RELATEC

Latin American Journal of Educational Technology

2025

Vol 24 (1)

ISSN: 1695-288X

Nodo Educativo (Research Group)
Publications Service – University of Extremadura (UEX)
University Network of Educational Technology (RUTE)

RELATEC
Latin American Journal of Educational Technology

2025 - Volume 24 (1)

Biannual Journal

Start date: 2002

http://relatec.unex.es

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https://doi.org/10.17398/1695-288X.24.1.9

RELATEC
Revista Latinoamericana de Tecnología Educativa

Received: June 25, 2024
Reviewed: November 12, 2024
Accepted: November 21, 2024

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ARTICLE / ARTÍCULO

Analysis of the Impact of Using a Gamified App for Spanish Spelling Practice in Primary Education

Análisis del impacto del uso de una aplicación gamificada para la práctica de la ortografía en español en Educación Primaria

Esteban Vázquez-Cano, Javier Fombona, Maria Belén Morales-Cevallos y Eloy López-Meneses

Abstract: This study evaluates the impact of GAUBI, a gamified app designed for Spanish spelling practice in primary education, using a quasi-experimental pretest-posttest design with 114 fourth-grade students. Participants were divided into three groups: traditional methods (control group), app use in classrooms (experimental group 1), and app use at home (experimental group 2). The app featured levels of arcade, research, and interactive fiction gameplay, scaling cognitive challenges to enhance learning. The intervention spanned three weeks, with participants engaging in structured app-based or traditional spelling exercises. Results showed that the group using the app at home achieved significantly higher spelling accuracy than those using traditional methods or app-only classroom approaches. Statistical analyses confirmed the superior effectiveness of home-based app use. The Binomial Effect Size Display highlighted notable improvements in specific spelling categories, such as complex letter combinations and accent rules. Discussion centered on the benefits of integrating gamification and ubiquitous learning tools in education, emphasizing the app's adaptability and immediate feedback, which encouraged independent learning and sustained motivation. The study advocates for blending traditional and gamified approaches to foster comprehensive spelling competence, supporting educators with analytics-driven insights. The research underscores the app's potential to address broader curricular goals, including sustainable development objectives.

Keywords: Gamification, Spelling Instruction, Mobile Learning, Primary Education, Educational Technology.

Resumen: Este estudio evalúa el impacto de GAUBI, una aplicación gamificada diseñada para la práctica de ortografía en español en Educación Primaria, utilizando un diseño cuasi-experimental con pretest y postest, y una muestra de 114 estudiantes de cuarto curso. Los participantes se dividieron en tres grupos: métodos tradicionales (grupo de control), uso de la aplicación en el aula (grupo experimental 1) y uso de la aplicación en el hogar (grupo experimental 2). La aplicación incluía niveles de juego tipo arcade, investigación y ficción interactiva, escalando desafíos cognitivos para potenciar el aprendizaje. La intervención duró tres semanas, con los participantes realizando ejercicios estructurados basados en la aplicación o métodos tradicionales de ortografía. Los resultados mostraron que el grupo que utilizó la aplicación en casa alcanzó una precisión ortográfica significativamente mayor que aquellos que usaron métodos tradicionales o la aplicación exclusivamente en el aula. Los análisis estadísticos confirmaron la efectividad superior del uso de la aplicación en el hogar. El tamaño del efecto mostró mejoras notables en categorías específicas de ortografía, como combinaciones complejas de letras y reglas de acentuación. La discusión se centra en los beneficios de integrar herramientas de gamificación y aprendizaje ubicuo en la educación, destacando la adaptabilidad de la aplicación y su retroalimentación inmediata, que fomentaron el aprendizaje autónomo y una motivación sostenida. El estudio aboga por combinar enfoques tradicionales y gamificados para fomentar una competencia ortográfica integral, apoyando a los educadores con análisis basados en datos. La investigación resalta el potencial de la aplicación para abordar objetivos curriculares más amplios, incluidos los relacionados con el desarrollo sostenible.

Palabras clave: Gamificación, Enseñanza de la ortografía, Aprendizaje móvil, Educación Primaria, Tecnología Educativa.

1. Introduction

Orthography is a fundamental component of the Spanish learning process, and mobile technology has been providing resources for orthographic learning for several years. However, a digital orthographic learning system that substantially improves students' orthographic skills has yet to be established. Digital orthographic learning is shaped by pedagogical and didactic proposals developed by many educators. These proposals are based on the educational use of social networks, microblogging applications, and the appropriate use of the spell-check tool in word processors, among other methods. Additionally, numerous websites and applications available on both the Android and Apple stores enable audiovisual work on orthographic content through gamified proposals. In this article, we will analyze the didactic functionality of the GAUBI App (https://www.gaubi.fun/), which is the result of the R&D project titled: «Gamification and Ubiquitous Learning in Primary Education. Development of a Competency and Resource Map for Teachers, Students, and Parents (GAUBI)» (RTI2018-099764-B-100). Its design and development have been approached from a theoretical-practical perspective, with a foundation in gamification, to offer an interactive, accessible, sustainable, safe, attractive application with a clear curricular connection for teaching Spanish orthography in Primary Education.

1.1. The Teaching of Orthography: From Paper Methods to Technology

According to the Common European Framework of Reference for Languages (CEFR), «orthographic competence entails the knowledge and skill in the perception and production of the symbols that comprise written texts» (Council of Europe, 2002, p. 114). Therefore, orthography is an essential aspect of linguistic and communicative competence in Spanish, as correct writing enhances written communication and reading comprehension. The significance of this is reflected in the foundational knowledge (content) of the Royal Decree of Minimum Teaching Requirements for Primary Education, which stipulates the following content under «3. Processes»: the production of written text through orthography based on textualization and automatic correction, individual or group work strategies that promote planning, revision, and self-correction of activities, in addition to correct writing accompanied by digital tools (Royal Decree 157/2022, p. 80).

Similarly, the orthographic component is integral to the objectives of basic education in both Primary and Secondary Education, impacting all areas and subjects of the curriculum from a cross-curricular perspective (LOMLOE, 2020). Article 19 of the LOMLOE (2020) delineates the pedagogical principles for the Primary Education stage, emphasizing the cross-curricular approach to reading comprehension and oral and written expression in all areas. In this regard, the acquisition of orthography in Primary Education is a crucial aspect, as it is during this stage that students lay the essential foundations for their development and application in written texts, making it an essential learning element connected to all areas.

Furthermore, it is important to highlight that the orthographic component, since the massive advent of technology, has adopted various methodological approaches. However, new challenges such as textisms and abbreviations have also emerged, complicating the consolidation of correct orthography when writing on screens in almost all languages (Finkelstein & Netz, 2023; Gómez-Camacho et al., 2023). According to the Royal Spanish Academy (RAE, 2010), orthography establishes the graphemes and rules for accentuation, punctuation, sounds, abbreviations, and the use of uppercase and lowercase letters in writing. This facilitates adequate linguistic and communicative competence in the production of written texts and aids in improving interpersonal and socio-professional relationships by demonstrating proper language use. The learning of orthography involves two fundamental spheres: the first is content-based, where the student must know the fundamental rules governing the orthographic system—in this case, Spanish. However, the most crucial aspect is the didactic and methodological approach used both inside and outside the classroom to develop orthographic knowledge and, most importantly, to ensure students' correct application in writing. Orthographic learning also contributes to the development of memory, attention, reasoning, auditory capacity, and visual skills (Rodríguez & Sánchez, 2018).

In this context, achieving adequate orthographic competence depends on various variables, including pedagogical methods, reading, continuous practice, feedback, and the student's critical analysis when composing their writings, as well as the socio-cultural and economic level of their families, among many other variables (Villacres Arias et al., 2020). It is important to note that methods for learning orthography differ among languages, as they do not share the same phonological system. In the case of Spanish, there are 24 phonemes—5 vowel sounds and 19 consonant sounds—and 24 letters or graphemes. This lack of correspondence between the graphic system and the pronunciation of certain consonants is the primary cause of difficulties in writing and correctly learning Spanish orthography. In contrast, other languages like English present a much more complex orthography due to phonetic inconsistencies and a large number of exceptions. Consequently, English-speaking children require significantly more time and effort to acquire orthographic skills because of the intrinsic difficulty involved in memorizing multiple spellings for the same sound, considering numerous exceptions.

Orthography can be approached from a literal (letters), accentual, or punctual perspective. In the context of this study, we will address a fundamental aspect of initial orthographic learning: literal orthography. To achieve an adequate understanding of literal orthography, it is essential to be familiar with the rules governing the use of letters according to the norms established by the Royal Spanish Academy and the connection between the idealized pronunciation through phonemes and their corresponding letters (Belduma et al., 2020).

For learning literal orthography, traditional approaches are still widely employed by many Primary Education teachers. These approaches involve the verbal or written transmission of rules and exercises to correct errors through phonetic exercises such as dictation or gap-filling, and the correction of poorly written texts using textbooks, and in other cases, workbooks or reinforcement sheets that promote automatization (Gómez, 2007; Bustos, 1995; Martínez, 2004). Although these traditional methods may be effective in the initial stages of learning, their continued use can often hinder the consolidation of correct practical application in students' writing. As Catalá (2009, p. 1) mentions, «traditional orthography teaching does not achieve the fixation of students' learning; in certain practices, instead of preventing orthographic errors, they contribute to solidifying them.»

This traditional approach has been evolving towards a communicative approach based on contextualized learning, where different communicative situations are proposed, and a holistic reflection is made on the various phonological, morphosyntactic, and pragmatic elements affecting the text. In this context, orthography is one of the elements reflected upon to improve written expression and communicative competence (Barberá et al., 2001; Blanco et al., 2018). These approaches are typically based on active methodologies that favor the design of learning situations where the student must contextualize the application of rules for correct written expression. This requires, in addition to individual effort, fostering collaborative and self-regulated environments and generating direct and active contextualized activities that can be applied in academic, personal, or socio-professional contexts. In such contexts, a much more constructive relationship between theory and practice is established (Espinoza & Campuzano, 2019).

1.2. Characteristics of Effective Mobile Applications for Orthographic Learning

From a socio-communicative perspective grounded in active methodologies, activities based on information and communication technologies, social media microblogging, and gamified activities in various formats such as apps (Romero Oliva et al., 2018), websites (Gómez-Camacho, 2007), chatbots (Vázquez-Cano, 2021), artificial intelligence (Mosqueira-Rey et al., 2023), and interactive quizzes in applications like *Kahoot*, *Quizizz*, *Quizlet*, etc., are being integrated and are increasingly perceived as more necessary by educators (Caballero-Mariscal, 2024). For these resources, particularly mobile applications, to effectively support orthographic learning, they must meet several fundamental characteristics, including adequate data protection, being free of charge, having a clear and direct curricular connection, providing feedback, and being adaptable to the students' learning paces, among other essential requirements (Vázquez-Cano et al., 2023ab).

In the current market, there are various apps available for learning orthography, yet they exhibit different limitations that hinder their proper application in Primary Education: (1) *Wlingua*: This app offers Spanish courses designed for speakers of various levels, including specific lessons on orthography and grammar. The main limitations are the restricted access to content; a subscription is required to unlock all functionalities. It also contains ads in the free version. (2) *Duolingo*: A popular language-learning application that includes Spanish lessons focused on orthography, grammar, and vocabulary. The main limitation is its very limited focus on orthography, as it is more geared toward general language learning. (3) *Learn Spanish Vocabulary*: Primarily designed to improve vocabulary, this app also includes exercises that reinforce correct spelling of Spanish words. The main limitations are that it contains ads in the free version and requires a purchase to remove ads and unlock more content. (4) *Busuu*: This language-learning app offers Spanish courses with orthography, grammar, and conversation exercises. The main limitations are that the free version is limited and requires a subscription to access all content, and it contains ads in the free version. (5) *Lingodeer*: Provides Spanish courses covering orthography, grammar, and vocabulary through structured lessons and interactive exercises. The main limitations are that the full version requires a subscription and it contains ads in the free version. (6) *Memrise:* A language-learning app that includes Spanish lessons with a focus on visual and auditory memory, useful for improving orthography. The main limitations are that the full version requires a subscription and it contains ads in the free version. (7) *SpanishDict*: A reference app for learning Spanish that includes dictionaries, verb conjugators, and lessons on grammar and orthography. The main limitations are that the full version requires a subscription and it contains ads in the free version. (8)

Ortografía Español: A specific app for practicing Spanish orthography through games and interactive exercises. The main limitations are that the full version requires a subscription and it contains ads in the free version.

Generally, these applications share common limitations: many require a subscription to access all their features and contain ads in their free versions. Additionally, not all of them explicitly guarantee data protection or inform if the servers hosting the data are authorized by educational authorities, which is crucial for safe use in educational environments. In this regard, mobile applications designed to teach Spanish spelling must be effectively crafted to maximize learning. Scientific literature underscores several key characteristics these applications should possess: (1) Interactivity: Mobile apps should be interactive, enabling students to actively engage in writing activities, correction, and spelling practice (Kukulska-Hulme, 2016). (2) Immediate Feedback: Immediate feedback is crucial for spelling improvement, allowing students to correct errors promptly (Greene, 2015; Butler et al., 2008; Salas-Rueda et al., 2019). (3) Adaptability: Apps should adjust to each student's competence level, offering exercises and lessons appropriate to their skill level (Clark et al., 2016; Ochoa-Guaraca et al., 2017). (4) Variety of Exercises: Apps should provide a wide array of exercises covering different aspects of spelling, such as accentuation, letter usage, and diacritics, among others (Chen, 2009). (5) Motivation: Gamification elements like rewards and scores can enhance students' motivation to practice spelling (Buckley & Doyle, 2016).

The use of mobile applications for orthographic learning can enhance student autonomy, as their ubiquity allows practice at any time and place (Al-Razgan & Alotaibi, 2022). When these applications are designed with appropriate cognitive scaling, they enable each student to progress at their own pace and focus on areas needing improvement (Pechenkina et al., 2017). Integrating gamification elements, such as achievements and challenges, can further increase students' motivation to practice orthography as if it were a game (Lyytinen et al., 2021). For these applications to be truly effective, they must provide immediate feedback, allowing students to learn efficiently from their mistakes and develop more personalized learning, which is particularly beneficial for those with varying levels of orthographic skill (Papadakis & Kalogiannakis, 2017). Linked to this feedback, tools should also facilitate tracking and evaluation so that students, parents, and educators can monitor progress. This enables the identification of areas requiring more attention and adjustments in the curriculum (Booton et al., 2021). Effective applications are not designed to replace traditional education but rather to complement it by assimilating theoretical-practical concepts that require continuous practice (Meyer et al., 2021).

Furthermore, the integration of mobile applications for orthographic learning in both classroom and home environments provides complementary benefits that amplify their educational impact. While classroom use allows for guided learning under teacher supervision, fostering collaboration and immediate clarification of doubts, at-home use enhances student autonomy and promotes self-directed learning (Arokiasamy, 2017). The flexibility of practicing at home enables students to engage with orthographic exercises at their own pace, adapting to their individual needs and schedules (Al-Razgan & Alotaibi, 2022). Studies show that the combination of these contexts creates a more holistic learning experience, as students can revisit and reinforce concepts introduced in the classroom during home practice (Zaheer et al., 2018). Additionally, home use of gamified applications, featuring achievements and challenges, sustains motivation beyond the structured classroom setting, encouraging consistent engagement (Lyytinen et al., 2021). This dual-context approach allows educators to leverage technology's adaptability, ensuring personalized feedback and progress tracking, ultimately enhancing learning outcomes (Drigas, & Pappas, 2015). Finally, the use of these digital resources must ensure sustainable and ethical usage, guaranteeing data protection for all users (Vázquez-Cano, 2022; 2023).

1.3. Educational Experience and Research Design

GAUBI is a serious game, designed to facilitate learning of orthographic rules through gameplay. To achieve this, three different game levels have been designed, each corresponding to distinct pedagogical functions.

First Level: This level is the most mechanical and aims to exercise basic cognitive functions such as recognition and identification of elements, attention, and memory. This is accomplished through Arcade-type game mechanics, fostering an automatism connected with the gameplay itself.

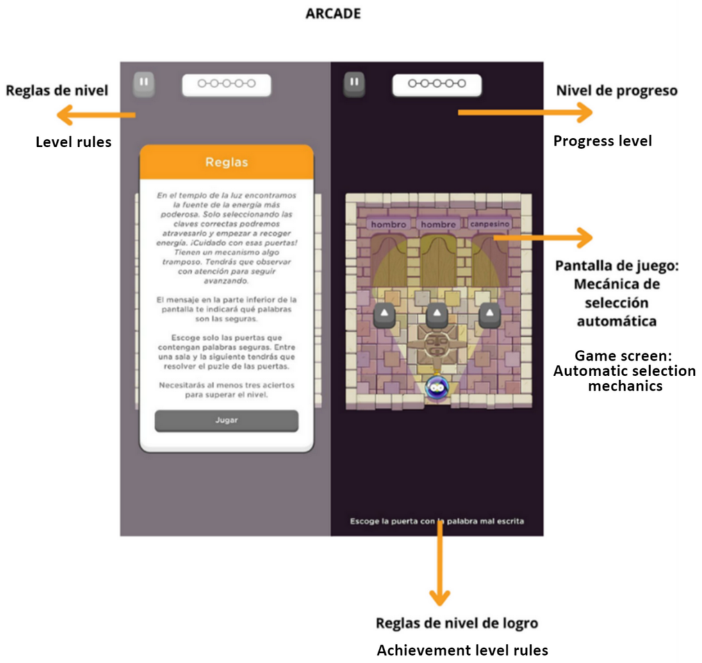


Figure 1. Level 1 of the game (Arcade).

Second Level: We aim for an exploratory phase involving decision-making regarding the sequence of selecting elements and completing challenges. Here, cognitive function expands to include association and linking of ideas, implementing learned concepts through various game mechanics such as selection, deletion, and more.

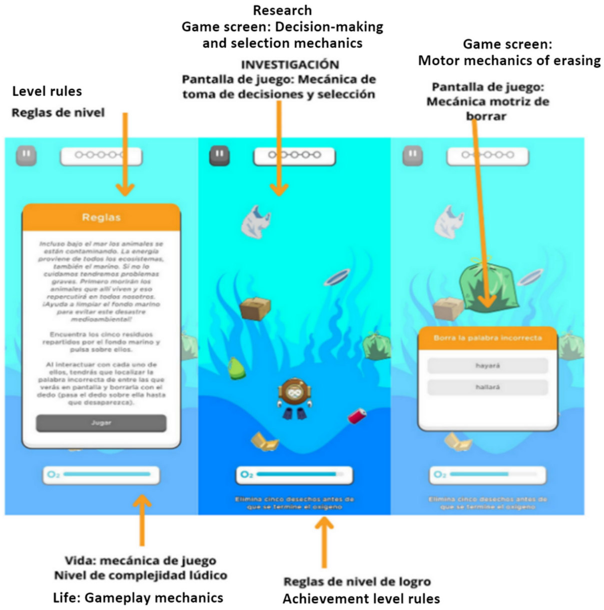


Figure 2. Level 2 gameplay (Research).

Third Level: Grounded in metacognitive processing, this level aims to encourage students to apply and create content independently. Students make decisions within an interactive fiction framework that allows them to complete the storyline based on mental health (SDG).

