulos de libro (3,8 %). En lo que se refiere al

análisis de la producción científica, no ha lugar la comprobación de la Ley de Price para identificar si la tasa de crecimiento de la producción científica tiene un crecimiento exponencial (Fernández et al., 2004), puesto que la muestra está compuesta por los artículos más relevantes, no por la producción total. Esta relevancia viene determinada por el número de citas, según los principios cienciométricos planteados por Garfield (1970) y Price (1965). En base a esta premisa, y tal como se ha indicado previamente, para poder estudiar los artículos más relevantes en los últimos años, además de los más relevantes en todos los tiempos, la muestra se ha subdividido en dos submuestras.

En la submuestra histórica, compuesta por los 250 artículos más citados de todos los tiempos (50 por cada subtema), encontramos un valor nulo de la moda, lo que indica varios años en los que no hay ningún artículo entre los 50 más citados en cada subtema. Estos años con 0 artículos se ubican en el intervalo 2021-2024, lo que es esperable teniendo en cuenta que la submuestra histórica comienza en el año 2000 (que es el primer año en el que hay registros en Scopus), y los últimos años han aparecido artículos que no han tenido el mismo tiempo para ser citados, a diferencia de artículos publicados con anterioridad. La desviación estándar, entre 1,83 y 2,24, indica variaciones moderadas en lo que se refiere a la producción científica anual de esta submuestra. Sin embargo, el mayor número de artículos se concentra en el intervalo 2011-2016, con n=104, lo que supone un 41,60 % de toda la submuestra histórica. Este dato cabe ser destacado puesto que, a pesar de que los artículos de los primeros años de la submuestra histórica tuvieron más años para ser citados (como sí que sucede en la submuestra reciente), los artículos que fueron citados más veces se concentran en este intervalo. Teniendo en cuenta que los Objetivos de Desarrollo Sostenible fueron adoptados por las Naciones Unidas en 2015, fecha que está incluida dentro del intervalo de mayor concentración de artículos relevantes, se puede inferir la relevancia de esta efeméride en las investigaciones sobre la ECM, en tanto en cuanto la ECM está incluida en la estructura general de los Objetivos de Desarrollo Sostenible (Collado, 2017). El modelo polinómico de evolución refleja esta cota superior, así como su posterior declive a partir de 2016, por el motivo ya expuesto del menor tiempo para poder recibir citaciones. A nivel de los subtemas, la mayor aportación de documentos por parte de un subtema en un único año fue “educación para el desarrollo sostenible” en 2019, que supuso un 58,33 % de las investigaciones de ese mismo año. El resto de las aportaciones puntuales en un único año descendieron notablemente, encontrando el siguiente valor en “educación intercultural”, que aparece en dos años: en 2015 supuso un 31,82 %, mientras que en 2011 aportó un 28,57 % de los documentos de ese año.

En la submuestra más reciente, los dos primeros años del intervalo analizado (2020-2024) cubren 180 artículos, lo que supone que el 72 % de los 250 artículos más citados recientemente se concentran entre 2020 y 2021. Diversas investigaciones reflejan un aumento significativo en la producción científica en diversas disciplinas durante 2021 (Obenauf, 2020; Rousseau et al., 2023), lo que podría atribuirse a la pandemia de COVID-19 y los consiguientes periodos de confinamiento. A partir de ese momento, tal como se puede identificar en el modelo polinómico de evolución correspondiente, el número de artículos por año desciende significativamente. Estos resultados son lo esperable, ya que los primeros años del intervalo han tenido más tiempo para ser citados, mientras que los de los años posteriores han tenido menos tiempo para recibir citas. Pero, como se ha indicado anteriormente, contrasta con los resultados de la submuestra histórica, cuyos artículos más citados están entre 2011 y 2016. En lo que se refiere a la submuestra reciente, las medidas de dispersión indican que este descenso no ha sido homogéneo en todos los subtemas.