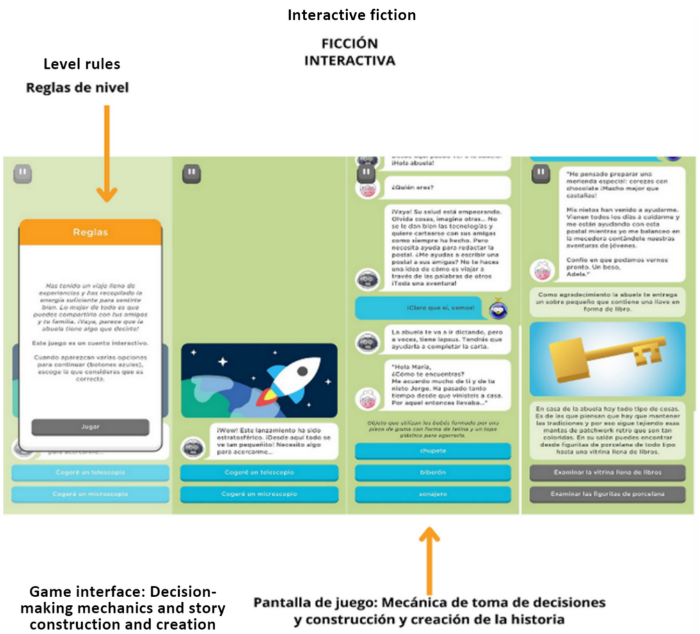


Figure 3. Level 3 gameplay (Interaction-Creation).

In all levels, there are three achievement levels marked by stars where mechanics and rules change:

a) The first level involves identifying the correct answer.

b) The second level involves identifying the incorrect answer.

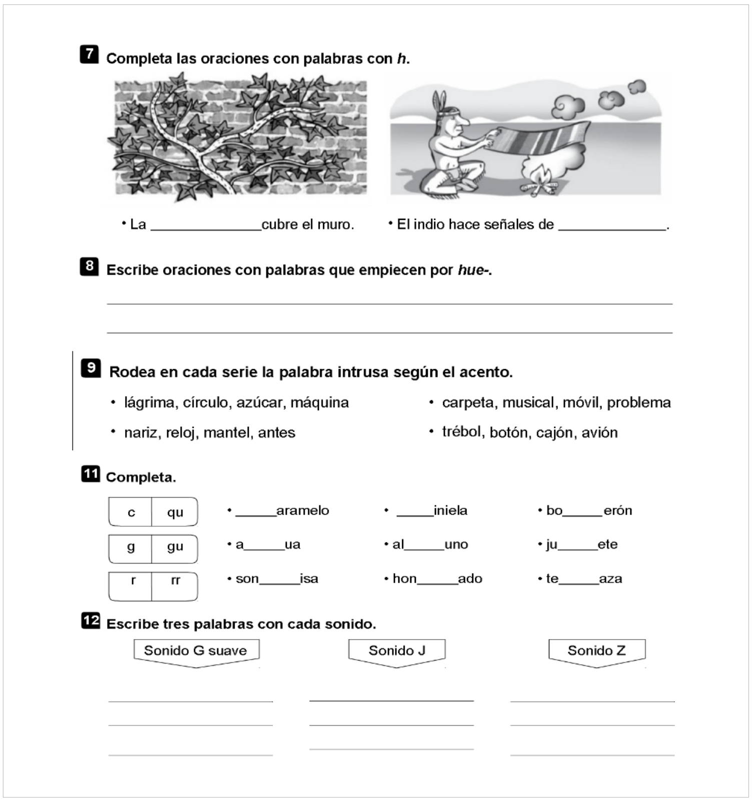
c) The third level involves distinguishing the correct answer from common errors that primary school students often confuse. Additionally, each level has 5 progress points displayed at the top, which light up in green/red depending on whether the answer was correct or incorrect.

In some levels, an additional gameplay element is introduced in progress, involving a «life» mechanic to increase the difficulty of the second level of gameplay. Figure 4 illustrates the progression map through different games and themes. Below is an example of students working in the classroom with the GAUBI app (Figure 5).

Figure 4. Game development roadmap.

Figure 5. Students playing the GAUBI app.

The control group students employed a traditional method consisting of exercises and spelling worksheets derived from the Santillana textbook, as depicted in Figure 6.


7 Completa las oraciones con palabras con *h*.

• La ____________cubre el muro. • El indio hace señales de ____________.

8 Escribe oraciones con palabras que empiecen por *hue-*.

9 Rodea en cada serie la palabra intrusa según el acento.

• lágrima, círculo, azúcar, máquina • carpeta, musical, móvil, problema
• nariz, reloj, mantel, antes • trébol, botón, cajón, avión

11 Completa.

c	qu	• _____aramelo	• _____iniela	• bo_____erón
g	gu	• a_____ua	• al_____uno	• ju_____ete
r	rr	• son_____isa	• hon_____ado	• te_____aza

12 Escribe tres palabras con cada sonido.

Sonido G suave | Sonido J | Sonido Z

Figure 6. Traditional spelling worksheets and exercises model.

2. Method

The study involved the use of the GAUBI app for practicing spelling content in fourth and fifth grades of primary education across various Spanish schools, within the context of a proof-of-concept to evaluate the effectiveness and functionality of the GAUBI app in teaching spelling during the academic year 2023/24. The research design aims to address the following questions:

1. Which of the three methods for practicing spelling is most effective in students' academic performance?
2. To what extent does the integration of a serious game for spelling practice enhance learning outcomes when used in the classroom compared to its use at home, and how do both settings compare to a control group?

The study employed a quasi-experimental quantitative framework utilizing a pretest-posttest design with convenience sampling. Initially, the normal distribution was assessed using the Kolmogorov-Smirnov Test. Subsequent to this, potential disparities between the pretest and posttest outcomes were scrutinized employing ANOVA and ANCOVA methodologies (Rosenthal & Rubin, 1982). Additionally, BESD (Binomial Effect Size Display) was employed to present the outcomes across spelling categories (Rosenthal, 1991).

2.1. Experimental process

Prior to the experiment, learners received two instructional sessions on using the GAUBI app. Subsequently, they completed pre-tests and pre-questionnaires. The experimental groups (EG1 and EG2) received 40 minutes of instruction using the GAUBI learning system, in which the difficulty of the spelling minigames increased as the learner's cognitive ability improved. Learners could only advance to the next level upon achieving the predetermined goal; otherwise, they were required to repeat the appropriate level until they attained the necessary knowledge. The app was implemented over a three-week period, with students engaging in 15-minute sessions each week. This resulted in a total of 15 classroom sessions and 225 minutes of gameplay, providing ample time for interactive learning and skill development. Depending on the mini-game in which students were engaged, the gameplay occurred individually, in pairs, or in groups of four. The estimated distribution of game modes during the classroom sessions was as follows: 50% of the time was spent playing individually, 25% in pairs, and 25% in groups of four. In contrast, control group 1 (CG1) practiced spelling using a traditional learning system based on paper activities with teacher guidance. At the end of the learning session, all learners were required to complete a 45-minute post-test and post-questionnaires.

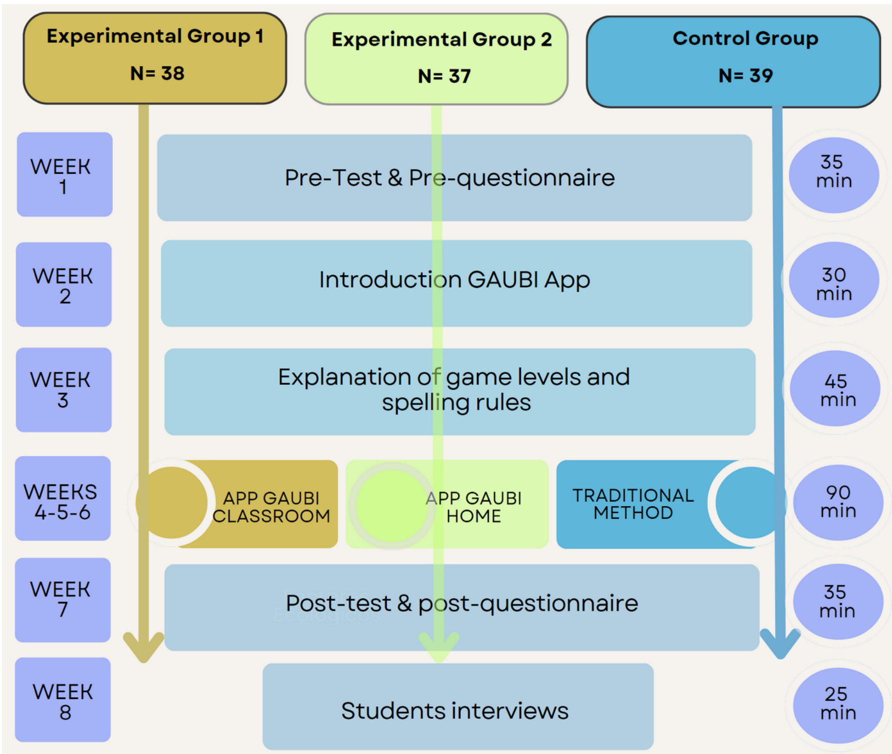


Figure 7. illustrates the experimental process in this study.

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The first week of the research was dedicated to conducting a spelling proficiency test focusing on letter orthography. The test comprised three parts: a dictation of 100 words, correction of a dictation with 100 misspelled words, and a third exercise where students had to choose between two options of correctly and incorrectly spelled words to complete a sentence. During the second and third weeks, students were introduced to the GAUBI app, including its features, functionalities, avatars, and gameplay mechanics. Students and families were informed of the maximum allowed usage time of 15 minutes per session in both the classroom and at home during the three-week duration of the study. An 8-inch tablet was used in the classroom, while at home, students used devices available to them (n=18 smartphones from parents / n=10 tablets, all of which were 8-inch tablets used in the classroom). Since both parents and students were informed about the procedure, the game-based activity was conducted autonomously by the students at home, adhering to the established time limits and without any assistance from other family members. In the fourth, fifth, and sixth weeks, theoretical and practical explanations were conducted in three different formats: Group 1 used the app in class, Group 2 used the app at home, and the control group used traditional exercises, worksheets, and dictations. Three different teachers participated, with an average age of 37.2 years, comprising two females and one male, each with over 7 years of teaching experience. Post-tests were conducted in the seventh week to assess students' progress, followed by interviews with students in the eighth week.

2.2. Participants

The participants in this study were fourth graders from six classes in three primary schools in Spain, which were automatically divided into three goups accordinto to the method used to parctise the spelling EG1 (App-Gaubi-Classroom), EG2 (App-Gaubi-Home), and CG1 (Traditional exercises-Classroom-Home). The study sample comprised 114 students (9-10 years old). To check whether the sample size was reasonable, a post hoc statistical power analysis was conducted using the G*Power 3.1 software (Faul et al., 2007). The calculated power value was 0.88, more than the basic level value of 0.80. Hence, the sample size of the present study was in line with the statistical requirements. Besides, every participant in this experiment was informed that he or she was allowed to withdraw at any stage, with no negative impact on the schooling. The experiment used anonymous methods to collect data and protect personal information. All data were only used for research purposes and would not affect the participants' studies and lives. In addition, the research has obtained the approval of the committee for projects involving human research of the Universidad Nacional de Educación a Distancia (Reference: 40-SISH-EDU-2023).

2.3. Instruments

The primary objective of the pre-test was to evaluate learners' prior knowledge of Spanish spelling. In contrast, the post-test aimed to assess their learning outcomes following the completion of the corresponding instructional methods. Both tests were comparable in complexity and comprised identical question types and scoring systems. Each test had a maximum score of 100 points, including 15 multiple-choice questions (30%), two texts for identifying spelling errors (30%), ten fill-in-the-blank questions (20%), and two spelling dictation tasks (20%). Two experienced Spanish teachers collaborated in developing the test content, which was validated by a third teacher to ensure validity and reliability. All three teachers reached a consensus to confirm that the pre- and post-test content adequately assessed the learners' proficiency. The Cronbach's alpha values for the pre-test and post-test were 0.81 and 0.83, respectively, indicating acceptable internal consistency (Cortina, 1993). The semi-structured interview questions consisted of 15 likert questions (e.g., «I prefer playing the app over doing written spelling homework at home». «With the app, I feel more motivated to learn spelling»). The Cronbach's alpha value was 0.89. Two open questions were added to measuse the most positive and negative aspects of the experience (https://forms.office.com/e/KJr6RsGy1X).

3. Results

First, normality (Table 1) and homogeneity of variances (Table 2) were calculated to ensure that ANOVA and ANCOVA tests could be conducted.

Table 1. Test of Normality.

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pre-test Score	Control	.121	9	.200*	.946	9	.758
	Exp. 1-2	.132	9	.201	.941	9	.832

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction.

It is verified that the dependent variable must be normally distributed for each combination of factors and covariates.

Table 2. Test of Homogeneity of Variance.

		Levene Statistic	df1	df2	Sig.
Pre-test Score	Based on Mean	1.475	3	32	.384
	Based on Median	1.269	3	32	.307
	Based on Median and with adjusted df	1.269	3	29.933	.307
	Based on trimmed mean	1.477	3	32	.382

The learners' pre-test results revealed that the three groups had equivalent levels of Spanish spelling proficiency prior to the experiment ($F_{(2,111)} = 2.94$, $p = 0.06 > 0.05$). The sample displayed a normal distribution, as indicated by the Kolmogorov-Smirnov test ($D = 0.07$, $p = 0.21$). Furthermore, the homogeneity of regression slopes was confirmed ($F = 1.11$, $p = 0.33$), demonstrating that ANCOVA analysis could be appropriately applied.

The ANCOVA analysis of the learners' spelling achievement is presented in Table 3. There was a significant difference in spelling achievement among the three groups ($F(2,111) = 10.10$, $p = 0.000 < 0.001$). Post hoc analyses using LSD tests revealed that learners in EG2 had significantly higher spelling acquisition than those in CG1 and EG1. Additionally, CG1 performed significantly better than EG1. These results indicate that practicing spelling with the GAUBI app significantly enhanced learners' spelling acquisition compared to using the app in the classroom (EG1) or traditional paper activities at home (CG1).

Table 3. The ANCOVA result of the practicing spelling.

Variable	Group	N	Mean	S.D	Adjusted-mean	F	Post-Hoc
	(1)EG2	37	83.41	13.99	81.72	10.101***	(1)>(2)
Post-test	(2)CG1	39	72.72	16.71	75.11		(1)>(3)
	(3)EG1	38	69.82	19.89	66.51		(2)>(3)

***P<0.001

To identify the importance of the effect of the EG2 (App-Gaubi-Home), we present the Binomial Effect Size (Table 4). The average scores are depicted alongside the Cohen's d effect size and the correlation coefficient (r) to measure the magnitude of the intervention effect and the strength of association, respectively. The results underscore that the intervention implemented in EG2 (0,56) was the most effective in enhancing orthographic skills, as evidenced by the higher mean scores and the greater effect size. This implies that the strategies utilized in EG2 should be further explored and possibly integrated into broader educational practices. Below, the box plot of the post-test results for the three groups is presented in Figure 8.

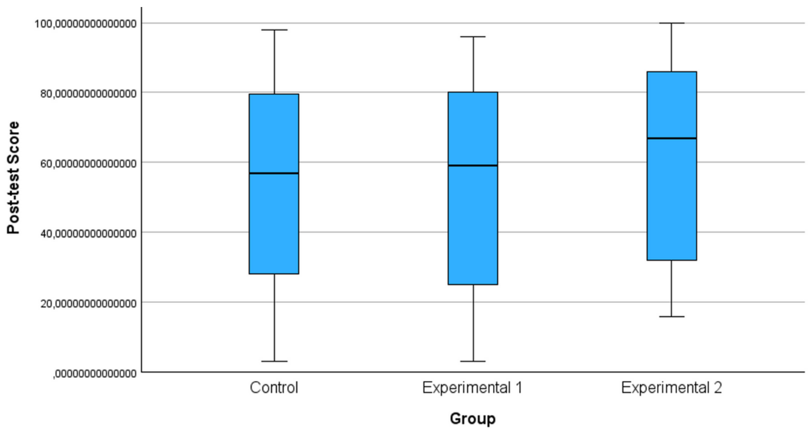

Figure 8. Boxplot graph experimental and control group comparison.

Table 4. Binomial Effect Size Displays of spelling categories.

Spelling categories	EG_2 Mean	EG_1 Mean	CG_1 Mean	Game Levels
Words with za/ce/ci/zo/zu	78	75	70	Arcade
Words with ca/que/qui/co/cu	80	78	75	Arcade
Words with ge/gi/je/ji	72	70	65	Arcade
Words with ga/gue/gui/go/gu/güe/güi	87	85	80	Arcade
Words with br and bl	82	80	75	Arcade
Words with bu-, bur-, bus-	76	74	70	Arcade
Words with hie- hue-	85	83	78	Arcade
Always write m before p and b	79	77	73	Arcade
Write c before e/i	74	72	68	Research
Write qu before e/i	80	78	74	Research
Words ending with -d or -z	86	84	79	Research
Words with ll	81	79	75	Research
Words with g	77	75	71	Research
Words with j	82	80	76	Research
Words with gu or gü	84	82	77	Research
Words with r/rr	88	86	81	Research
Words with b	79	77	73	Research
Words with h	83	81	76	Research
Words with y	87	85	80	Research
Forms ending in -aba	89	87	82	Research
Words with initial b	78	76	72	Research
Words with x	75	73	69	Research
Words with v	82	80	76	Research
All the rules	84	82	77	Interactive Fiction
Cohen's d	0.56	0.42	0.44	
r	0.27	0.20	0.21	

The findings indicate that experimental group two (EG2) achieved the highest effect size (0.56), suggesting that a blended approach incorporating the app is more effective for orthographic learning than traditional paper-based methods or using the app exclusively in the classroom. Using the app at home offers distinct advantages over classroom-only or paper-based learning. Home use allows students to practice at their own pace, reinforcing skills beyond the constraints of classroom time.

Moreover, the app's variety of mini-games provides a broad spectrum of orthographic challenges, facilitating the development of both foundational and complex skills. This independent learning model encourages self-regulation, which is essential for fostering deeper engagement and mastery. It enables students to revisit and reinforce difficult concepts at their convenience, supporting sustained learning. Such continuous, out-of-class practice bridges the gap between theoretical knowledge and practical application, ultimately enhancing long-term retention and skill acquisition.

4. Discussion

Gamification and serious games have become popular tools in education, especially in teaching first and second languages. This research has focused on evaluating whether didactic strategies based on serious games can significantly enhance Spanish spelling learning among primary education students. We have observed that the methodological approach yielding the most significant results involves using the application as a complement to traditional homework in printed or audiovisual formats. This approach is characterized by its ubiquity, mobility, and gamification through cognitive scaling based on spelling challenges, which also provides learning analytics. This enables feedback and guidance for student learning while ensuring data protection and the ethical, sustainable use of the application. Additionally, the challenges and mini-games have been designed to address the treatment of Sustainable Development Goals integrated with the development of spelling competence.

The results indicate that experimental group 2 improved the spelling component related to letter accuracy through the lexical content introduced in the app and the audiovisual format for word identification. In this regard, other studies have shown that gamification can enhance the acquisition of new vocabulary and retention of new words, as students prefer these approaches over more traditional methods such as printed worksheets or flashcards (Ahada, 2021; Yu, 2023). Another fundamental element underpinning the app's development is game-based learning, which gamifies aspects of learning that require extensive practice, and which traditional methods struggle to sustain student attention and motivation. The use of games, even if not inherently serious, can also help increase motivation, attention, and positive attitudes toward language learning, as recently highlighted in studies on the educational use of the popular game 'Among Us' (Casanova-Mata, 2023). Therefore, gamification has proven effective in teaching various aspects of language, including grammar and overall linguistic proficiency, suggesting it may also be beneficial for improving spelling practice (Wen, 2023; Brazo Millán et al., 2018).