La mayor dispersión de datos se ha dado en "educación para el desarrollo sostenible" (SD=12,19), lo que indica que la cantidad de artículos publicados oscila ampliamente a lo largo de los años, mientras que el subtema de "educación en derechos humanos" (SD=5,87) mantiene una homogeneidad mayor, con unos valores de dispersión menores. Los subtemas que más artículos aportaron en un único año (2020) fueron "educación para el desarrollo sostenible", que supuso un 30 % de los artículos del año, seguido por "educación para la ciudadanía mundial" (19 %) y "educación para la paz" (18 %).

En lo concerniente al análisis de las autorías de las investigaciones, el primer dato a destacar es que un amplio porcentaje de las autoras y autores realizaron investigaciones en colaboración con otras personas (81,20 %). A pesar de este porcentaje tan elevado, las colaboraciones no fueron demasiado numerosas en cada uno de los artículos, puesto que el promedio de autores/as por artículo es de 1,63. La cifra es baja si la comparamos con otros estudios bibliométricos en campos como el de las tecnologías educativas, con promedios de autores/as por artículo cercanos a 3 (Roda-Segarra et al., 2022), pero significativamente mayor que en las investigaciones en historia de la educación, con cifras menores a 1 (Roda-Segarra et al., 2023).

En la submuestra histórica hay un alto grado de especialización entre los autores y autoras con mayor grado de producción científica, puesto que ninguna de las personas aparece en más de un subtema. Destaca Torres con 5 artículos entre los más citados en el subtema de "educación para la ciudadanía mundial", pero teniendo en cuenta que en 3 de ellos firmó con otras personas, y en solo uno de ellos firmó en primer lugar, con lo que su índice de dominancia desciende a 0,33. Con 4 artículos en el mismo subtema, pero con un índice de dominancia de 1 por el único artículo que firmó con otras personas, encontramos a Karen Pashby, afiliada a la Manchester Metropolitan University. También con 4 artículos en el mismo subtema y valores inferiores de dominancia están Heela Goren del University College London y Miri Yemini en Technion, mientras que Michalinos Zembylas de la Open University of Cyprus y Zvi Bekerman de The Hebrew University of Jerusalem también cuentan con 4 artículos en el subtema "educación para la paz".

Sin embargo, en la submuestra reciente sí que aparece un autor en dos subtemas diferentes: Abdeljalil Akkari de la University of Geneva ("educación para la ciudadanía mundial" y "educación intercultural" con 3 y 2 artículos respectivamente, todos ellos escritos en colaboración con otras personas y siempre como primer firmante). En esta submuestra destaca por su amplia producción Emiliano Bosio de la Toyo University, con 11 investigaciones en el subtema de "educación para la ciudadanía mundial", destacando que en 7 de ellas firmó con otras personas, pero no como primer firmante (índice de dominancia de 0,29). En cualquier caso, el dato de su producción implica que el 22 % de los 50 artículos más relevantes en el intervalo 2020-2024 en el subtema de "educación para la ciudadanía mundial" fueron firmados por este autor.

Solo 4 autores aparecen tanto en la submuestra histórica como en la submuestra reciente. Estos son Gisela Cebrián (Universitat Rovira i Virgili) en "educación para el desarrollo sostenible", Karen Pashby y Carlos Alberto Torres en "educación para la ciudadanía mundial" y Michalinos Zembylas en "educación para la paz".

Para el análisis de las citaciones de la submuestra histórica, el subtema que más citaciones ha acumulado es "educación para el desarrollo sostenible" y el artículo *Key competencies in sustainability: A reference framework for academic program development* (Wiek et al., 2011) concentra el 46,91 % de las citaciones totales de los 5 artículos más relevantes en el subtema. Así pues, el reparto de citaciones en este subtema no es homogéneo, y se puede observar un salto abrupto en el porcentaje de citaciones acumuladas con

el siguiente artículo (16,96 %), que es *Future-oriented higher education: Which key competencies should be fostered through university teaching and learning?* (Rieckmann, 2012). Los 3 artículos restantes del subtema tienen un 12 % o menos de las citaciones.

Paralelamente en la submuestra reciente, encontramos de nuevo "educación para el desarrollo sostenible" como el subtema con más citaciones acumuladas, y el primer artículo en la lista corresponde al artículo más citado en la submuestra histórica. Sin embargo, el interés por este artículo no radica en el intervalo reciente de 2020-2024, ya que estos 5 años acumularon solo un 21,92 % de las citas totales que recibió, mientras que el 78,08 % de las citas restantes las recibió en los primeros nueve años desde su publicación (2011-2019).

Analizando ambas submuestras destaca el hecho de que el artículo *Key competencies in sustainability: A reference framework for academic program development* (Wiek et al., 2011) es el único que coincide en la submuestra histórica y en la reciente. Este punto refuerza el planteamiento de partida de la presente investigación, que ha consistido en realizar un análisis diferenciado entre los documentos más citados, y los más citados de los últimos años. La práctica totalidad de los artículos más citados en los últimos años (96 %) eran artículos que no aparecían en el listado de los artículos más citados desde que se tienen registros en Scopus, debido a la menor cantidad de años que tuvieron para poder recibir citas, haciendo que los artículos más recientes se invisibilizaran.

En cuanto a las fuentes, en el subtema "educación para el desarrollo sostenible" coinciden 4 de las 5 principales revistas tanto en la submuestra histórica como en la reciente. Estas son Environmental Education Research, International Journal Of Sustainability In Higher Education, Sustainability (Switzerland) y Sustainability Science. Estas 4 revistas han mantenido el liderazgo publicando los artículos más relevantes de todos los tiempos en "educación para el desarrollo sostenible", y han mantenido esta posición en los 5 últimos años. En el subtema de "educación en derechos humanos" esta situación solo ocurre con la revista Educational Review, al igual que en "educación para la ciudadanía mundial" con la revista Globalisation Societies and Education, o en "educación para la paz" con Journal of Peace Education. En "educación intercultural" aparecen dos revistas: Intercultural Education y Language and Intercultural Communication.

También se ha identificado un grado de especialización muy alto en el análisis de las fuentes. En la submuestra histórica, las únicas revistas que publicaron los artículos más relevantes de más de un subtema fueron Educational Review ("educación en derechos humanos" y "educación para la ciudadanía mundial") y Compare ("educación para la ciudadanía mundial", "educación para la paz" y "educación intercultural"). En la submuestra reciente, la única revista que publicó en más de un subtema fue Globalisation Societies and Education ("educación para la ciudadanía mundial" y "educación intercultural").

Respecto al análisis de los países de la filiación institucional de los autores de correspondencia de las investigaciones, cabe destacar la emergencia de una serie de países en los artículos más relevantes de los últimos 5 años, que no se encontraban entre los artículos más relevantes de todos los tiempos. Estos países son Australia, Chile, China, España, Finlandia, Israel, Italia, Japón y Sudáfrica. Destacan los casos de España, Chile e Italia en los tres primeros lugares que, con 16, 8 y 6 artículos respectivamente, se sitúan entre los países de correspondencia con más autores y autoras de las investigaciones más relevantes en los últimos 5 años. España lidera en el subtema "educación para el desarrollo sostenible", mientras que Chile e Italia están en primer y segundo lugar en "educación intercultural".

Para el último análisis de las palabras clave más frecuentes en la muestra global, compuesta por la submuestra histórica y la reciente, en la que se han incluido todos los subtemas sin diferenciación, se han identificado 26 términos que cumplían los requisitos establecidos (al menos debían haber aparecido 2 veces en un único año). Estas 26 palabras clave más utilizadas en la muestra global se han agrupado en cuatro grandes bloques de términos: geográficos, sociopolíticos, conceptuales y científico-metodológicos.

El primer bloque de términos geográficos está compuesto por las palabras clave *africa*, *colombia*, *europe*, *israel*, *united kingdom* y *united states*. El segundo bloque sociopolítico está formado por las palabras clave *conflict management*, *cultural relations*, *human rights*, *institutional framework*, *political system*, *social conflict, sustainable development* y *sustainable development goal.* El tercer bloque conceptual está compuesto por las palabras clave *decision making*, *education*, *geography education, holistic approach*, *language, philosophy, strategic approach* y *young population.* El último bloque científico-metodológico corresponde a las palabras clave *article, empirical analysis, interview* y *questionnaire survey.*

Todos los términos geográficos emergieron en momentos puntuales, con un interés muy breve a nivel temporal, a excepción de dos: *israel* y *united states*. Ambos términos geográficos comenzaron a tener relevancia en 2008, y esta se extendió durante una década después hasta 2018.