The ludified approach to spelling combined with traditional methods has a positive impact on competencies related to writing, composition, pronunciation, and text interpretation (Tovar Rua et al., 2024). By employing techniques that enhance attention, motivation, and visual memory, improvements in visual attention and memory are achieved (Paredes, 1997, p. 616), while reducing rote learning of unnecessary spelling rules in primary education in favor of continuous practice on manifest errors in common letters and words (Carratalá, 1997). Another challenging aspect in improving correct spelling acquisition is the necessary evaluation and feedback from teachers, which often proves difficult. Tools like the one analyzed in this study enable feedback from families and teachers by providing student performance reports linked to assessment criteria established in the curriculum. In this sense, it adheres to the recommendations set forth by Cassany et al. (1994, p. 415): «the spelling points that are necessary for each group of students should be addressed according to their knowledge and difficulties.»

Different studies demonstrate that the use of mobile applications across both home and school environments fosters continuous learning and facilitates the development of a cohesive and integrated educational experience (Camilleri &

Camilleri, 2019). This dual-context approach enhances learning outcomes by blending structured, teacher-led instruction with opportunities for independent exploration. Meyer et al. (2021) underscore the importance of classroom-based use, where educators can provide scaffolding, immediate feedback, and opportunities for collaboration, which collectively support the development of critical cognitive and interpersonal skills. Complementing this, research by Khaddage et al. (2016), Cruaud (2018), and Murray (2014) highlights the benefits of at-home use, which enables learners to study autonomously, engage at their own pace, and revisit challenging material—key factors for reinforcing knowledge and fostering self-regulation. Additionally, Papadakis and Kalogiannakis (2017) emphasize that linking structured classroom learning with the gamified, flexible features of mobile applications enhances motivation and engagement. This alignment enables students to apply and deepen their understanding in diverse settings, ultimately maximizing the educational impact of mobile learning technologies.

Another aspect where games have demonstrated greater effectiveness is when they are linked to challenges based on research, interaction, and creation (Somoano García et al., 2018). Primarily, through metacognitive processing aimed at applying and creating content by students, making decisions in an interactive fiction that allows them to complete the story based on mental health (SDGs). Several authors have shown the effectiveness of certain didactic strategies based on technology to improve spelling learning that enable the application of theoretical knowledge through visual, auditory, playful, and above all, dynamic content that generates greater motivation among students (Chaverra-Fernández et al., 2016; Guamán Paida, & Álvarez Lozano, 2022).

5. Conclusion

This research has clearly demonstrated that the use of the GAUBI app for teaching spelling can enhance student motivation and the acquisition of literal spelling skills through a cognitive scaling approach with different levels of interaction using arcade-style games, research, and interaction. These elements allow spelling practice to be addressed from a playful perspective linked to the curriculum, with an ethical and responsible approach to data protection and integration with other cross-curricular elements such as Sustainable Development Goals. Furthermore, the application facilitates feedback on the teaching-learning process and provides teachers and families with student progress reports, enabling support and enrichment of aspects that may have been limited in the development of spelling learning through gameplay.

Undoubtedly, at this educational stage, students not only need to know spelling rules but also understand their application in various contexts. This requires continuous practice enriched through diverse methodologies that sustain constant engagement without generating boredom due to the typology of exercises and activities linked to spelling work. When spelling skills are solidified in these formative years, the benefits are substantial: students gain confidence, minimize errors, and foster correct language use regardless of the printed or digital context, ultimately improving both linguistic competence and communicative skills among primary education students.

Availability of data and materials

The dataset of the study can be consulted in the following link (Harvard Dataverse: https://doi.org/10.7910/DVN/B0UQSM)

Funding

This work has been developed within the framework of the «Proof of Concept» Project entitled: «GAUBI-ORTO. Evaluation of a digital model and application for sustainable, ubiquitous and gamified learning of Spanish spelling in Primary Education» (PDC2022-133185-I00). State Program to Promote Scientific-Technical Research and its Transfer, of the State Plan for Scientific and Technical Research and Innovation. Ministry of Science and Innovation (Spain). Funded by the European Union-Next Generation EU.

Ethics approval and consent to participate

The research has obtained the approval of the committee for projects involving human research of the Universidad Nacional de Educación a Distancia (Reference: 40-SISH-EDU-2023).

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Revista Latinoamericana de Tecnología Educativa, 24(1)
https://doi.org/10.17398/1695-288X.24.1.29

RELATEC
Revista Latinoamericana de Tecnología Educativa

Received: April 30, 2024
Reviewed: December 9, 2024
Accepted: December 17, 2024

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ARTICLE / ARTÍCULO

Analysis of Pedagogical-Digital Competence in Teacher Educators: Practices and Perceptions

Análisis de la competencia didáctico-digital en formadores de futuros docentes: prácticas y percepciones

Lorena Berríos-Barra & Margarita Calderón-López

Abstract: The digital competence of future teachers has been a concern of public policy in Chile, reflected in the development of Information and Communication Technology (ICT) standards that emphasize the importance of incorporating digital technologies pedagogically in initial teacher education (ITE). A lack of digital pedagogical skills has been reported among teachers in training (Silva et al., 2019). The development of digital teaching competence (DTC) also involves those who train teachers. This study focuses on exploring the beliefs of university professors to analyze their impact on the use of technologies in ITE. A Sequential Exploratory Design (DEXPLOS), combining qualitative and quantitative methods, was conducted with teacher trainers. Content analysis was performed in the qualitative phase (n=13), and factorial analysis in the quantitative phase (n=67) using a questionnaire. The results reveal advances in the ethical and digital citizenship aspects of the DTC of the participating teacher trainers but do not suggest a reflective approach during practice, which affects the development of agency among future teachers. In summary, the didactic integration of digital technologies is not evident. The guidelines for didactic-digital competence highlight the importance of promoting and integrating these skills into teaching practices as an essential requirement to improve the conditions of children and adolescents facing the uncertainty of the 21st century.

Keywords: Digital literacy, Multiple literacies, Computer Literacy, Teacher Education, Beliefs.

Resumen: La competencia digital de los futuros docentes ha sido una preocupación de la política pública en Chile que se ha materializado con la elaboración de estándares TIC y que declaran la relevancia de incorporar pedagógicamente las tecnologías digitales en la formación inicial docente (FID). Se ha señalado una falta de competencias pedagógicas digitales en el profesorado en formación. El desarrollo de la competencia digital docente (CDD) atañe también a quienes forman profesores. El estudio se centra en explorar las creencias de docentes universitarios para analizar su impacto en el uso de las tecnologías en la FID. Se llevó a cabo un DEXPLOS (Cual-cuan) con formadores de docentes. Se realizó un análisis de contenido para la fase cualitativa (n=13) y factorial para la fase cuantitativa (n=67) a través de un cuestionario. Los resultados si bien revelan un avance en los aspectos éticos y de ciudadanía digital en la CDD de los docentes participantes, no se visualiza un enfoque reflexivo en las prácticas, que impacta en el desarrollo de la agencia de futuros profesores. En síntesis, no se percibe la integración didáctica de las tecnologías digitales. Dentro de las orientaciones para una competencia didáctico-digital, se revela la importancia de su promoción e inserción en las prácticas docentes como requisito esencial para mejorar las condiciones de niños y adolescentes que enfrenten la incertidumbre del siglo XXI.

Palabras clave: Alfabetización digital, Alfabetización múltiple, Competencia digital, Formación del Profesorado, Creeencias.

1. Introduction

The digital competence of future teachers has become a significant issue in public policies and education. The use of digital tools in the classroom is essential for fostering the skills and competences needed for everyday life (OECD, 2019), better addressing the rapid advancement of knowledge, meeting the challenges of the future, and developing critical thinking to combat disinformation (Frau-Meigs et al., 2017). In this context, the digital literacy of future teachers becomes increasingly important in addressing the digital divide and the lack of adequate digital infrastructure in schools (Rivera Polo, 2023).

However, several studies highlight a lack of pedagogical skills in using technologies in Initial Teacher Education (Silva et al., 2019). Cabello et al. (2020) conclude that the curricula and graduate profiles of Primary and Secondary Pedagogy programs at the national level do not incorporate digital technologies, even at the introductory basic level. On the other hand, students in Initial Teacher Education (ITE) are unfamiliar with using digital technologies as a pedagogical tool (Ayala, 2015; Sandoval Rubilar et al., 2017) and recognize that their teacher training has been based on the most basic and conventional practices, such as using PowerPoint, organizing work, and planning classes (Brun & Hinostroza, 2014).

The digital teaching competence of teachers in training is an important aspect in higher education programs and institutional profiles, as well as for the professors who implement these guidelines. In this respect, it is important to investigate the conceptions of professors involved in ITE and their pedagogical practices in teaching technology.

In the case of Chile, the limited development of digital teaching competence (DTC) in teacher training has promoted studies outlining follow-up actions for universities in implementing ICT standards (Silva, 2012). Similarly, research has shown that the pedagogical dimension of DTC is rarely present, and there is a need for training in digital technologies (Badilla-Quintana et al., 2013). Other studies have identified a discrepancy between the digital practices of pedagogy students and their pedagogical knowledge of digital technologies (Ayala, 2015; Sandoval Rubilar et al., 2017; Silva Quiroz, 2017), as well as their lack of autonomy in integrating these technologies to construct pedagogical knowledge (Cerda et al., 2017).

According to Modelski et al. (2019), the digital fluency of teachers and their teaching practices enable students to make connections that enhance their understanding of digital resources and technologies from a didactic perspective. In this regard, teacher trainers must be a model for the use of digital technologies (Santos et al., 2022) and encourage their use through didactic strategies, so that future teachers can incorporate and internalize digital technologies into their emerging professional practice.

The existing literature on DTC in teacher training is limited. A review by Esteve-Mon et al. (2020) concludes that digital competency models present a traditional view of the use of technological tools and that university professors, on average, have a low level of DTC. Similarly, knowing how to use ICTs does not necessarily equate to their appropriate pedagogical use.

In line with this, digital competence in university professors must include both a personal component and a professional commitment to its development and the generation of new knowledge (García Vélez et al., 2021). Therefore, it is crucial to move beyond the technical use of digital technologies toward a more reflective, collaborative, and inclusive application.

Studies on digital competences in university professors agree that faculty members have low digital competence in assessment and feedback (Santos et al., 2022; Torres Barbazal et al., 2022). This contrasts with the emphasis on the didactic use of technologies (Santos et al., 2022) and the medium-to-high level of digital competence, which, however, is weak in innovation (Cateriano-Chávez et al., 2021).

In general, the aforementioned studies emphasize the need for a more pedagogical integration of ICTs and methodologies that challenge their implementation (Cateriano-Chávez et al., 2022), especially in those responsible for training future teachers for 21st century society. Therefore, the challenge is to transition from digital teaching competence to didactic-digital competence for teachers in training.

1.1. Digital teaching competence and multiple literacies: A digital and critical didactic framework for ITE

The concept of digital teaching competence has been approached from various perspectives, highlighting the importance of didactics, mastery of digital skills, and the development of digital skills (Esteve-Mon et al., 2020; García Vélez et al., 2021; Verdú-Pina et al., 2023).

This article addresses DTC from a holistic and critical perspective, considering digital technologies as tools for reflection and didactic action. This view aligns with the definition proposed by Castañeda et al. (2018), who characterize it as «holistic, situated, oriented towards roles of performance, function and relationship, systemic, trainable and constantly developing» (p. 14). This conceptualization of DTC is closely related to everyday teaching practices and incorporates a dimension of social engagement. According to Esteve-Mon et al. (2016), DTC is not limited to the possession of skills, knowledge, and attitudes, but rather implies «the ability to put them into action, mobilize them, combine them and transfer them, to act in a conscious and effective way with a view to a purpose» (p. 47). This approaches a didactic dimension, as it involves engaging critically by integrating digital technologies into teaching practices.

As a way of addressing digital teaching competence from a didactic perspective, the pedagogical approach of multiple literacies has been considered (Cazden et al., 1996). This approach is linked to inclusion and social justice, proposing epistemic movements and selecting strategies based on context and promoting student agency (Cope & Kalantzis, 2023).

The pedagogy of multiple literacies is a framework that proposes knowledge processes to address experimentation, the conceptualization of theory, critical analysis, and the application of the knowledge addressed in classes. Additionally, this pedagogy encourages the appropriation and transformation of the world through its impact on its own context (Kalantzis et al., 2019). In this sense, it is possible to incorporate a critical dimension for reflection on the context and the possibilities of social transformation through the realization of projects in communities. These projects allow students to apply their knowledge in the real world, promoting meaningful learning and engagement with their environment.

1.2. Teaching perceptions to promote the didactic use of digital resources

To understand DTC from a didactic approach, it is essential to consider the perceptions that university professors have about digital technologies within the framework of ITE. This exploration allows teachers to deepen their understanding of the use of digital technologies in the classroom, an aspect that has been identified as an obstacle to the effective integration of technologies in the educational process (Ottestad et al., 2014; Tondeur et al., 2017; Voogt et al., 2013).

It should be noted that this negative perception of the use of digital technologies contrasts with the favorable self-perception that university professors have of their own digital competence (Cateriano-Chávez, 2022). This dissonance highlights the need to understand the underlying conceptions that inform teaching practices in relation to digital technologies. To design more effective training strategies, it is necessary to promote an integrated and meaningful use of technologies in the classroom.

In the case of this study, perceptions have been considered from the extrinsic and intrinsic aspects that influence the belief system (Fons & Palou, 2014). In other words, the perceptions related to both professional practice and the action and the principles in that frame this action were considered. The latter involves implicit theories that constrain the way teachers approach and interpret different teaching-learning situations (Pozo et al., 2006, p. 70).

2. Method

This study aims to investigate the perceptions of university teaching staff regarding the use of digital technologies in the pedagogical field.

The general objective of the research is to analyze the perceptions of university professors who train teachers in the use of digital technologies from the pedagogical approach of multiple literacies. The study seeks to explore whether these beliefs influence the conception and use of technologies in their teaching practices for teacher training.

In this regard, three objectives have been proposed to guide the study:

a) Analyze the personal and professional use of digital technologies by university professors.

b) Describe the digital skills of teachers based on the DigCompEdu dimensions and their technological fluency.

c) Identify the degree of knowledge that faculty members have about multiple literacies in ITE.

A sequential exploratory design (DEXPLOS) with a qualitative emphasis was employed and its results were explored through an extended sample by using a questionnaire in a quantitative phase.

The sample for both the qualitative and quantitative phases is non-probabilistic (Hernández Sampieri et al., 2014) and purposive, as the aim of the research was to explore the conceptions of professors working in ITE. For the selection of the sample, the minimum requirement was to teach a pedagogy program and have at least three years of experience training teachers at the university level. The general criteria were based on the literature reviewed regarding the level of competence and use of digital technologies in ITE. Participants in the qualitative phase consisted of 13 professors from a public university. These participants taught on the degree programs of Pedagogy in Primary Education (6), Scientific-Humanistic Secondary Education with a specialization (3), Pedagogy in Kindergarten Education (2), Pedagogy in Secondary Education in Biology and Chemistry (1), and Pedagogy in Secondary Education in Mathematics and Physics (1). The characteristics of the participants are detailed in Table 1.

Table 1. Description of participants.

Participant	Description				
	Sex	**Age**	**Field of expertise**	**ITE experience (<10, >10)**	**ICT training**
D1	F	65	Didactics	>10	No
D2	F	55	Language	>10	Yes
D3	F	50	Psychology	<10	No
D4	F	56	Early Childhood	>10	No
D5	M	35	Mathematics	<10	Yes
D6	M	68	Curriculum	>10	No
D7	F	38	Language	<10	No
D8	M	38	Chemistry	<10	Yes
D9	M	60	Mathematics	>10	Yes
D10	F	40	Mathematics	<10	Yes
D11	F	55	Philosophy	>10	No
D12	F	55	Biology	>10	No
D13	F	38	Language	<10	No

The qualitative phase included interviews and observations of classes or digital didactic resources. The analysis of the interviews and observations of classes and didactic resources was conducted using mixed coding that integrated dimensions from the literature review and emerging categories aligned with the objectives of the study. The analysis was performed using Atlas.ti.v.8.4.5 software. The observation of the resources, which were provided by the participating professors, was carried out based on criteria that incorporated the dimensions of DTCs and digital fluency, in accordance with the European Framework for Digital Competence for Educators, or DigCompEdu (Redecker, 2017). Additionally, two dimensions were included: the didactic use of digital technologies, grounded in the pedagogy of multiple literacies, and pedagogical interaction. The resources included classes (6), presentations (7), pedagogical material in PDF format (7), and digital pills (2).

For the quantitative phase, a questionnaire was applied, developed based on a literature review and the dimensions derived from the qualitative phase. The following dimensions emerged from the first phase of the study: use of technology and incorporation of digital tools (referring to the university professor as a technology user), digital technology for ITE (referring to the planning and execution of learning experiences with digital technologies), mastery of technology (addressing digital training) and the role of technologies in the classroom (exploring professors' beliefs and attitudes about technology and their role as teacher trainers).

The questionnaire was validated using Cronbach's alpha coefficient, which yielded a reliability statistic of .898, indicating internal consistency (Rodríguez-Rodríguez & Reguant-Álvarez, 2020) and an adequate level of reliability. A description of the items in the questionnaire can be found in Table 2.

Subsequently, university teacher trainers were invited to participate. The invitation was extended via social media, instant messaging, and email, specifying criteria for participation: university professors teaching in a pedagogy program, having at least 3 years of experience training teachers at the university level, and using digital technologies in ITE. In this phase, a total o 67 professors participated, representing public (n=46) and private (n=21) universities that met the selection criteria established in the qualitative phase.

For the questionnaire, a multivariate analysis was conducted using SPSS Statistics v.27 software and the exploratory factor analysis technique. This technique enables the identification of internal attributes not directly observable in the data, which underlie the relationships among a set of variables (Walker & Maddan, 2012), enabling the expression of a case.

Analysis models were developed based on the study objectives to explain the conceptions of digital technologies from a pedagogical approach, thereby expanding the results of the qualitative phase. For analyzing pedagogical resources, an observation guideline was prepared, incorporating areas of competence from DigCompEdu (professional commitment, teaching, and learning) and the processes of the multiple literacies pedagogical approach by Kalantzis et al. (2019), which include experimenting, analyzing, conceptualizing, and applying.

For both phases, participants were engaged through informed consent to ensure adherence to ethical principles, including rational understanding, voluntary acceptance, and the reversibility of the process (Villarroel Soto, 2018).

3. Results

The results address perceptions and beliefs regarding digital technologies, organized around three core concepts aligned with the research objectives: personal and professional use of digital technologies by university educators, digital teaching competence of teacher trainers, and the degree of knowledge that faculty members have about multiple literacies for ITE.

3.1. Personal and professional use of digital technologies

Qualitative data analysis categorized the interviewees as technology users. The participants were characterized based on their level of technology training and their self-perception as users. These dimensions revealed that the teacher trainers interviewed primarily developed their digital competence through self-directed learning. Seven professors reported a lack of formal technological training during their university education (D2, D3, D4, D5, D6, D7, D11). Only three educators indicated (D2, D8, D9) receiving formal instruction during their undergraduate studies, with a disciplinary distinction favoring scientific fields. Educators from scientific disciplines noted that technology played a more significant role in their undergraduate training, regardless of their age (D8, D9, D10).

The absence of formal university training in technology underscores the importance of self-directed learning in professional development. It should also be noted that most professors indicated that they used digital tools and Office programs, such as email, Word and PowerPoint, throughout their academic careers. PowerPoint, in particular, was frequently highlighted as a tool they continue to use consistently, in some cases even representing an advance from older technologies. This reliance reflects a comfort zone and the belief that teacher training aligns with transmitting content in a secure and fixed medium. The collaborative aspect of self-directed training was also highlighted, involving students (D1, D3, D4) or colleagues (D3, D5).

Similarly, most professors categorized themselves as basic-level technology users, employing traditional and/or commonly used tools in daily life, academia, and professional contexts. While not considering themselves experts, most of them affirmed that they use technology on a daily basis and that it has been a significant part of their pedagogical practice over the years:

> «I consider myself a good user. I'm not afraid of using technology; in fact, I like to use it for basic things in my personal life. I'm not very sophisticated in its use» (Professor D10).

In this sense, although the use of technologies was present in pedagogical practice in the pre-pandemic educational context, they were not central to teachers' pedagogical practice.

However, the 2020 health crisis is understood as a turning point in their educational trajectory regarding technology. The context of classes during the pandemic required teachers to become familiar with or deepen their use of new digital platforms such as Classroom, Google Forms, Moodle, and YouTube. These tools were used to interact didactically with students, both for the transmission or creation of content and for evaluative processes. Furthermore, it is notable that most reported using and mastering tools such as Zoom and Meet to establish telematic communication with their students. In this context, Zoom was highlighted for group work because it replicates in-person collaboration in an online format.

To qualify these results, the quantitative phase provided a broader characterization of university professors' personal and professional use of technologies. It is worth noting that the factorial analysis of the questionnaire was conducted using models that explain the consistency of the questions based on their correlation. The components account for the consistency of the correlation between the model's questions. In this way, consistency is reinforced and indicates a trend. For better understanding, consistency is achieved with values above 0.80 or 0.90 (Rodríguez-Rodríguez & Reguant-Álvarez, 2020). In the case of the models, the predominant factors are those with values above this threshold and in correlation with two components.

Among the models obtained through factorial analysis, two predominant factors emerged regarding the use of digital technologies for communication with students and teaching. Regarding the first factor (component 1), university professors consider the use of technologies in the classroom a relevant tool for communicating with their students. One of the biases that may have been a conditioning factor was the remote classroom setting during the pandemic, wherein digital technologies were used to foster a more emotional connection with students.

The other predominant factor is the use of digital technologies to record activities with an emphasis on assessment (component 2). This reflects the use of analytics to assess learning rather than to enhance DTC in future teachers, as shown in Table 2.

Table 2. Personal and professional use of digital technologies based on their importance.

Factor	Component 1	Component 2
Tools for teaching	.874	-.114
Importance of using digital technologies in the classroom	.821	-.127
Communication with students	.761	-.338
Assessment and recording of activities	.706	.257
Use of technologies	-.075	.953

3.2. Digital competences of university professors on ITE

Most professors reported that the use of digital tools increased as a result of the health crisis. On the one hand, they described having to train in the use of different platforms. Additionally, they noted the need to innovate in how they conducted their classes and maintained contact with their students.

Regarding the configuration of the digital competences of the interviewees, it is significant that these competencies largely stemmed from informal experiences rather than their educational training or the institutions where they work. In this regard, the results of the quantitative phase revealed criteria used by university professors to incorporate digital technologies into their teaching practices, as well as aspects of digital citizenship that, it could be said, are not formally taught.

Within the observed models, the independent variables reflected the ethical criteria used by university professors when incorporating a digital tool. Both models identified the communality of two factors each (Table 3), allowing for the differentiation and analysis of the predominant factors in the development of digital teaching competencies among this group of university professors.

Table 3. Criteria for incorporating digital tools and ethical aspects.

Factor	Component 1	Component 2
Interaction between teachers and students	.816	.220
It is free to use or has a low cost for the educational institution	-.089	.727
Talking about plagiarism and intellectual property on the internet	.360	-.775
Using chat or audio to obtain feedback from the students	.812	-.075

According to Table 3, the criteria for using and selecting digital technologies can be distinguished. These technologies are perceived as facilitators of relationships with students and of learning, as they enable smooth interaction and personalized feedback, reflecting a pedagogical rather than formative or technical bias in how tools are viewed for assessment purposes.

Regarding the criteria for selecting technologies, teachers prefer to use tools that do not incur costs or are low-cost for the educational institution. For instance, Zoom is one of the most widely used platforms as it is provided by the institution.

In terms of aspects related to digital citizenship, teachers demonstrate an ethical and responsible approach to the use of technologies. For example, most faculty members value discussions with students about plagiarism and the misuse of online information. Additionally, during remote classes, they established recording protocols that required consent, an issue that is linked to citizenship and the ethical use of digital resources.

Moreover, interaction with students is important for university professors, who select the most suitable digital tools for this purpose, such as using audio and chat channels during synchronous classes.

3.3. Degree of knowledge that faculty members have about multiple literacies for ITE

This objective focused on identifying university professors' knowledge about multiple literacies as a didactic approach to digital technologies. It corresponds to a pedagogical dimension of knowledge, integration, and interaction with technologies for teaching purposes.

In the results of the qualitative phase, the analysis of the interviews revealed two key dimensions: motivation and attention and the didactic use of technologies to achieve learning objectives.

The importance of motivation and attention highlights the use of digital technologies to foster engagement with the content delivered during classes. Specifically, it is noted that visual and audiovisual presentation software enables content to reach a large number of students simultaneously, with fewer distractions, as the professor selects and organizes the information to sustain attention:

> «It helps me convey things in a less boring way, but there is also very interesting audiovisual material and I can share it with all of them at the same time. It's like bringing in a recess or something more festive or playful» (Professor D3).

The professors recognize that technologies are an integral part of students' lives outside the university teaching environment, making their inclusion in teaching a way to address their interests. In this regard, digital technologies provide communication channels that students use in their daily lives:

> «The use of computers, the use of other tools, the use of cell phones in class—it's something tied to the students. I think that for learning to be meaningful, we need to connect with their interests, and their interests lie in that direction» (Professor D7).

In this way, the faculty members perceive the relevance of digital technologies in ITE primarily in two aspects: the connection with students and as part of their world, culture, and imaginaries. From the perspective of teacher training, they believe that future teachers should be trained in the use of digital tools to establish links between their teaching practices and the university context.

In this regard, digital technologies are seen as more playful and relatable tools in connection with students' cultural practices and interests. This relationship facilitates the presentation of content and the achievement of teaching objectives:

> «Creating visualizations, engaging in a semiotic process (of semiosis and noesis) to be able to present the concept, having to verbalize the concepts you are working on, the situations, or how to solve a problem, or how you reflect on ... they are support tools for achieving your objectives» (Professor D10).

From a didactic perspective, digital technologies are seen as tools that facilitate the exploration and use of various resources to strengthen the connection between the teacher, the learning objectives, and the curricular content developed in classes. This aspect is reinforced when comparing the use of digital technologies with other resources, as it is pointed out that they foster the understanding of content that could not be achieved with other means (for example, calculations that cannot be done by hand or with a calculator). Using such technologies would allow the exploration and analysis of content and processes that cannot be done using analog resources:

> «If I didn't have these technological means, it would only be what I could do by hand, and that, of course, limits the exploration of the behavior of some functions, of some variables» (Professor D9).

This disciplinary distinction is particularly emphasized in the Biology-Chemistry Pedagogy course, where it is noted that digital technologies encourage reflection on worlds that would otherwise be inaccessible because they are not perceptible to the human eye (animations, simulations, and illustrations of abstract content are inferred). It is underscored that it is necessary to reflect on the didactic use of technology in the classroom:

> «If you understand didactics as this space where the subjects relate to the resources, the curriculum, the teachers, and their intentions, clearly technologies play a really key role because they are in that corner of resources» (Professor D8)

In general, there is evidence of a positioning of digital technologies as tools that should be used from a critical-reflective standpoint rather than a merely technical one.

Regarding the knowledge processes related to multiple literacies, the observation of pedagogical practices revealed that experimentation of the new in relation to the known is the knowledge process that occurs most frequently. However, only 53.8% of teachers connect with students' previous experiences or present a resource that is linked to their prior knowledge. In this sense, this aligns with the noted playful aspect of digital technologies. Nevertheless, only 38% of teachers engage in conceptualization with their students, as they generally lean more toward teaching than learning. The knowledge process of "analyzing" multiple literacies is developed by 30.7% of the teachers through resources and classroom activities with digital technologies.

On the other hand, the dimension that appeared the least frequently was the application, either creatively or appropriately, of the knowledge addressed in classes. Only one of the participating professors demonstrated this practice in their classes, and 30.7% approach it without fully implementing it. However, despite the digitalization of teaching during the pandemic, most professors fail to promote student agency in using and incorporating digital technologies. Therefore, the adaptation of content and how students have opportunities to transform the content they develop in classes remains unclear. This aspect is identified as one of the lowest among the dimensions analyzed.

However, in the analysis of the questionnaire, the impact that the digital tool has on students and the didactic interaction enabled by the tool is evident. Tools that enhance creativity and information management were also observed, as shown in the chart (Figure 1). A second model focused on the independent variable of experience with the digital tool, which revealed conceptions about the interactivity it enables and its potential as a didactic tool (Figure 2).

The figure 1 demonstrates that professors view digital technologies as tools that foster processes of autonomy and motivation, which influence learning processes. However, autonomy is one of the most valued aspects, more so than motivation.

Regarding tools that enhance creativity and interaction, the professors report using them when they foster didactic interaction. That is, when they foster connections between the resource and the student and among students themselves, and not just between teacher and students. This is explained by the characteristics of the resources. For example, Mentimeter allows students to share their own ideas and comments without necessarily requiring teacher intervention and in the case of Jamboard, students can work collaboratively without teacher intervention.

With regard to tools that promote creativity and management, most teachers associate them primarily with the use of Excel and Canva. It should be noted that Canva, unlike Excel, is characterized by its multimodal nature, which makes it a versatile tool for creating engaging and dynamic educational materials.

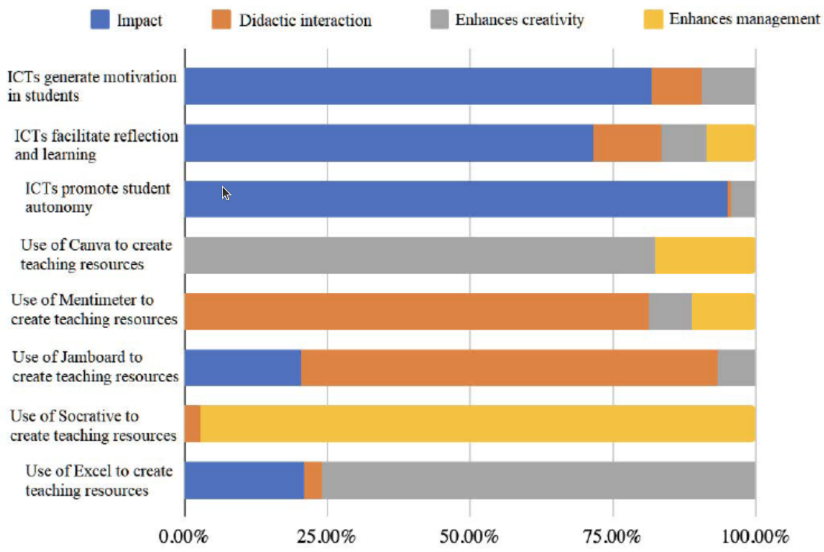

Figure 1. Interacción didáctica y herramientas que potencian la creatividad y la gestión de la información.

Regarding experience with the digital tool, the interaction is understood as a space for connection and relating with students, occurring within the framework of what the tools allow them to do. As the tool facilitates greater interaction with students, it is perceived as didactic (e.g., Zoom or Google Meet). In contrast, PowerPoint, YouTube, and multimedia videos are relevant insofar as their interactivity replicates the traditional classroom, as can be seen in Figure 2.

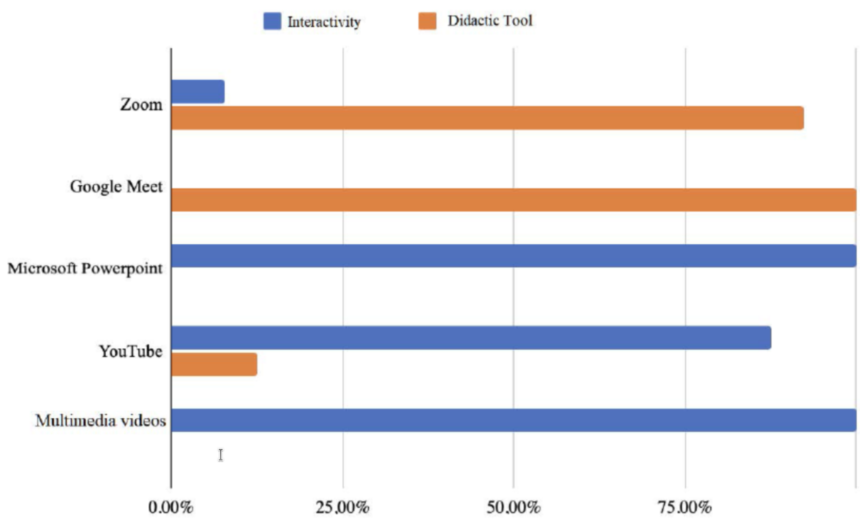

Figure 2. Concepción sobre la herramienta según la experiencia o conocimiento del docente universitario.

4. Discussion and conclusions

This study addressed teacher trainers' perceptions of the pedagogical use of digital tools in the university classroom to analyze their didactic digital competence.

Regarding the digital teaching competence of the participants, it is noteworthy that these competencies predominantly stem from informal experiences rather than from their formal training or the institutions where they work. These experiences shape their relationship with digital tools and their potential for interaction and didactic use. Furthermore, a clear distinction is made between the use of digital technologies pre- and post-pandemic and their impact on the relationship with digital technologies for teaching. In this regard, and given the importance of self-directed training, it can be inferred that the pandemic contributed to the teacher trainers' interest in deepening their knowledge about technology.

The participating faculty members express concern about the lack of systematic integration of digital technologies in ITE, as it currently depends largely on the initiative and individual training of each professor. While technologies are perceived as tools that facilitate learning in students considered digital natives, their current use mainly focuses on technical aspects, neglecting the reflective and intentional approach, which is an aspect that should be fundamental in their training. In this sense, ethical and citizen awareness emerges as a relevant aspect, as noted by Cateriano-Chávez et al. (2022).

The professors see themselves as users of technology, with a large majority of them reporting that they frequently use digital tools in initial teacher training. Thus, ICTs are a central or crucial element for the development of the classes they teach. The professors primarily use widely-known tools such as PowerPoint presentations or YouTube videos. While digital resources are employed to generate debates and reflections on various issues, it is unclear whether the teacher trainers instruct students on the use and understanding of these technologies. Instead, digital tools often seem to serve merely as channels or instruments to mediate dialogue, rather than being fully integrated into the educational process or fostering student agency. This situation contrasts with the ideal teaching model proposed by Santos et al. (2022), where digital technologies are used strategically to enhance learning and the development of critical skills in students.

Although the study has limitations, including a limited sample in the quantitative phase and the context in which it was conducted (pandemic and post-pandemic), it can be stated that the results obtained are significant and can guide the development of digital competence in initial teacher education, steering it toward a more holistic, integrative, and situated didactic-digital competence that emphasizes classroom teaching practices.

In this context, the results of this research confirm the importance of promoting digital competences that support the didactic use of technologies. Digital teaching competence (DTC) refers to the ability of teachers to effectively integrate their knowledge of digital technologies into the curriculum.

This integration should encompass the stages of planning, implementation, and assessment of teaching activities, with the objective of improving and facilitating the teaching process, as indicated by Esteve et al. (2016).

DTC implies that teachers consider their knowledge, attitudes, and skills about digital tools when planning their classes. Thus, the digital didactic integration of technologies would involve directing planning toward the learning objective so that future teachers have meaningful learning experiences and can integrate them into their own learning process. These aspects could be considered in future research aimed at gaining a deeper understanding of this integration in a larger sample and in more diverse application contexts.

The integration of digital technologies in education is an urgent necessity, as students are currently immersed in a world shaped by these tools. It is essential for teachers to take advantage of the opportunities offered by digital technologies to innovate in the teaching process, adopting a critical and reflective perspective on the tools they use.

For Chilean society, teachers with DTC are highly valuable. Although Chile has been a Latin American benchmark for the incorporation of programs to promote the integration of ICT in the school classroom (TALIS-OECD, 2018), there is still a long way to go in the incorporation of digital technologies as an integrated formative process that promotes the development of competencies in both students and teaching. The ability of teachers to integrate digital technologies into teaching contributes to the development of key competencies in students, which in turn improves the quality of education and active participation in society. Therefore, it is essential to include DTC in the curricula for education students in order to rethink training actions that ensure the integration of technologies, as suggested by Esteve et al. (2016), but also the ethical and critical aspects of their understanding.

When teachers are able to perform within a classroom applying DTC, the education of children and young people will be positively transformed, as their proper use «will condition, to some extent, the development of children's DC [digital competence] and how they will be able to become digitally competent citizens» (Santos et al., 2022, p. 50) to actively participate in society.

In summary, DTC involves both technical skills and a reflective pedagogical approach to the integration of technology, so that future teachers are able to incorporate new digital tools into teaching and promote their proper use.

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6. Annex I. Items and indicators of the questionnaire linked to the Digital Teaching Competence.