El término más relevante a nivel de constancia en su aparición a lo largo de los años es *human rights*, del bloque sociopolítico, cuyo interés comienza en 2005 y se extiende hasta 2020, con un punto álgido en 2012, en el centro del intervalo. También ha sido el tercer término que más veces ha aparecido en la muestra global (n=17). En el extremo opuesto está el término *sustainable development*, también del bloque sociopolítico, que aparece en 37 ocasiones, más del doble que *human rights*, pero cuyo interés se concentra en solo dos años (2019-2020). Así pues, ha sido un término emergente muy reciente y con un impacto muy elevado en los artículos más relevantes, situándose en como la segunda palabra clave más utilizada.

Por su parte, el bloque más numeroso es el conceptual con 9 términos, y dentro de los mismos destaca por su amplitud en la línea temporal *strategic approach*, cuya relevancia comienza en 2007 y finaliza en 2020, siendo más destacada hacia el final del intervalo (2017). El resto de los términos son emergentes, con una distancia menor entre el primer y el tercer cuartil, a excepción de *education*, cuyo interés se extiende entre 2011 y 2021, con una mayor relevancia al final del intervalo (2020) y *young population* (aunque su interés es anterior, entre 2006 y 2014).

La coincidencia de estos tres últimos términos sugiere que los conceptos *strategic approach*, *education* y *young population* constituyen elementos clave en la producción científica sobre ECM. La relación entre los tres conceptos enfatiza la relevancia de adoptar un enfoque estratégico en el ámbito educativo, especialmente dirigido a la población joven, siendo esta una piedra angular para la formación de ciudadanas y ciudadanos globales. Este hallazgo remarca la importancia clave de diseñar prácticas educativas y políticas que desarrollen las competencias en ECM desde una edad temprana.

5. CONCLUSIONES

En la presente investigación se ha realizado un análisis de la producción científica con una muestra de 500 artículos, corroborando que en la submuestra histórica en últimos años no hay artículos relevantes (por

la lógica del tiempo necesario para recibir citaciones), y destacando que el mayor número de artículos relevantes se concentra en el intervalo 2011-2016, alrededor de la adopción de los Objetivos de Desarrollo Sostenible en 2015; en este sentido también cabe mencionar que el subtema "educación para el desarrollo sostenible" es el que más citaciones acumula.

Con los análisis de autorías y de fuentes, se ha identificado que, a pesar de que hay un número elevado de autores y autoras que realizaron la investigación con otras personas, el promedio de personas por artículo es bajo (1,63), con lo que no son colaboraciones demasiado extensas. También se ha podido observar un grado de especialización alto, al menos en la submuestra histórica, de tal forma que ninguna persona publicó en más de un subtema, y solo 1 lo hizo en más de un subtema recientemente. Esta especialización también se aplica a las fuentes, de tal forma que solo tres revistas repiten publicando en más de un subtema.

El análisis reciente ha permitido identificar una serie de instituciones de investigación de países que han emergido en el último lustro, erigiéndose como los países de las autoras y autores de correspondencia de las investigaciones más relevantes en los últimos años, aunque con unas tasas de colaboración entre instituciones de diferentes países en las investigaciones bajas. Entre estos países destacan España, Chile e Italia en los tres primeros lugares.

Finalmente, un estudio de la evolución de las palabras clave más frecuentes ha permitido identificar cuatro grandes bloques de términos: geográficos, sociopolíticos, conceptuales y científico-metodológicos. Destaca la emergencia y brevedad de los términos geográficos (a pesar de la constancia de *Israel* y *nited states*). También destaca la amplitud del bloque conceptual, dentro de la cual se ha identificado la relevancia de la terna *strategic approach*, *education* y *young population*, que constituyen tres elementos clave de la producción científica sobre ECM, y que, juntos, enfatizan lo pertinente de adoptar un enfoque estratégico en el ámbito educativo, dirigiéndose a la población joven, diseñando prácticas educativas y políticas que fomenten las competencias en ECM desde una edad temprana.