Ítem	Indicador
8.- How important is it to use ICTs in the classroom?	Where 1 is Not at all important and 5 is Very important
9.- Do you use ICTs in the classroom?	Yes (if you answer YES, please go to question 9.1 and then go to question 10 onward)
	No (if you answer NO, please go to question 10)
9.1 On a scale of 1 to 5 where 1 is Not at all important and 5 is Very important, please, indicate how important the use of ICT is for you for the following purposes:	Tools for teaching
	Communication with students
	Assessment and recording of activities
10. From the following reasons for the use of ICT in the classroom, select the three most important for your teaching work (where the first selection is the most important, the second selection is moderately important, and the third selection is the least important).	To encourage student motivation
	To encourage student attention
	To connect with students' daily practice
	They are necessary for educational work
	They allow transversal integration across disciplines
	They promote more dynamic interaction
	They facilitate administrative work related to teaching
	They support research processes
11.- How willing are you to incorporate digital tools into your pedagogical practice?	Where 1 is No willingness and 5 is Total willingness
12.- Of the ICT resources mentioned below. Select the level of use of each in your personal and/or work life (First selection – Very used, Second selection – Moderately used, Third selection – Rarely used).	Administration (Email, Moodle, Classroom, UCurso, etc.)
	Presentation (Power Point, Prezi, etc.)
	Pedagogical interaction (Menti, Simulations, Padlet, etc.)
	Communication (Zoom, Meet, Jipsy, etc.)
	Creation (Canva, Loom, Genially, etc.)
	Social interaction (Whatsapp, Facebook, Messenger, etc.)
	Assessment (Google Form, Baamboozlee, Kahoot, Socrative, etc.)
13.- For what reasons do you use ICT in your personal and/or work life? Select the 3 most used (First selection – Very used, Second selection – Moderately used, Third selection –Rarely used).	I use them now mostly for communication.
	I use them now mainly for presentation of content
	I use them now to create new resources (visual, sound, audiovisual, etc.)
	I use them now mainly for formative and summative assessment
14.- Do you consider the didactic use of ICT in the planning and programming of your courses?	Yes
	No
	Sometimes
	Don't know/Not applicable
15.- If you answered "yes" or "sometimes" to the previous question, how important are the following examples of the didactic use of ICT to you (where 1 is Not important at all and 5 is Very important)?	Innovating in assessment instruments
	Facilitating the exchange between students and teaching interventions, understanding the prior knowledge of the students
	Discussion and group work

https://doi.org/10.17398/1695-288X.24.1.29

Ítem	Indicador
	Organizing information
	Development of teaching material
	Creation of audiovisual material by students
	Development of concept maps
	Use of tools for deepening specialized knowledge of content
	Development of expository classes
	Development of online forums
	For assessment
19.- To what do you agree with the following statements?	Where 1 is Strongly disagree and 5 is Strongly agree
The error or failure of digital technology IS a relevant factor that you consider when deciding whether or not to implement it in your courses.	
The error or failure of digital technology is NOT a relevant factor that you consider when deciding whether or not to implement it in your courses.	
20. Of the following options, select the three most important criteria you consider when incorporating a digital tool into your teaching (Where the first selection is Very important, the second selection is Relatively important, and the third selection is Least important)	To improve student learning outcomes
	It is free or has a low cost for the educational organization
	It offers personalized and frequent feedback
	Suggestions from my educational organization
	For interaction between teacher and students
	To facilitate student learning
21.- Based on your experience or knowledge regarding the use of ICT, how much interactivity with students do the following tools facilitate? You should respond to each of the tools listed below.	Zoom
	Google Meet
	Microsoft PowerPoint
	YouTube
	Multimedia Videos
	Moodle
	Google Classroom
22.- How skilled do you think your students are in ICT?	1. Very poorly skilled
	2. Very skilled
23.- On a scale of 1 to 5, how much you agree with the following statements (1 is Strongly disagree and 5 is Strongly agree)	ICT can have a pedagogical use, as they are tools that generate motivation in students
	Digital tools facilitate reflection and learning
	Digital tools promote student autonomy in their teaching-learning process

Ítem	Indicador
24. What aspects of digital citizenship do you consider most important to include in your role as a trainer of teachers? (Indicate the level of importance of the following aspects of digital citizenship and check the boxes in the columns for your selections).	Recording the class with the consent of the students
	Discussing plagiarism and intellectual property on the internet
	Promoting safe use of the internet in their teaching
	The material shared is easy to access and read
	Attempting to diversify the use of platforms for the students
	Limiting the use of networks to protect your privacy and that of your students
	Using chat or audio to obtain feedback from the students
25. How important is it to you to use each of the following digital tools to create pedagogical resources? (1. Very important, 2. Moderately important, 3. Not very important)	1. Genially
	2. Power Point
	3. Canva
	4. Mentimeter
	5. Jamboard
	6. Zoom chalkboard
	7. Mote
	8. Kahoot
	9. Socrative
	10. Quizizz
	11. Google Classroom
	12. Excel
26. Regarding the level of flexibility of ICT tools to adapt to the university classroom, one could say they are:	1.Not adaptable at all
	5.Completely adaptable

Revista Latinoamericana de Tecnología Educativa, 24(1)
https://doi.org/10.17398/1695-288X.24.1.49

RELATEC Revista Latinoamericana de Tecnología Educativa

Received: February 15, 2024
Reviewed: October 11, 2024
Accepted: November 8, 2024

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ARTICLE / ARTÍCULO

Digital Competence among Teacher Training Master's Degree Students: Differences by Gender, Age, and Field of Study

Competencia Digital en alumnado del Máster de Formación de Profesorado. Diferencias con base en el género, la edad y la especialización

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Abstract: Digital competence (DC) among education professionals is a very popular object of study in approaches oriented towards educational innovation. This study aims to analyse digital skills and relate them to sociodemographic characteristics in a sample of future teachers. Participants were 154 Teacher Training Master's Degree students. The Questionnaire for Studying the Digital Competence of Higher Education Students (CDAES) was used to measure DC. The results reveal that future teachers have a medium-low level in the different dimensions of DC. Specifically, they scored highly for basic tasks associated mainly with 'Digital Literacy', although shortcomings were observed in activities related to 'Creativity and Innovation' and 'Critical Thinking'. The results also revealed that DC decreases as age increases, and that students coming from Social Science degrees had the lowest CD indexes, whereas those from Technology and the Natural Science had the highest scores. There is a need for DC training plans that include personalised innovative educational strategies, or in other words, strategies specifically adapted to the characteristics of different university degrees.

Keywords: Digital Competence, Teacher Education, Postgraduate Students, Gender Differences, Age Differences, Academic Specialization.

Resumen: El estudio de la competencia digital (CD) entre agentes educativos constituye un objeto de estudio muy popular entre los abordajes orientados a la innovación educativa. Este trabajo persigue analizar las destrezas digitales y relacionarlas con características sociodemográficas en una muestra de futuro profesorado. Los y las participantes son 154 estudiantes del Máster de Formación de Profesorado. Para medir la CD, se utilizó el Cuestionario para el estudio de la Competencia Digital del Alumnado de Educación Superior (CDAES). Se aprecia que el futuro profesorado muestra un nivel medio-bajo en las distintas áreas que componen la CD. En concreto, destacan en tareas básicas asociadas, sobre todo, a la «Alfabetización Digital», aunque presentan lagunas en actividades vinculadas a la «Creatividad e Innovación» o «Pensamiento Crítico». Además, los datos revelan que según aumenta la edad disminuye la CD. También, que el alumnado que procede de titulaciones de Ciencias Sociales es el que peores índices de CD presenta, mientras que el de Tecnología o Ciencias Naturales es el que más destaca. Se necesitan planes formativos centrados en la promoción de la CD que incluyan estrategias educativas innovadoras personalizadas, es decir, adaptadas a las características de las titulaciones universitarias.

Palabras clave: Competencia Digital, Formación del Profesorado, Estudiantes de posgrado, Diferencias por género, Diferencias por edad, Especialización académica.

1. Introduction

Globalisation and the swift development and spread of Information and Communication Technology (ICT) have triggered deep-rooted changes in society that have greatly affected the way in which we work, live together and relate to each other (Grajales & Osorno, 2019). One of the spheres in which these changes are most evident is education (Carrasco-Mullins & Villero, 2022), which has undergone major transformations in key areas such as goals, content, resources and, above all, the role of both teachers and students in educational practice. All members of the classroom community have had to adapt to the demands of an ever-changing digitalised environment (Cabero-Almenara et al., 2020).

Digital Competence (DC), or the set of skills that enable individuals to use technology safely, critically, responsibly and efficiently to rise to the challenges posed by the new information society (Cabero-Almenara et al., 2020; Gisbert et al., 2016), has become a key requisite in (among others) the educational environment. In this environment, Digital Competence in Teaching (DCT) is particularly important and involves the development and acquisition of the attitudes and knowledge required to teach, learn, work with, research, share information and interact in an educational setting (Rodríguez-García et al., 2019). In other words, DCT enables teachers to create inclusive educational environments with specific didactic materials and strategies to support students' autonomous learning in a digitalised context (Domingo-Coscollola et al., 2020).

In this sense, Organic Act 3/2020 of 29 December, which modifies Organic Act 2/2006 of 3 May, on Education (LOMLOE), establishes that education administrations must commit to fostering the development of DC at all stages of the education system. It also states that each school must have sufficient material and resources to that end. Studies carried out in this field (Gisbert et al., 2016) have identified universities as a privileged environment that must rise to the challenge of offering ongoing, updated teacher training based on the key competencies of the 21st century (Ostanina et al., 2023), as stipulated by Organic Act 2/2023, of 22 March, on the University System (LOSU). The overarching aim is to guarantee the training and digital inclusion of citizens, as established in the National Digital Competence Plan, which forms part of the Recovery, Transformation and Resilience Plan (Spanish Government, 2021).

In light of this, it is vital to have a basic standard or framework of reference for DC and DCT (Recio-Muñoz et al., 2020) that is aligned with the guidelines established by the European Commission. To this end, the European Commission has designed the European Digital Competence Framework, or 'DigComp' (the current version is DigComp 2.2.) that defines five key components of digital competence for citizens: (1) information and data literacy, (2) communication and collaboration, (3) digital content creation, (4) safety, and (5) problem solving (European Commission, 2022). This approach has given rise to a number of proposals aimed at establishing priority areas in the process of developing the DC of the different stakeholders involved in the teaching-learning process (school staff, students, teachers, etc.). In relation to teachers, the following international proposals are worth mentioning: 'DigCompEdu' or the adaptation of the DigComp framework to educational contexts (Redecker, 2017), and the ICT Competency Framework for Teachers (UNESCO, 2018). At a national level, the

INTEF's Marco Común de Competencia Digital Docente - Common Framework for Digital Competence in Teaching (2017) is of particular importance.

Thanks to the complementary standardisation and publication of these frameworks, empirical research has begun to develop different instruments for assessing DC, mainly self-perceived DC, as a first step towards designing resources and proposals aimed at developing and fostering it. Although as yet no consensus has been reached regarding which instrument is the most appropriate, mainly because every study is based on a different standard (Nóbile & Gutiérrez-Porlán, 2022), one of the online instruments for measuring DC that best adapts to the guidelines established by the European Commission (2022) is the questionnaire for studying the Digital Competence of Higher Education Students (CDAES), developed by Gutiérrez-Castillo et al. (2017). This instrument is the most comprehensive because not only does it take the DigComp 2.2. (European Commission, 2022) proposal as its framework of reference, it also uses the National Educational Technology Standards for Teachers (NETS-T) (International Society for Technology in Education –ISTE-, 2023) to define six components of DC. Furthermore, similarly to the approach adopted by DigCompEdu (DCT) (Redecker, 2017), it establishes five levels of DC: novice (0 to 4.9 points), explorer (5 to 6.9 points), integrator (7 to 8.9 points), expert (9 to 9.49) and pioneer (9.5 to 10) (Romero-Tena et al., 2020; Gutiérrez-Castillo et al., 2017).

Using these instruments, some authors have started to measure the digital skills of students and teachers in the university setting (Solórzano, 2021), particularly in relation to teaching degrees (Colomo et al., 2023). The resulting studies, which mainly use a quantitative methodology, reveal that despite not having acquired the competencies necessary to use technological tools proficiently in their educational and professional environment, participants nevertheless consider themselves to be competent in more basic aspects, such as searching for information and using different programs to present and organise content (XXX, 2024). What is striking, however, is their low level of competence in using technologies that have recently been incorporated into the classroom for (among other tasks) creating and managing content (Andía et al., 2020; Jiménez-Hernández et al., 2020; Røkenes & Krumsvik, 2014; Su & Yang, 2024), for which the level obtained was low-medium (Basilotta et al., 2022; Cabero-Almenara et al., 2021; García-Vandewalle et al., 2023).

Other studies reveal differences in ICT skills in accordance with students' gender and age. Some authors, for example, found that men scored higher than women for DC and were more able to gather information by technological means (Cabanillas García et al., 2020; Garbada-Méndez et al., 2023; Su & Yang, 2024), whereas others, including López-Belmonte et al. (2019), found that women were more competent in the fields of communication and collaboration. Studies focusing on age have found generational differences in ICT proficiency, with young students being more able to use technology than their older counterparts, mainly because they are accustomed to using it frequently for their own personal communications and leisure (Cabero-Almenara et al., 2021; Esteve et al., 2020).

Another emerging avenue of research focuses on exploring and describing the digital capacities of students on Teacher Training Master's degrees for compulsory secondary education, further education (A-levels or Spanish Baccalaureate), vocational training and language teaching (from here on TTM students). In this field, although Cornejo-Valdivia et al. (2024) found that future secondary school teachers had an intermediate- high or advanced level of DC, most other initial studies report TTM students having a medium-low general DC level (García-Delgado et al., 2024), particularly in more specialist ICT activities such as generating codes in nEtiqueta or content creation (Napal et al., 2018). Some authors report differences in accordance with sociodemographic aspects such as gender (Pérez-Navío et al., 2021), age and university access pathway (Marín-Suelves et al., 2022). In this context, it should be mentioned that one study found differences in DC development in accordance with knowledge area. Specifically, in a longitudinal study with 485 TTM students, Jiménez-Hernández et al. (2020) found that those from the field of architecture or engineering had higher DC levels. However, the authors also acknowledge that this question has received very little attention to date and state that universities, which have different specialist areas within TTM and students with a wide range of academic-personal characteristics and diverse digital skills, should take it into consideration as part of their effort to promote fair and inclusive education that guarantees comprehensive training designed to enable students to participate effectively in our ever-changing digitalised world.

The present study therefore aims to analyse the DC of a sample of TTM students and to identify the sociodemographic and academic factors that may affect it. To fulfil this aim, several research questions were posed, linked to a number of different specific objectives:

1. What DC level do TTM students achieve in the Questionnaire for Studying the Digital Competence of Higher Education Students (CDAES)?

    1.1. To analyse participants' general self-perceived level of DC according to the CDAES scale.

    1.2. To analyse participant's self-perceived level of competence in the different dimensions and sub-dimensions of the CDAES scale.

2. Does DC differ in accordance with gender, age or specialist area?

    2.1. To study and compare participants' general and dimension-specific levels of DC in accordance with gender.

    2.2. To study and compare participants' general and dimension-specific levels of DC in accordance with age.

    2.3. To study and compare participants' general and dimension-specific levels of DC in accordance with their specialist knowledge area.

2. Method

To achieve the aforementioned aims, the present study follows a quantitative, exploratory, descriptive, comparative and correlational design.

2.1. Participants

Participants were recruited using a non-probabilistic sampling method. The sample comprised 154 students (from a total cohort of 182) enrolled on a face-to-face Teacher Training Master's degree for compulsory secondary education, further education (A-levels or Spanish Baccalaureate), vocational training and language teaching at a Spanish university. In terms of specialist knowledge area, 27 were from Educational Guidance, 41 from Social Science, 41 from Technology and 45 from Natural Science. Finally, 51.3% were men, 47.4% women and 1.3% chose the 'other' option (M= 26.91; SD= 6.39).

2.2. Instruments/Materials

Data were collected using an instrument containing a battery of sociodemographic questions (about gender, age, etc.), along with a scale for measuring self-perceived levels of the dependent variable (in this case, DC): the Questionnaire for Studying the Digital Competence of Higher Education Students (CDAES), validated and standardised for future teachers by Gutiérrez-Castillo et al. (2017). The questionnaire contains 44 items (rated on a Likert-type scale ranging from 1-10) and has been found to have adequate internal consistency (α= 0.966). It measures six areas of DC: (1) Digital Literacy (effective use and application of ICT): 'I can use different digital image, audio and video processing tools'; (2) Information Search and Processing (ability to find, analyse, assess and communicate information using ICT): 'I can organise, analyse and make ethical use of information from a variety of different sources and media'; (3) Critical Thinking (defining, planning, developing and managing projects using digital resources): 'I can identify and define problems and/or research questions using ICT'; (4) Communication and Collaboration (ability to collaborate and interact online): 'I can coordinate group activities using online tools and resources'; (5) Digital Citizenship (ethical, safe and responsible use of digital resources): 'I display leadership skills for digital citizenship within my group'; and (6) Creativity and Innovation (use of innovative tools to modify and improve existing knowledge): 'I develop materials in which I use ICT creatively, supporting the construction of my own knowledge'.

As in other studies carried out in the same field (Gutiérrez-Castillo et al., 2017; Romero-Tena et al., 2020, 2021), the reliability analysis of the questionnaire revealed good internal consistency, both at a general level (α = 0.954; Ω = 0.953), and for each dimension.

2.3. Procedure

A detailed description of the project (aims, method, etc.) was submitted to the programme leader for approval by the Academic Commission (AC) and help arranging the data collection with the lecturers teaching on the Master's degree. As one of the reasons for accepting the proposal, the AC highlighted the need to carry out a diagnostic study of students' DC in order to find a way of improving the syllabus for future academic years.

We then contacted the lecturers teaching in the different specialist areas, who recommended that the data be collected face-to-face rather than remotely, given the low level of student participation in recent studies. Lecturers who agreed to collaborate set aside 10 minutes in one of their classes to enable students to fill out an online questionnaire using Microsoft Forms, which they accessed using a QR code. Participation was anonymous and voluntary as stipulated in the informed consent form all participants were asked to complete beforehand, and no financial compensation was offered. The entire process was approved by the University of the Basque Country's Ethics Committee (CEISH) (Code: M10_2023_178).

2.4. Data analysis

Once the data had been obtained, they were processed and cleansed before being used to conduct the statistical analyses using SPSS (v. 28). The same software package was used to carry out the univariate descriptive analyses, reliability analyses and correlational analyses (Pearson). After the Kolmogorov-Smirnov test had determined that the data followed a normal distribution ($p \geq .05$), comparative analyses were conducted using parametric tests (Student's t and analysis of variance - ANOVA). We also calculated effect sizes using the Cohen's d and eta squared (η2) indexes, applying the criteria established by Camacho (n.d.): $d = 0.20$ and $\eta^2 = 0.01$ indicate a small effect size, $d = 0.50$ and $\eta^2 = 0.06$ indicate a medium effect size and $d = 0.80$ and $\eta^2 = 0.14$ indicate a large effect size.

3. Results

3.1. General results on the CDAES scale, by dimension

To respond to the first research question and its specific aims, descriptive analyses were conducted. The results revealed that, in general terms, participants had a medium-low level of DC in the different skills assessed by the CDAES. Specifically, the scores obtained revealed that the dimensions in which participants were most proficient were 'Digital Literacy' ($\bar{X}$= 7.26; SD= 1.31) and 'Information search and processing' ($\bar{X}$= 7.05; SD= 1.25), in which, according to the categorisation system proposed by Romero-Tena et al. (2020), most attained 'integrator' level. However, in all other areas, participants' self-perceived DC was lower, more akin to 'explorer' level, particularly in relation to 'Creativity and Innovation' ($\bar{X}$= 6.61; SD= 1.77) and 'Critical Thinking' ($\bar{X}$= 6.53; SD= 1.63), where the means were considerably lower (Figure 1).

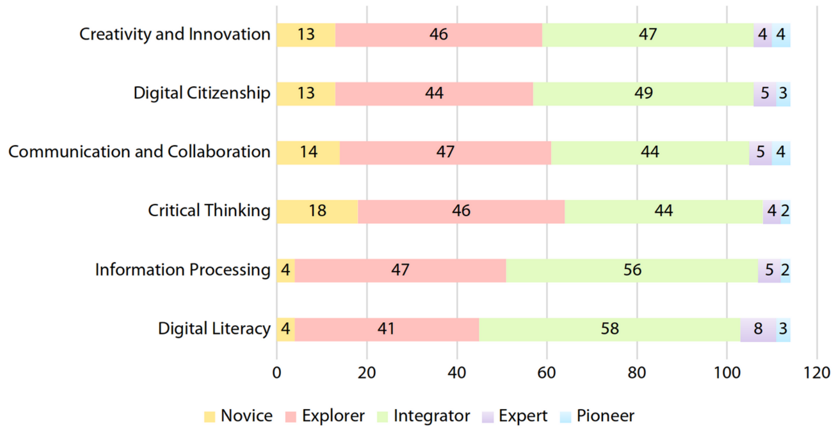

Figure 1. Self-perceived competence level in each dimension of DC.

A more specific analysis of the different sub-areas revealed that the activities in which participants considered themselves most competent involved basic tasks carried out as part of their everyday lives, such as using ICT systems (Area 1.1.: $\bar{X}$= 7.96; SD= 1.44), using learning management systems (Area 1.4.: $\bar{X}$= 7.97; SD= 1.59), participating in or coordinating online groups (Area 4.4.: $\bar{X}$= 7.83; SD = 1.79), planning strategies for conducting a study (Area 2.1.: $\bar{X}$= 8.38; SD= 1.20) and assessing and selecting appropriate information sources (Area 2.3.: $\bar{X}$= 7.96; SD= 1.30). In all these areas, their self-perceived level was that of 'integrator'. However, they had serious difficulties and an 'explorer' level in more complex and less common tasks, such as data processing (Area 2.4.: $\bar{X}$= 5.97; SD= 1.78), configuring software and hardware in order to resolve virtual problems (Area 3.4.: $\bar{X}$= 5.18; SD= 2.55) and using ICT models to create and develop digital material (Area 6.3.: $\bar{X}$= 5.84; SD= 2.22).