6. CONTRIBUCIÓN DE AUTORES

Conceptualización: Autor/a1, Autor/a 2, Autor/a 3; Curación de datos: Autor/a1, Autor/a 2, Autor/a 3; Análisis formal: Autor/a1, Autor/a 2, Autor/a 3; Adquisición de fondos: Autor/a1, Autor/a 2, Autor/a 3; Investigación: Autor/a1, Autor/a 2, Autor/a 3; Metodología: Autor/a1, Autor/a 2, Autor/a 3; Recursos: Autor/a1, Autor/a 2, Autor/a 3; Supervisión: Autor/a1, Autor/a 2, Autor/a 3; Validación: Autor/a1, Autor/a 2, Autor/a 3; Visualización: Autor/a1, Autor/a 2, Autor/a 3; Redacción – borrador original: Autor/a1, Autor/a 2, Autor/a 3; Redacción – revisión y edición: Autor/a1, Autor/a 2, Autor/a 3.

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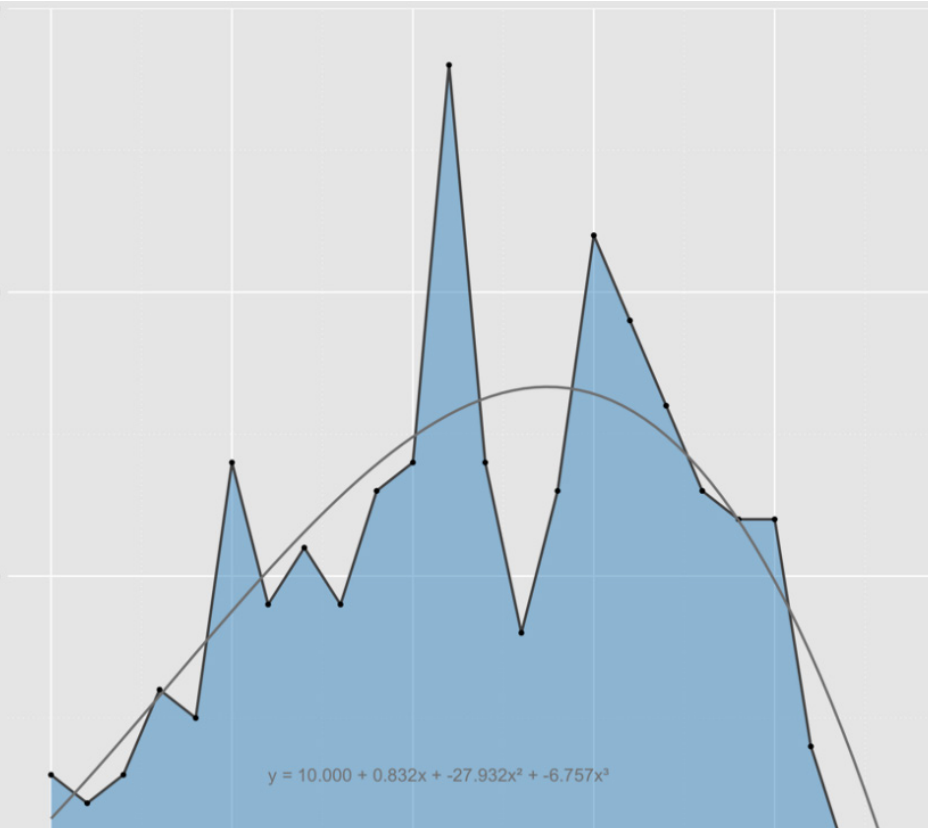
ANEXO A. DATOS COMPLEMENTARIOS