3.2. DC by gender

To respond to specific aim 2.1., a means comparison was carried out between men and women using Student's t test. The group who selected the 'other' option in response to the gender question were not included in the analyses due to the small size of this sub-sample. The results are presented in Table 1.

Table 1. Means, standard deviations and analyses of variance (ANOVAs), by gender.

Gender	Descriptive statistics		Comparison			
	Men M(SD)	**Women M(SD)**	***Dif***	$t_{(110)}$	***p***	***d***
Digital Literacy	7.33(1.39)	7.13(1.22)	0.20	.831	.408	---
Information Processing	6.78(1.25)	7.30(1.27)	-0.52	-2.226	.028	0.41
Critical Thinking	6.51(1.63)	6.46(1.61)	0.51	.167	.868	---
Communication and Collaboration	6.80(1.65)	6.54(1.56)	0.26	.847	.399	---
Digital Citizenship	6.72(1.69)	6.91(1.50)	-0.19	-.622	.535	---
Creativity and Innovation	6.73(1.74)	6.38(1.76)	0.35	1.069	.287	---

Note: Men (n= 79) and Women (n= 73). M(SD): Mean and Standard Deviation.

Men scored higher than women for 'Digital Literacy' (p= .408), 'Communication and Collaboration' (p= .399) and 'Creativity and Innovation' (p= .287), although the differences were not significant. For their part, women scored higher than men for 'Digital Citizenship' (p= .535) and, particularly 'Information Search and Processing' (p= .028; d= .41), with a medium effect size.

At the same time, an analysis of the specific digital skills reported by men and women revealed that men see themselves as more proficient in tasks linked to research and problem solving using online resources (Area 1.3.: p= .009; d= .50), as well as in using ICT to explore alternative solutions (Area 3.4.: p= .009; d= .50), with the results indicating explorer level in these areas. For their part, women see themselves as more competent in activities that require them to process data and communicate the results (Area 2.4.: p= .006; d= .53) (explorer level), as well as in planning activities online (Area 3.2.: p= .034; d= .40), in which area they attained 'integrator' level. The effect size of the differences between the two groups was medium-large.

3.3. DC by age

To respond to specific aim 2.2., i.e., to explore differences in DC in accordance with age, a bivariate Pearson correlation analysis was conducted. In addition to confirming the close relationship that exists between the different dimensions of DC (p <.01), this analysis also revealed that DC decreased with age, particularly in areas such as 'Communication and Collaboration' (r= -.289**) and 'Digital Citizenship' (r= -.263**). In other words, the older the participant, the poorer their ability to use digital resources and platforms to interact or work as part of a team, the less positive their attitude and the scarcer their knowledge of how to use ICT ethically and responsibly.

3.4. DC by specialist knowledge area

To respond to specific aim 2.3., i.e., to explore differences in DC in accordance with specialist knowledge area, another analysis of variance (ANOVA) was conducted. The results are presented in Table 2 and Figure 2.

The results reveal that students from degrees associated with Natural Science and Technology had a higher level of DC, attaining 'integrator' level in various sub-dimensions. In contrast, those from degrees associated with Social Science had the lowest level of DC, attaining only 'explorer' level in all dimensions of DC.

Table 2. Means, standard deviations and differences by specialist knowledge area.

	Descriptivos				**Comparación**		
Género	**Orientación M(SD)**	**Sociales M(SD)**	**Tecno M(SD)**	**Naturales M(SD)**	**F(gl)**	**p**	**η^2**
Digital Literacy	7.11(1.05)	6.92(1.32)	7.65(1.60)	7.30(1.10)	1,692(3)	.173	---
Information Processing	7.08(1.37)	6.87(1.12)	6.97(1.51)	7.26(1.07)	0,570(3)	.636	---
Critical Thinking	6.74(1.45)	5.76(1,64)	6.70(1.74)	6.95(1.44)	3,529(3)	.017	.088
Communication and Collaboration	6.56(1.31)	6.20(1.63)	7.15(1.80)	6.87(1.51)	1,980 (3)	.121	---
Digital Citizenship	6.93(1.11)	6.37(1.66)	6.61(1.87)	7.34(1.32)	2,418(3)	.070	---
Creativity and Innovation	6.77(1.77)	5.65(1.93)	6.95(1.58)	7.09(1.49)	4,760(3)	.004	.115

In general, it is important to note that, as shown by the eta squared indexes, no significant differences between knowledge areas were observed in the different dimensions, with the exception of 'Critical Thinking' (p= .017; η^2= .088) and 'Creativity and Innovation' (p= .004; η^2= .115), in which the effect size of the differences was large.

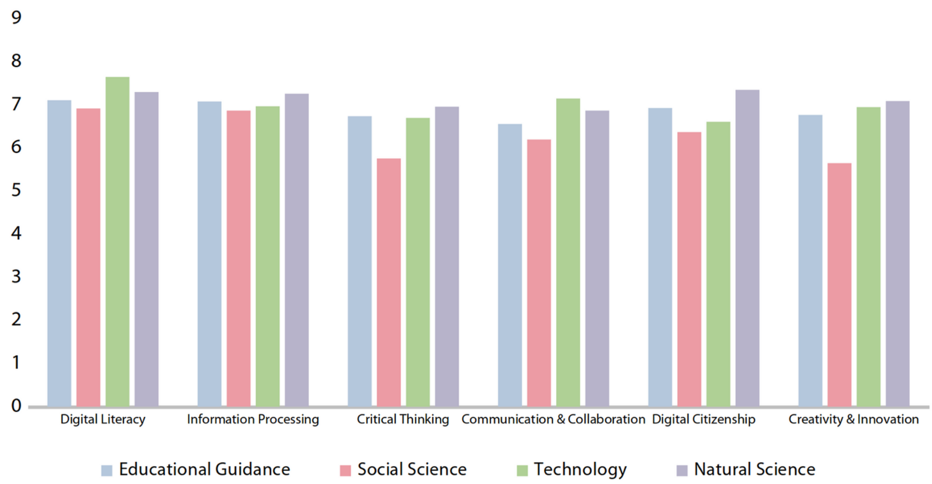

Figure 2. Visual comparison of DC by specialist knowledge area.

In both these dimensions, those from Natural Science degrees scored higher than the others; in the 'Critical Thinking' dimension, the difference in comparison to Social Science students (p= .002; d= 0.78) had a medium-large effect size, and in 'Creativity and Innovation', Natural Science students were the only ones to achieve 'integrator' level. For their part, students from Technology degrees scored highest for 'Digital Literacy' and, above all, 'Communication and Collaboration'. Indeed, this was the only group that perceived themselves as 'integrators' in this last dimension, with significant differences being observed between them and the Social Science group, with a medium effect size (p= .034; d= 0.50). The greatest differences between students from Natural Science and Technology degrees were observed in 'Digital Citizenship', in which the former perceived themselves as 'integrators' and the latter as 'explorers', even though the differences failed to reach significance level (p= .066).

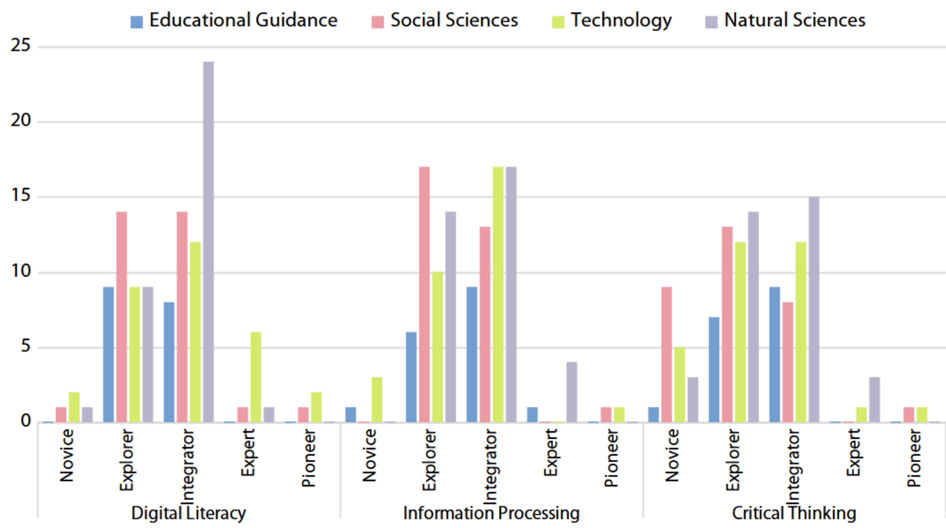

Figure 3. Competence level in the first three dimensions, in accordance with specialist area.

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Competence levels are shown in Figures 3 and 4, which reveal that most participants, regardless of their specialist area, attained an intermediate level (explorer or integrator). The figures also show that, in general, students from the Technology and Natural Science areas were represented most at the higher levels and that (with a few exceptions) those from Social Science were represented most at the lower levels.

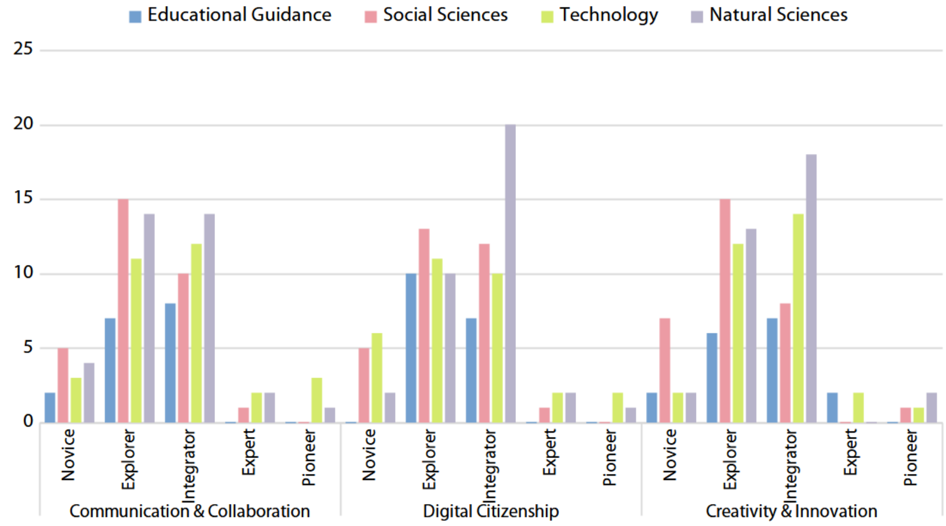

Figure 4. Competence level in the last three dimensions, in accordance with specialist area.

4. Discussion

There is broad consensus in the literature regarding the fact that, alongside critical thinking, flexibility and collaboration (García-Correa et al., 2022), DC constitutes one of the most basic skills that citizens living in this 'digitalised' century must acquire in order to participate in society, engage in lifelong learning and progress in their lives (Gabarda-Méndez et al., 2020; European Commission, 2022). In this context, in which the Spanish government has recently made a commitment to Europe to train teachers in DC (Omedes, 2022) in order to guarantee interactive and motivating learning processes that foster students' active engagement in the classroom and lead to meaningful learning (Recio-Muñoz et al., 2020), many diagnostic studies have been carried out (Basillota et al., 2022), similar to the one presented here.

The present study had several different aims that can be summed up as follows: to determine the level of a group of Master's degree students in the different dimensions and sub-dimensions of DC, using the CDAES, and to describe and analyse differences in accordance with gender, age and specialist knowledge area.

In relation to the first aim, the results reveal that trainee teachers have a basic-intermediate level of DC, also referred to as 'explorer' level, although they sometimes attain 'integrator' level. These findings are similar to those reported by García-Delgado et al. (2024) with a sample of Pre-school and Primary Education undergraduates, as well as to those presented by authors who, despite not establishing specific competence levels, nevertheless highlight the fact that future teachers currently have a medium-low level of DC that is significantly below the threshold established by European governments (Andía et al., 2020; Cabero-Almenara et al., 2021, XXX, 2024). In other words, the findings confirm the existence of a notable gap between the training received and the expectations and demands of 21st century society (Marín-Suelves et al., 2022).

The best results were attained in the 'Digital Literacy' and 'Information Search and Processing' dimensions of DC. In contrast to that found in previous studies (Marín-Suelves et al., 2022; Pozo-Sánchez et al., 2020), our results did not indicate that the 'Communication and Collaboration' dimension was the one in which students scored highest. Indeed, our findings suggest that students (or future teachers) have significant gaps in their knowledge of how to engage in digital activities linked to interaction (Su & Yang, 2024). Consistently with previous studies, however, our results do support the idea that although participants use ICT, they do so only at a very basic or traditional level, and fail to take full advantage of all the possibilities it offers (García-Vandewalle et al., 2023; Jiménez-Hernández et al., 2020; Pérez-Navío et al., 2021). In other words, their DC is higher in activities such as searching for information, using learning management systems like Moodle, and managing programs designed to create presentations or organise content (García-Varcárcel & Martín del Pozo, 2016), but significantly lower in other areas such as 'Digital Content Creation', 'Problem Solving' (Jiménez-Hernández et al., 2020; Pozo-Sánchez et al., 2020) and 'Creative Use of ICT' (Aguilar et al., 2021).

In relation to the second aim, the different comparisons carried out in accordance with gender, age and specialist knowledge area returned varying results.

In terms of gender, in contrast to that reported by Jiménez-Hernández et al. (2020), our results fail to indicate any gender gap in favour of men. However, similarly to that observed by Pérez-Navío et al. (2021) in a sample of Teacher Training Master's (TTM) students, our results did indicate that men were more able to make effective use of ICT in different digitalised contexts, whereas women were more proficient at using digital resources to search for or process information for publication. We also found that men see themselves as being more proficient at using ICT creatively and innovatively to explore alternative solutions to problems, possibly due to the fact that they generally express more interest in this field (Siddiq & Scherer, 2019). Furthermore, in contrast to that reported by López-Belmonte et al. (2019), the men in our sample scored higher than their female counterparts for communication and collaboration. It is important to note, however, that none of these differences reached statistical significance (Marín Suelves et al., 2022).

In terms of age, our results are consistent with those reported by other studies that detected significant generational differences in the use of ICT in all dimensions of CD. In other words, our results confirm that older individuals have more difficulties in this field than their younger counterparts (Cabero-Almenara et al., 2021; Esteve et al., 2020). However, it is important to note that, in the present study, this trend was only found to be significant in the 'Communication and Collaboration' and 'Digital Citizenship' dimensions of DC.

Significant differences were found in the development of CD in accordance with the specialist knowledge area from which participants came (Cabero-Almenara et al., 2021). Consistently with that reported by Jiménez-Hernández et al. (2020), the group that came from Social Science had the lowest level of DC, whereas those who came from Technology had the highest. However, unlike the aforementioned authors, we also found that participants from Natural Science degrees also saw themselves as being more proficient in terms of DC. This is one of the novel findings of the present study. However, the differences observed between the groups, even in relation to those who came from the field of Educational Guidance, were not particularly large, suggesting that the education system trains all students in a similar manner. One finding that was particularly striking was the fact that this last group (from the field of Educational Guidance) had an acceptable level of DC in dimensions such as 'Critical Thinking' and 'Creativity and Innovation', in which students generally tend to score lower (Andía et al., 2020; Røkenes & Krumsvik, 2014). Given that many of these people come from different degrees in the general field of Education, in which a concerted effort is made to develop students' capacity for critical, innovative and creative thinking (Varías & Callao, 2022), it may be that the training they received on their undergraduate degree is responsible for their scores in these dimensions.

5. Conclusions

The results of the present study enable us to conclude that the DC of future teachers could be improved, since most participants attained only 'explorer' level. Given that teacher training has a direct impact on teaching quality, it is essential to focus more on the different dimensions of DC in order to ensure that trainee teachers feel capable and confident about integrating and using ICT in the classroom.

Bearing in mind the importance of the topic under study and the scarcity of research to date focusing on TTM students, the present study constitutes an important step forward for both the field in general and the institution in which it was carried out in particular. Although further research is required to ensure a more accurate diagnosis of the situation and to validate and generalise the preliminary results presented here, our findings provide important insights that will help inform the design of the specific strategies for fostering DC that need to be included in university teacher training syllabuses and adapted to each area of specialist knowledge. Although we currently have good instruments for diagnosing the DC of (future) teachers, there is still a need to design standardised strategies for fostering the acquisition of DC among university students, or perhaps even an official qualification earned by completing a dedicated subject taught across multiple academic years and specialist areas.

The present study has a series of limitations that should be taken into consideration in future research, given that they prevent the results from being generalised due to issues linked to the size of the sample and the methodology used. The first is that the groups were formed by a maximum of 35 people who participated voluntarily with no inclusion criteria being established beyond being a student on a TTM in one of the specialist areas to which we had access, a circumstance that may have influenced the results. In this sense, future studies should strive to recruit larger and more representative samples that encompass other specialist areas and types of TTM, in order to explore any differences or similarities that may exist in terms of DC. Another important limitation is linked to the type of instrument used to measure CD, which was based on participants' self-perceptions. These types of self-report instruments do not generally provide a comprehensive picture of the true situation, but rather reflect each respondent's subjective perception, which may, on occasions, be influenced by social desirability bias (Alcaraz et al., 2006). Although we tried to reduce the effect of this lack of objectivity by taking the means for the different sub-areas into account, future studies may wish to collect data using techniques that assess participants' real DC and compare it with their self-perceived level, as in the study by Gabarda-Méndez et al. (2017). In terms of exploring different means of improving DC in this context, quantitative methodologies offer only a limited view. Future studies may therefore wish to use a qualitative or mixed methodology to analyse the situation in greater depth, including the specificities of each area and the factors that affect their development, in order to provide a more efficient and defective response.

Despite the limitations outlined above, our results confirm the need for continued research in this field. Future studies may wish to explore the differential educational practices that are fostered in each degree course and have an impact on improving DC, as a first step towards designing innovative educational strategies specifically adapted to the demands of today's digital society. Researchers may also wish to conduct comparative studies that focus on different university access pathways or other variables associated with learning, such as motivation, satisfaction, autonomy and academic performance, none of which have received much attention to date in the literature.

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Revista Latinoamericana de Tecnología Educativa, 24(1)
https://doi.org/10.17398/1695-288X.24.1.65

RELATEC
Revista Latinoamericana de Tecnología Educativa

Received: March 17, 2024
Accepted: October 11, 2024

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ARTICLE / ARTÍCULO

Phubbing as a Social Norm: Effects on Fear of Missing Out (FoMO) and Perceived Exclusion

El phubbing como norma social: Efectos en el 'miedo a perderse algo' (FoMO) y la exclusión percibida

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Abstract: Technology and social media have transformed the way we communicate, interact, and stay informed. *Phubbing* is a term that comes from two words «phone» and «snubbing» and represents the act of ignoring a person in a real life setting by paying attention to their cell phone. This behavior may be normalized or cause social difficulties in certain situations. The aim of this study was to analyze the levels of normative behavior and their relations with FoMO, feelings of social exclusion and the phubbing perceived scale. A cross-sectional study was conducted, and the participants were 1506 people in Argentina (50.79% identified as women and 49.21% as men), with an age range between 18 and 65 years old who completed an online survey. The results confirmed that phubbing is perceived as normative behavior in most of the participants, representing a predictor of phubbing in their social interactions. Relations were also found between the perceived normative phubbing and levels of Fear of Missing Out (FoMO) and feelings of social exclusion. Implications of the variables studied are discussed as possible predictors of phubbing and are to be considered in its approach. The study examines phubbing as a normative behavior in Argentina. No previous studies have been carried out in our country that consider Fear of Missing Out (FoMO), Feelings of Social Exclusion and Perceived Phubbing as predictor variables.