TABLA A1. Datos relativos a la obtención de las submuestras

Cadena de búsqueda	Registros Scopus totales		Excluidos de los 50 más citados			
	Sub. histórica (n)	Sub. reciente (n)	Sub. histórica		Sub. reciente	
			n	%	n	%
"Educación para el desarrollo sostenible OR "Education for Sustainable Development"	3308	1770	8	16%	14	28%
"Educación en derechos humanos" OR "Human Rights Education"	706	232	16	32%	17	34%
"Educación para la ciudadanía mundial" OR "Global Citizenship Education"	847	502	7	14%	3	6%
"Educación para la paz" OR "Peace Education"	1071	401	3	6%	7	14%
"Educación intercultural" OR "Intercultural Education"	1778	671	2	4%	5	10%

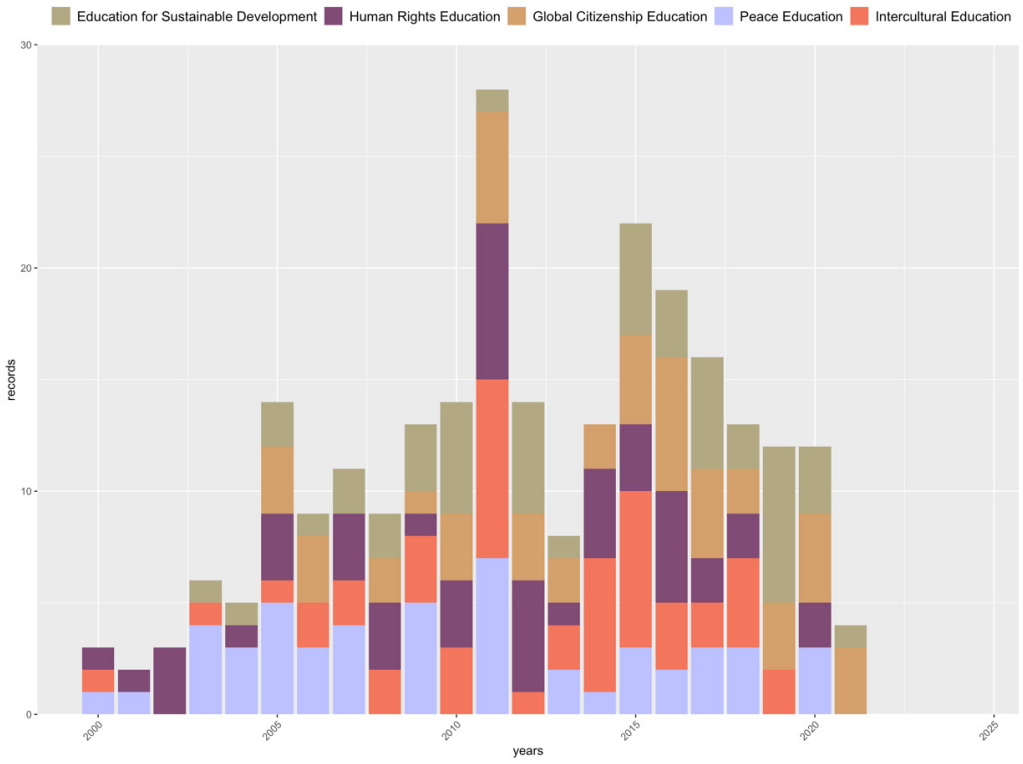
Fuente: elaboración propia

FIGURA A1. Distribución temporal de la submuestra histórica junto a su modelo de evolución



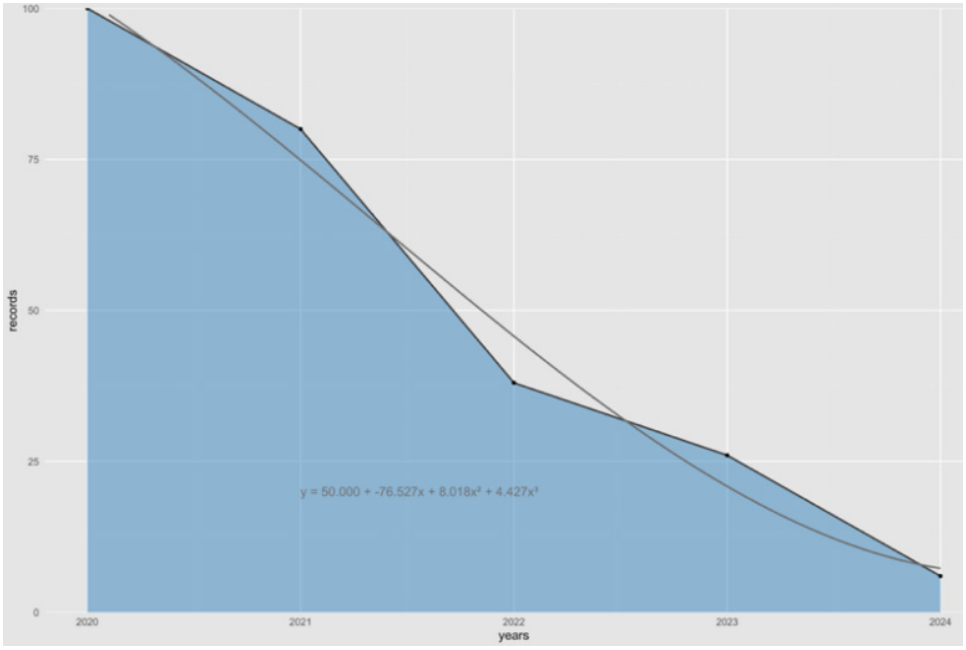
Fuente: elaboración propia

FIGURA A2. Aportación de cada subtema a la submuestra histórica



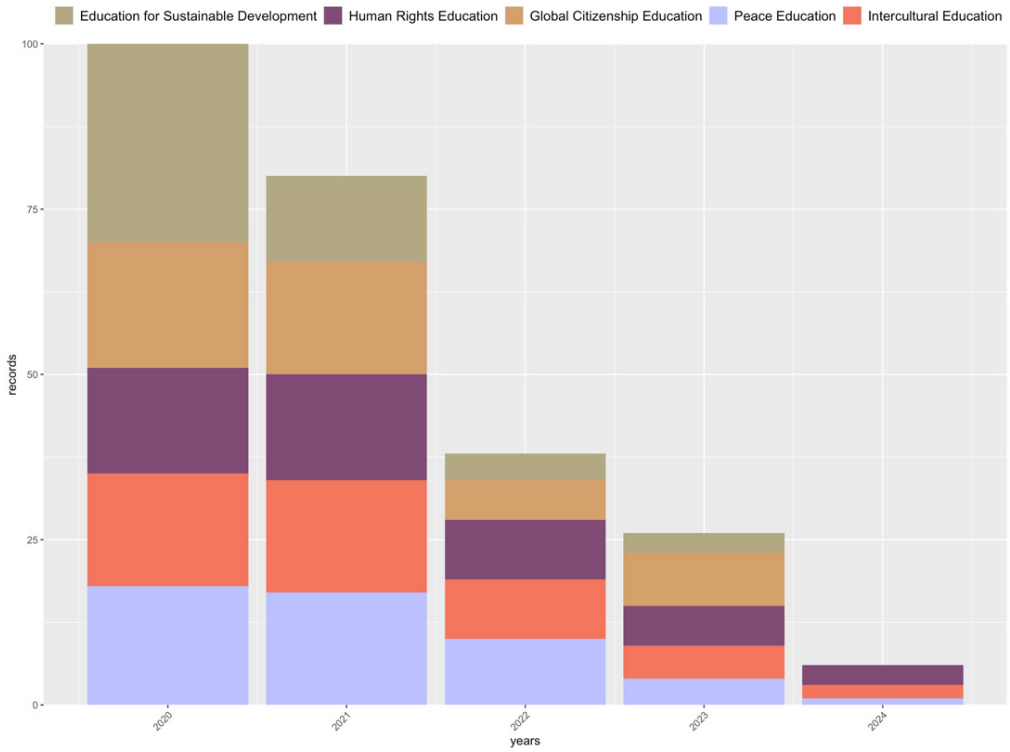
Fuente: elaboración propia

FIGURA A3. Distribución temporal de la submuestra reciente junto a su modelo de evolución



Fuente: elaboración propia

FIGURA A4. Aportación de cada subtema a la submuestra reciente



Fuente: elaboración propia

ANEXO B. REFERENCIAS DE LOS ARTÍCULOS MÁS CITADOS

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