Keywords: Phubbing, Fear of Missing Out (FoMO), Social Isolation, Behavior Standards, Smartphone.

Resumen: La tecnología y las redes sociales han transformado nuestra forma de comunicarnos, interactuar y mantenernos informados. *Phubbing*, en español «Ningufoneo», es un término que proviene de dos palabras «phone» (teléfono) y «snubbing» (desairar) y representa el acto de ignorar a una persona en un entorno de la vida real prestando más atención a su teléfono móvil. Este comportamiento puede estar normalizado o causar dificultades sociales en determinadas situaciones. El objetivo de este estudio fue analizar los niveles de comportamiento normativo y sus relaciones con el FoMO, los sentimientos de exclusión social y la escala de phubbing percibido. Se realizó un estudio transversal, y los participantes fueron 1506 personas en Argentina (50,79% identificadas como mujeres y 49,21% como hombres), con un rango de edad entre 18 y 65 años que completaron una encuesta online. Los resultados confirmaron que el phubbing es percibido como un comportamiento normativo en la mayoría de los participantes, representando un predictor del phubbing en sus interacciones sociales. También se encontraron relaciones entre el phubbing normativo percibido y los niveles de FoMO y sentimientos de exclusión social. Se discuten las implicaciones de las variables estudiadas como posibles predictores del phubbing y que deben tenerse en cuenta en su abordaje. El estudio examina el phubbing como conducta normativa en Argentina. No se han realizado estudios previos que consideren el Miedo a Perderse Algo, los Sentimientos de Exclusión Social y el Phubbing Percibido como variables predictoras.

Palabras clave: Ningufoneo, Miedo a perderse algo (FoMO), Aislamiento social, Normas sociales, Teléfono móvil (celular).

1. Introduction

The vast proliferation of information and communication technologies (ICT) has changed the way people relate to each other, as well as social and communication patterns (Tandon et al., 2022). The negative effects of this change have been studied as the downside of digitization (Turel et al., 2019), among which we find phenomena associated with the downside of social media, such as the fear of missing out (FoMO; Budnick et al., 2020; Tandon et al., 2021) and with the excessive use of smartphones, such as phubbing, among other dysfunctional uses (Al-Saggaf & Macculloch, 2019; Roberts & David, 2020).

The word «phubbing» first appeared in 2007 when a Macquarie dictionary update included the combination of the words «phone» and «snubbing», a problem that is considered to be at the heart of many behavioral addictions. (Aljasir, 2022). Phubbing is described as the act of snubbing others in social interactions by choosing to pay more attention to a cell phone instead of paying attention to them (Chotpitayasunondh & Douglas, 2018). There are authors who consider that phubbing is not always intentional behavior even though it may upset others (Ranie & Zickuhr, 2015).

Nowadays, there are an increasing number of daily activities that people do from their phones. Mobile devices and social media comprise a number of utilities that make it increasingly difficult for our attention to be diverted from staring at the screen even at night (Boniel-Nissim et al., 2023). Thus, there seems to be a socially common pattern of behavior where people are constantly online in the anticipation of receiving and responding to messages and e-mails, and they are ready to engage in a conversation with another person at any given time, which generates stress and overwhelm, among other symptoms (Derks et al., 2021; Yousaf et al., 2019; 2022).

1.1. Phubbing, Perceived Social Norms, FoMO, and Feelings of Social Exclusion

The use of technology involves new forms of interaction, and phubbing, although perceived as a generalized behavior, is not socially acceptable in all environments (Leuppert & Geber, 2020). Moreover, phubbing has changed the dynamics of interpersonal communication, especially in the last decade (Kadylak, 2019), generating in most human dynamics conflicts that may include relationship, work, and intergenerational problems, among others (Vanden Abeele, 2018; Rendón Vélez, 2022).

Phubbing and its perception in various everyday situations play a fundamental role in an individual's sense of well-being (David & Roberts, 2020). For example, being phubbed leads to feelings of social exclusion, a greater need for attention, and more intensive use of digital media. According to David and Roberts (2017), given the importance of feeling connected to our peers, the feelings of exclusion triggered by being phubbed increase the need to reclaim inclusion, which leads to a discomfort that makes it difficult to control our thoughts, emotions, and behaviors. From this perspective, to regain the sense of inclusion threatened by a lack of face-to-face interaction, people may turn to their smartphones and social media to engage with others and relieve the pain associated with being phubbed.

In this regard, one of the vulnerabilities that may cause a person to constantly pay attention to their phone could be the fear of being left out (FoMO: Fear of Missing Out; Blanca & Bendayan, 2018). This term refers to the distress generated by the feeling that others may be experiencing particularly rewarding experiences in which the individual is not participating (Przybylski et al., 2013). The FoMO construct consists of two dimensions (Li et al., 2023), the first is the Fear of Missing Novel Information (FoM-NI), which refers to the ongoing search for new information in social media. On the other hand, the Fear of Missing Social Opportunities (FoM-SO) is linked to the feeling of missing out on social interactions that others may be having (Durao et al., 2023; Zhang et al., 2020). According to Tandon et al. (2022) FoMO leads to phubbing, as people try to mitigate the anxiety that may arise from missing up-to-date information about their virtual friends.

Phubbing victims often feel rejected and undervalued (Vanden-Abeele & Postma-Nilsenova, 2018) and perceive this behavior as aggressive and disrespectful, which generates feelings of social exclusion (Aagaard, 2020). Paying constant attention to their cell phone makes it difficult to talk to and interact with the people around them. Thus, these behaviors (phubbing and FoMO) are closely linked to feelings of social exclusion and loneliness (Ivanova et al., 2020). The feeling of social exclusion affects the ability to regulate our emotions, thoughts, behaviors and even our perception of the passing of time (Téllez Rojas & Rivera Fong, 2020). For its part, as well, the feeling of social connection implies that the person perceives closeness in their social ties and a sense of belonging that results in emotional and physical well-being (Koebner et al., 2018). The latter differentiates from social disconnection that causes socioemotional distance from one's surroundings (Pancani et al., 2021).

1.2. Phubbing Assumed as Normative and its Implications

Based on the extent of phubbing and the different variables involved, it is essential to study this issue, focusing on the phubbees and the impact this behavior has on their perception and coexistence with their social environments. Currently, in any modern society, the vast majority of people are exposed to more or less close social interactions and exchanges, in which they suffer or will suffer phubbing (Haigh, 2015). Thus, phubbing is no longer just an isolated behavior or associated with specific situations or contexts; on the contrary, it has become normal or acceptable. It is therefore a challenge to study and analyze the relationship between the suffering of phubbing, to what level this may lead to a better acceptance of phubbing by assuming it as a normal practice, and the possibility that this may lead to phubbing towards other people in the same group. This could be linked to the notion of reciprocity, which in the field of social psychology plays a key role in the study of social interactions (Falk and Fischbacher, 2006). Such reciprocity would make those who are frequently phubbed in their social environments and assume such behavior as normative, more likely to return this behavior even if it has negative consequences for others (Keysar et al., 2008).

Therefore, disregarding or ignoring others in one's social environment through the use of a phone can make said behaviors become normative (and even acceptable) and therefore reciprocal, albeit unintentionally (Chotpitayasunondh & Douglas, 2016). It is important to note that it does not always take years or decades for a social norm to become established, but on the contrary, it can be established in societies quickly and abruptly (Sunstein, 1996), easily turning into observable behaviors (Miller & Prentice, 1996) as in this case. Therefore, the aim of this study was to analyze the levels of phubbing perceived as normative behavior, their relationships with FoMO and with feelings of social exclusion and between the five indicators of perceived phubbing as normative and the perceived phubbing scale in their social settings.

2. Method

2.1. Participants

A cross-sectional study was conducted with and intentional sample based on the geographical areas of Argentina. A total of 1506 people participated in the study (with a sampling error of 2.5% and a confidence level of 95%), 50.79% (n = 765) of the participants identified as woman, and 49.21% (n = 741) as men. The participants' ages ranged from 18 to 65 years (M = 43.21; SD = 11.71). 4.9% of the sample had only completed their primary education, 31.8% had completed their secondary school, 31.4% had finished their tertiary education, and 31.9% had finished their university studies.

2.2. Measures

A variety of evaluation tools, including a battery of self-report measures, were used:

- Perceived Social Norms of Phubbing: Participants completed the «*Perceived Social Norms of Phubbing Scale»* (PSNP; Chotpitayasunondh & Douglas, 2016), which consisted of two items measuring injunctive norms—the inference of others' approval toward phubbing—and three items measuring descriptive norms based on their observations of others' behavior.

- Phubbing Scale. We used the scale developed by David and Roberts (2017), which is comprised of nine items that measure how often people use their smartphones while spending time with their contacts (i.e., friends, neighbors, family, etc.) (e.g., "People who I spend time with often glance at their cellphone when talking to me", "When their cellphone rings or beeps, they pull it out even if we are in the middle of a conversation", "When I spend time with people, they keep their cellphone where they can see it "). The response format ranges from 1 = Never to 5 = All the time.

- FoMO Scale. We used the adaptation and validation of the scale's original version (Przybylski et al., 2013), which consists of 10 items that determine dimension 1, FoM NI (for example, "I fear my friends have more rewarding experiences than me"), and dimension 2, FoM SO (for instance, "It bothers me when I miss an opportunity to meet up with friends"). The response format was Likert-type, with 1 denoting "strongly disagree" and 5 denoting "strongly agree".

- Feelings of Social Exclusion Scale. The scale originally developed by Williams, Cheung, and Choi (2000) and reformulated by David and Roberts (2017), is made up of six items that explore feelings of social exclusion (e.g., "To what extent when spending time with other people, do you experience feelings of being ignored?", "To what extent when spending time with other people, do you experience feelings of being excluded?", "To what extent when spending time with other people, do you experience feelings of being rejected?"). The response format is five anchors, ranging from 1 = Not at all to 5 = Very much.

- Socio-demographic Data Questionnaire: Information about gender, age, and highest level of education was collected from the participants.

2.3. Procedure and data analysis

Based on the quotas established for the sample distribution, those who satisfied the requirements for age (over 18) and geographic location were asked to participate via social media answering a geolocalized online questionnaire. We work with an intentional, non representative sample. The study's aim, the organization in charge of it, and a contact email address were communicated to the participants, requesting their informed consent to take part in the study. Additionally, they were made aware that the information gathered for this study would be protected in line with Argentine National Law 25,326 on the protection of personal data and would only be used for academic and scientific purposes. The SPSS for Windows version 19.0 (George & Mallery, 2010) was used for the statistical analyses. Descriptive statistics (mean, standard deviation, skewness, and kurtosis) were examined for each Phubbing indicators. Also correlations, t-test, and a multiple regression were calculate.

3. Results

The descriptive statistics of the Perceived Social Norms of Phubbing were analyzed in the Argentine context (Table 1).

Table 1. Descriptive statistics of phubbing indicators.

	M	SD	S	K	Responses (%)				
					1	2	3	4	5
1. Do these types of situations happen?	4.41	1.12	-.94	1.12	3.8	15.7	25.3	42.3	12.9
2. Do you think people are aware that they use the phone at all times (dining, drinking, conversations, etc.)?	3.40	1.58	-.21	-.90	23.1	24.7	27.8	14.7	9.7
3. Would you say that the people you spend time with are constantly interacting with their cell phone?	4.43	1.17	-.94	.83	4.1	17.6	20.1	43.2	15.1
4. Do you think you spend a lot of time on your cell phone when you are with other people?	2.94	1.55	.01	-1.17	33.2	26.7	23.7	12.5	3.8
5. Are you affected / bothered / annoyed / offended by other people using cell phones while you are having a conversation?	4.06	1.59	-.36	-.73	11.5	26.7	22.7	11.1	28.1

Note: adequate values of Skewness (S) and Kurtosis (K): -1.4 < X < 1.4.
1: Not at all; 2: A little bit; 3: Sometimes; 4: Frequently; 5: Very much

First, no differences were found based on the participants' gender or age. According to Table 1, there is a perception of excessive cell phone use during interactions in social contexts, although there is no awareness of this fact among those who do so. Additionally, this form of social interaction, in which phubbing exists, is in most cases a source of discomfort. However, as many as 66.8% of cases reported using their phones longer than desired while engaged in social interactions.

Relations in the five indicators of phubbing, FoMO dimensions, and feelings of social exclusion were analyzed next (Table 2).

Table 2. Relationships among the five indicators of perceived phubbing, FoMO dimensions, and feelings of social exclusion.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Do these types of situations happen?	-	.070**	.591**	.408**	.045	.167**	.114**	.136**
2. Do you think people are aware that they use the phone at all times (dining, drinking, conversations, etc.)?		-	.110**	.103**	.010	.115**	.034	.054
3. Would you say that the people you spend time with are constantly interacting with their cell phone?			-	.365**	.100**	.150**	.079**	.167**
4. Do you think you spend a lot of time on your cell phone when you are with other people?				-	-.213**	.210**	.151**	.113**
5. Are you affected / bothered / annoyed / offended by other people using cell phones while you are having a conversation?					-	.102**	.081**	.130**
6. FoMO - NI						-	.452**	.425**
7. FoMO - SO							-	.161**
8. Feelings of social exclusion								-

*. $p < .05$; **. $p < .001$.

Table 2 shows significant relationships between the various items that evaluate normative phubbing in the participants' social environment and FoMO and feelings of social exclusion. In relation to FoMO, the FoMO-NI subdimension was the most significantly related to all indicators. As for feelings of social exclusion, these were also moderately positively related to all items of perceived phubbing as normative, with the exception of Item 2 (Do you think people are aware that they use the phone at all times (dining, drinking, conversations, etc.)?). The strongest relation ($r = .42$; $p < .001$) was found between FoMO-NI and feelings of social exclusion.

Next, in Table 3, a multiple regression was calculated between the five indicators of phubbing as normative and the perceived phubbing scale in their social settings.

The results show that, with the exception of Item 2 of the scale of phubbing perceived as normative, the rest of the indicators significantly predict the phubbing suffered by the person in their environment. Thus, a significant association is shown between Item 1 ($\beta = .017$; $p < .001$), Item 3 ($\beta = .017$; $p < .001$), Item 4 ($\beta = .011$; $p < .05$), and Item 5 ($\beta = .010$; $p < .001$).

Table 3. Linear multiple regression model between phubbing as normative and the perceived phubbing scale.

Predictors	β	R2
1. Do these types of situations happen?	.374***	
2. Do you think people are aware that they use the phone at all times (dining, drinking, conversations, etc.)?	-.021	
3. Would you say that the people you spend time with are constantly interacting with their cell phone?	.375***	.496***
4. Do you think you spend a lot of time on your cell phone when you are with other people?	.058*	
5. Are you affected / bothered / annoyed / offended by other people using cell phones while you are having a conversation?	.104***	

*. p < .05; **. p < .001.

4. Conclusion

Considering that phubbing no longer represents a mere isolated event, but has become an increasingly accepted and sometimes normative behavior (Haigh, 2015), the main objective of the present study was to analyze the levels of phubbing in the Argentine context, as well as the relationships with other variables that literature suggests as related (Cheung & Choi, 2000; Przybylski et al., 2013).

The results of the present study indicate that participants frequently recognize instances of phubbing in their social interactions. Even though this generates certain levels of discomfort, it is not usually attributed to those who perform it. Similarly, more than half of the participants acknowledge that they spend a lot of time on their cell phones when they are with other people. In line with what has been proposed by different authors (Haigh, 2015; Miller & Prentice, 1996; Sunstein, 1996), these findings would reinforce the hypothesis of phubbing as a normative and acceptable behavior, quickly translated into an observable behavior in the Argentine context, as well. Also, these findings are consistent with results from previous studies in other contexts (Chotpitayasunondh and Douglas, 2016) and with other theoretical models that have been depicted (Falk & Fischbacher, 2006). Thus, we may conclude that the perception of phubbing as a normative behavior in social situations of which an individual is a part may lead them to engage in phubbing as a reciprocal behavior (Keysar et al., 2008), regardless of the suffering it might cause others.

Second, the results indicated that phubbing perceived as normative is significantly and positively related to other variables contrary to individuals' psychosocial well-being such as FoMO (Przybylski et al., 2013). As already mentioned, one of the things that may trigger phubbing is the fear of being left out (FoMO; Blanca & Bendayan, 2018) and an increase in distress levels caused by the feeling that others may be experiencing enjoyable and rewarding experiences in which the individual is not participating (Przybylski et al., 2013). Additionally, all phubbing indicators were positively and more strongly related to the Fear of Missing Novel Information (FoM-NI) dimension than to the Fear of Missing Social Opportunities (FoM-SO) dimension. In line with Li et al. (2023), the results of this study seem to indicate that individuals pay more attention to their phones to access any new information that might come up on social media, rather than for fear of missing out on the desired social interactions that others may be having.

Third, as suggested in the theoretical model of David and Roberts (2017, 2020), the significant relationships found between phubbing indicators, feelings of social exclusion, and Fear of Missing Novel Information (FoM-NI) would support the hypothesis of the former as an important element in the emergence of the latter and a consequent fear of being left out linked to the abusive use of social media (Roberts & David, 2019).

Finally, we further analyzed the association between phubbing perceived as normative and phubbing suffered directly in the participants' social surroundings. From this perspective, and in line with previous studies (Li et al., 2023; Leuppert & Geber, 2020) a significant association was found that allows us to predict the degree of phubbing that a subject suffers directly in their daily life based on the degree of normativity that they perceive in their social environments regarding the use of cell phones during interactions. The results suggest that phubbing may now be becoming increasingly universal, and this is becoming more and more normalized in today's society. This fact may create expectations and a stronger tendency towards phubbing, even in interactions in close or intimate social settings.

To conclude, the present study has provided evidence of significant relationships between phubbing, FoMO, and feelings of social exclusion in the Argentine culture. This finding is considered an advance not only in the theoretical understanding of the factors linked to the downside of social media in general, but also in the understanding of this problem in an underdeveloped country where access to technology and the Internet is increasingly unequal.

Despite the mentioned contributions, the present study has coexisted with a series of limitations that it is hoped can be further explored in future research on the subject. First, a more extensive consideration of the participants' sociodemographic characteristics that may affect access to technology and Internet would allow for greater control over the relationships between phubbing, FoMO, and feelings of social exclusion. In that sense, future work should include more sociodemographic characteristics of the participants, as well as the conditions of effective access to technology and the Internet, since these could operate as possible moderators of the relationships between the variables. Secondly, the use of self-administered questionnaires constitutes a potential response bias that may obstruct the analysis of causal relationships between the variables under study. Therefore, it is recommended that future studies may advance on the adoption of mixed methods or experimental methodologies to carry out this type of work. Lastly, a challenge for the future is the development of other positive and healthy social norms aimed at reducing the perceived social norms of negative behaviors such as phubbing. Given the direct influence of the social context and the norms assumed in relation to phubbing, it is important to address the problem in a social and not only individual sense, thus avoiding the idea that it is only individual behaviors, beliefs, and attitudes that lead to an unhealthy use of digital media.

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Revista Latinoamericana de Tecnología Educativa, 24(1)
https://doi.org/10.17398/1695-288X.24.1.77

RELATEC
Revista Latinoamericana de Tecnología Educativa

Received: July 15, 2024
Accepted: December 17, 2024

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ARTICLE / ARTÍCULO

The Use of GeoGebra in Teaching Mathematical Concepts: Practices, Barriers, and Teachers' Perceptions

El uso de GeoGebra en la enseñanza de conceptos matemáticos: prácticas, barreras y percepciones docentes

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Abstract: The use of GeoGebra in teaching mathematics has grown significantly in recent years, so this study aims to explore the use of this software by teachers in teaching the limit of a function. For this purpose, a questionnaire was designed and validated and has been answered by 129 mathematics teachers. The data were analysed both quantitatively and qualitatively with the aim of discerning obstacles in the use of GeoGebra and the development of ad hoc applets, identifying the most outstanding features of GeoGebra applets for teaching the limit concept and determining the stages in the teaching-learning process at which this tool is used. Thus, a limited use of GeoGebra in teaching the limit concept and a very low percentage of teachers developing their own applets has been identified, mainly due to a lack of technological resources and lack of knowledge. Furthermore, interactivity and the possibility of using various systems to represent the limit concept are revealed as the characteristics most highly valued by teachers. Finally, GeoGebra is used most to give examples but rarely used in the evaluation process.

Keywords: GeoGebra, Educational Technology, Mathematics Teachers, Mathematical Concepts, Mathematics Curriculum, Secondary Education.

Resumen: La utilización de GeoGebra en la enseñanza de las matemáticas ha crecido notablemente en los últimos años, por lo que en este estudio se pretende indagar acerca del uso de este software por parte del profesorado en la enseñanza del límite de una función. Para ello, se ha diseñado y validado un cuestionario que ha sido respondido por 129 docentes de matemáticas. Los datos han sido analizados tanto cuantitativa como cualitativamente con el objetivo de conocer obstáculos para el uso de GeoGebra y para la elaboración de applets propios, identificar las características más destacadas de los applets de GeoGebra para la enseñanza del límite y determinar los momentos del proceso de enseñanza-aprendizaje en los que se utiliza esta herramienta. Así, ha sido identificado un escaso uso de GeoGebra en la enseñanza del límite y un bajo porcentaje de docentes que elaboran sus propios applets debido, fundamentalmente, a la ausencia de recursos tecnológicos y a la falta de conocimientos. Además, la interactividad y la posibilidad de utilizar varios sistemas de representación del límite se revelan como las características más valoradas por los docentes. Finalmente, GeoGebra es especialmente utilizado a la hora de mostrar ejemplos y apenas se usa en el proceso de evaluación.

Palabras clave: GeoGebra, Tecnología Educativa, Profesorado de Matemáticas, Conceptos matemáticos, Curriculum de Matemáticas, Educación Secundaria.

1. Introduction

The notion of limits is highly important from a mathematical perspective. A limit is a complex object commonly found in advanced mathematical thought (Tall, 1991), which has received a lot of attention in research on mathematics education. Furthermore, numerous research projects have explored the potential of using dynamic and interactive environments for teaching the limit concept (Martinovic and Karadag, 2012). At present, GeoGebra is one of the most widespread dynamic and interactive mathematics learning environments (Hohenwarter et al., 2009). Within the context of learning the limit concept, the use of GeoGebra could help students to overcome certain significant obstacles linked to this concept (Rodríguez et al., 2020). Hutkemri (2014) also notes that this tool enables students to enhance their conceptual and procedural knowledge about the notion of limits, but that it "is necessary to provide training for teachers on the advantages of GeoGebra and its operating skills" (p. 880). To provide this training, a clear vision is needed of the features of the available applets in official GeoGebra repositories (Barreras et al., 2022), but it is also important to understand teachers' practices when using this software in situations involving teaching-learning of the limit concept.

In this context, the following general research question can be raised: How often, why and in what way do teachers use GeoGebra when teaching and learning the limit concept? This study aims to advance, at least partially, in answering this research question. In particular, the following specific objectives have been set:

1. Determining how often teachers use GeoGebra in teaching-learning processes involving the limit concept and identifying possible obstacles.
2. Discerning how often ad hoc GeoGebra applets are designed and possible obstacles to doing so.
3. Examining how useful GeoGebra is in teaching-learning processes involving the limit concept.
4. Determining the points in the instruction process at which GeoGebra is used.

1.1. Literature review

Martinovic and Karadag (2012) note that dynamic and interactive mathematics learning environments provide an environment of experimentation of great pedagogical value, offering students the possibility to explore different mathematical concepts and the relationships between these concepts so that they can develop their own cognitive frameworks. In particular, these authors assert that «the perception of constant change in mathematical objects may affect students' understanding of these concepts, leading them to develop a new type of learning.» (p. 47).

Thus, the use of GeoGebra for teaching differential calculus —and the limit of a function in particular— may help students gain a better understanding of the mathematical concepts discussed. Among other factors, this is due to the interactivity of applets, their dynamic nature (Sari, 2017) and the possibility of working simultaneously with diverse systems of representation (Caligaris et al., 2015). In relation to this, Barreras et al. (2022) analyse the use of GeoGebra for teaching the limit concept, focusing on several variables: interactivity, conceptual image, systems of representation and actions. In their work, they conclude that these variables should be interconnected when it comes to using this software, and therefore, interactivity should be one of the resources for combining different systems of representation, so as to foster efficient conceptual images of the limit.

Conceptual aspects aside, one of the matters to bear in mind when integrating GeoGebra into learning situations is the way in which the tool can contribute to the development of different mathematical processes in students (NCTM, 2000). In this regard, it has been found that GeoGebra may offer sufficient support to achieve a decent level of development in mathematical skills related to processes of concept representation, problem solving, reasoning and proof, making connections and communication (Romero et al., 2015).

In addition, GeoGebra prompts students to play a more active role in their learning and enables teachers to design more effective learning situations, promoting a two-way process of teaching and learning (Hutkemri, 2014). In general, it has been found that conceptual aspects related to functions and their representation are learned more effectively when GeoGebra is used, even when working in groups, due to the possibilities for exploration and construction. The reason for this is that students can devote more time to analysing connections between mathematical concepts than to doing calculations. Furthermore, GeoGebra also enables students to recognise whether they have learned correctly and to detect errors themselves (Takaci et al., 2015). However, certain attitudes, such as creativity or reasoning and proof, may develop in a smaller number of students, so the teacher must act in real time to orchestrate individual dynamics (García et al., 2021, p. 194). The interactivity and browsability of GeoGebra foster the development of autonomy in students, boosting their flexible thinking capability in problem solving. In addition, GeoGebra offers students the option of making their own representations stemming from decisions and strategies they come up with themselves which, with the aid of guided questions from the teacher, increases the level of precision and rigour with which they can work in class and the development of students' reasoning capabilities (Romero and García, 2023).

However, the teacher's role when using GeoGebra in the classroom must be assessed in order to ensure that the benefits that this tool can afford are actually achieved (Iranzo and Fortuny, 2009). In fact, as Arnal-Bailera and Oller-Marcén (2020) have noted, low levels of training in the use of GeoGebra can lead to misuse of the tool. This entails the need to add the use of GeoGebra in teacher training, so that they integrate knowledge stemming from diverse domains (pedagogical knowledge, content knowledge and technological knowledge), as Koehler et al. (2013) propose.

The use of GeoGebra in teacher training programmes was recently found to be beneficial in the assimilation and application of mathematical concepts (García-Lázaro and Martín-Nieto, 2023) and in the visualisation of geometric concepts (Dockendorff and Solar, 2016) in future teachers and in students (Guarin and Parada, 2023). The tool is also effective when it comes to improving attitudes of teachers in training towards mathematical demonstrations (Zengìn, 2017b). In fact, Zengìn (2017a) believes that teachers in training should become acquainted with this software because of the benefits offered in developing their mathematical communication capabilities. In turn, when active teachers participate in training programmes on the use of GeoGebra, these teachers then take a more student-focused approach to their teaching (Marange and Tatira, 2023).

At any rate, the ways in which teachers actually use this software before or after the training process, and the reasons for doing so, must be examined. Lasa and Wilhelmi (2013) describe three possible stages at which a teacher may integrate the use of GeoGebra in the classroom in relation to geometry: exploratory (constructing models for solving exercises and problems or for inferring properties, illustrative (giving examples of properties based on specific cases) and demonstrative (proving and demonstrating inductive and deductive properties). These authors also discuss the potential of this software for coordinating the work done at these three stages. Other research (Carvalho et al., 2023; Rosyidi et al., 2024) has also described the possibility of integrating the use of GeoGebra at the evaluation stage.

In addition, McCulloch et al. (2018) describe the reasons why teachers integrate the technology in the classroom: generating opportunities to enhance conceptual or procedural comprehension, avoiding mistakes in performing routine tasks, giving meaning to ideas and implementing mathematical procedures. They also note that the factors involved in choosing a specific technology instrument include aspects such as ease of use, access options, interactive features and potential for enhancing the instruction process. Saralar-Aras (2022), in turn, points out motives related to visualisation, enhanced student learning, the increase in student motivation and the decrease in teacher workload. This author also describes obstacles such as classroom management and lesson planning. However, integrating GeoGebra poses certain challenges related to issues that go beyond teacher training per se, such as access to technological resources and students' difficulties in using the tool (Wassie and Zergaw, 2019).

2. Method

To achieve the specific objectives described above, an exploratory and descriptive research approach was used. The methodological design coincides with what Creswell (2012) referred to as 'embedded design'. In this case, the design involved the use of quantitative primary data gathered from a questionnaire, which also contained open questions that provide qualitative secondary information to support and supplement the quantitative data.

2.1. Instrument

The questionnaire is divided into three sections. The first section contains 7 questions to provide context. The second section has 5 questions about general issues related to teaching-learning about the limit of a function. Finally, the third section contains questions about the use of GeoGebra by the surveyed teachers in teaching the function limit.

After drafting a preliminary version of the questionnaire, in order to verify its validity (Elangovan and Sundaravel, 2021), four researchers and university instructors in the area of didactics of mathematics, selected at the authors' discretion, were asked to assess it. These experts were consulted with regard to the clarity and pertinence of each of the questions, and were able to make remarks and suggestions in relation to the questions and overall design of the questionnaire. The following two criteria were used in relation to the experts' opinions:

- If two or more experts indicated that a question was not pertinent, it would be removed from the questionnaire.

- If one expert deemed a question to lack clarity, the wording would be revised.

Following the experts' remarks, certain questions were added and the value of the Likert scales was also clarified, adding verbal explanations to the numerical scores: 1 (not important), 5 (very important).

A pilot test of the second version of the questionnaire was conducted on ten Spanish secondary school mathematics teachers, also selected at the authors' discretion. These teachers filled out the questionnaire and were then asked about the clarity and pertinence of the questions. They were also asked about how useful the questions were for gathering information about the use of GeoGebra in teaching the limit. All the participants in the pilot test agreed that the wording of the questions was clear and that all the questions were pertinent. The suggestions received for improvements in the questionnaire dealt with matters unrelated to the research aims, so they were excluded from this study. The final version of the questionnaire can be found in Appendix I.

2.2. Sample

The questionnaire was sent by email, using the Survey Monkey tool, to a total of 514 teachers enrolled in a Master's in Didactics of Mathematics in Compulsory and Post-Compulsory Secondary Education. It was available from 24 October to 13 November 2023. The participation rate was approximately 25%, and responses were received anonymously from 129 mathematics teachers from several countries: Colombia (57.4%), Ecuador (38%), Dominican Republic (2.3%), Uruguay (1.5%) and Mexico (0.8%). 55.8% of the participants were men and 44.2% women. The average age of the participants was 37.9, with standard deviation of 8.8 years.

According to their responses, these teachers have an average of 7.7 years of experience teaching mathematics in secondary school (students from 12 to 18 years old). In this regard, inexperienced teachers are deemed to have 2 or fewer years of experience (OECD, 2013) while expert teachers are those with more than 10 years of teaching experience (Huang and Li, 2012). Therefore, the sample is composed of 34 participants with little experience, 35 teachers with extensive experience and the remaining 60 with average experience.

Finally, the figure below shows the formal education of the respondents, except for 8 responses (6.2%) which were too ambiguous to classify.

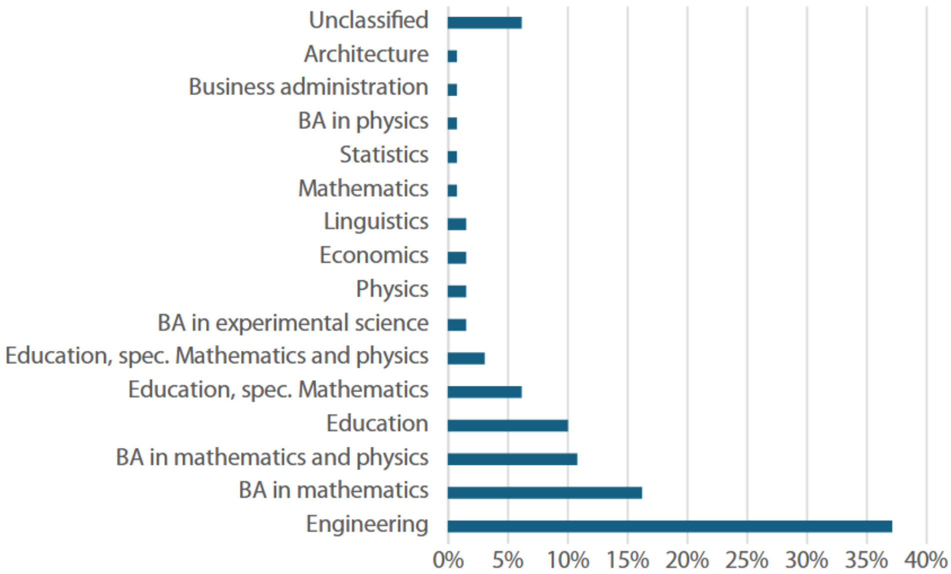

Figure 1. Formal education.

2.3. Analysis

To analyse the quantitative data collected in the questionnaire, statistical tools of an essentially descriptive nature were used, bearing in mind the ordinal numbers of the Likert scales used in some of the questions (Blaikie, 2003). Furthermore, in line with the research objectives described above, the questionnaire also included certain questions in which the participants had to choose between several options and others with an open response.

In relation to the first objective, the participants that had not used GeoGebra to teach the limit concept were asked to indicate the reasons in an open question, conducting an inductive analysis of the contents of their responses. The categories that emerged from this process are shown in Table 1.

To address the second objective, the participants were given the following list of reasons why they may have decided not to design their own GeoGebra applets (González Pérez and De Pablos Pons, 2015): Lack of knowledge, lack of time, use of applets available over the internet and others (filling in the reasons).

Table 1. Categories for analysis of reasons why GeoGebra is not used.

Categories	Description	Example
Lack of technological resources	GeoGebra is not used to teach the limit concept because the schools or students lack the required technological resources.	ID4: «We do not have technological resources to use applications at the institution.»
Lack of opportunity	GeoGebra was not used to teach the limit concept due to a lack of professional experience or not having taught this unit.	ID13: «Because I have not had a chance to teach this unit.»
Lack of knowledge	GeoGebra is not used to teach the limit concept because of a lack of knowledge about how it works.	ID42: «Lack of awareness about how the tool works.»
Out of didactic considerations	GeoGebra was not used to teach the limit concept because it was not deemed suitable from a didactic perspective.	ID45: «Because of the time it takes to explain to the secondary school students how to use GeoGebra, the available manuals are not comprehensible to them.»

In relation to the third objective, the teachers who claimed to have used GeoGebra were first asked to rank from 1 to 5 the different features of the applets. The proposed features were: jointly addressing several conceptual aspects, combining several representation systems, interactivity and others (filling in the features). In turn, in an open question they were also asked to provide an explanation about the reasons why they considered it useful in teaching the limit concept. These responses were analysed based on three variables: didactic criterion, advantages of using GeoGebra and processes. The description of the different categories (which are not mutually exclusive) considered for each one can be found in Table 2. The first variable and its categories were generated in an emerging fashion. In relation to the second variable, the categories considered were taken mainly from the work of Barreras et al. (2022). Finally, for the third variable, the mathematical processes defined by the NCTM (2000) were taken into account.

Finally, in relation to the fourth objective, the participants who claimed to have used GeoGebra in teaching the limit concept were asked about the stages of the instruction process where it was used. The closed but not mutually exclusive options provided were: when introducing concepts, when giving examples, when solving exercises, when solving problems and in the evaluation. These categories aim to somehow encompass the most common teaching practices in mathematics classrooms (Perrin-Glorian, 1999).

Table 2. Variables and categories for analysing GeoGebra usefulness. Variable: Didactic criterion.

Categories	Description	Example
Teaching	The response includes aspects inherent to the teacher's practices.	ID94: «The opportunity offered by the application when it comes to graphing and visualising functions is quite significant in the teaching process.»
Learning	The response includes aspects inherent to students' practices.	ID9: «GeoGebra provides tools for making the concepts more comprehensible.»

Table 3. Variables and categories for analysing GeoGebra usefulness. Variable: Advantages of using GeoGebra.

Categories	Description	Example
Visualisation	Applets facilitate visualisation of the limit of a function.	ID48: «Graphic visualisation is crucial and GeoGebra makes graphic analysis much easier.»
Interactivity	Applets offer the possibility of interacting.	ID95: «It allows the student to interact with the limit concept, making the learning meaningful.»
Combination of representation systems	Applets offer the possibility to combine different systems for representing the limit of a function.	ID30: «It allows students to integrate algebraic and graphic aspects of the limit concept, there they can analyse and compare.»
Support in problem solving	Applets foster problem solving using the limits of functions.	ID49: «It motivates the student for meaningful learning, it is representative for analysing and verifying solutions to problems.»
Emotional or motivational aspects	The use of applets motivates students and/or prompts a positive attitude.	ID127: «Students are more motivated to learn when these tools are used.»
Understanding the limit concept	The use of applets facilitates an understanding of the concept of the limit of a function.	ID16: «It is a way for the kids to understand better, more easily and simply.»

Table 4. Variables and categories for analysing GeoGebra usefulness. Variable: Processes

Categories	Description	Example
Problem-solving	Possibility of developing mathematical problem solving in all kinds of contexts.	ID81: «It helps us solve complex problems quickly.»
Reasoning and proof	Possibility of developing mathematical demonstrations and doing reasoning, making guesses and assessing arguments.	ID112: «GeoGebra is a tool that makes it possible to guess and verify those guesses.»
Representation	Possibility of using different representations of mathematical concepts.	ID20: «A limit of a function can be clearly visualised.»
Connections	Possibility of creating connections between different mathematical ideas or with everyday life.	ID21: «Because it allows for interaction between new technologies and knowledge applied in real life.»
Communication	Possibility of expressing mathematical ideas, communicating those ideas and practicing mathematical language.	n/a

To analyse the participants' responses to the open questions (Tables 1 and 2), each of the three researchers did their own analysis. Afterwards, the individual classifications were compared in order to reach a consensus. This triangulation process (Flick, 2004), in which three researchers use the same records, boosts the internal validity and reliability of the research (Hernández et al., 2010).

3. Results

The contents of this section are broken down according to the four research objectives described in the introduction.

3.1. Use of GeoGebra

Out of the 129 teachers who answered the questionnaire, just 54 (41.9%) claimed to have used GeoGebra at some point in their professional career in processes of teaching-learning the concept of the limit of a function. The remaining 75 claimed not to have used GeoGebra at all in teaching the limit concept. Figure 2 shows the distribution of this variable according to the participants' level of experience. Although not statistically significant, a greater use of GeoGebra for teaching the limit concept is seen among teachers with extensive experience. Approximately 46% claimed to have used it, compared to 35.3% of teachers with little experience and 43.3% of those with average experience.

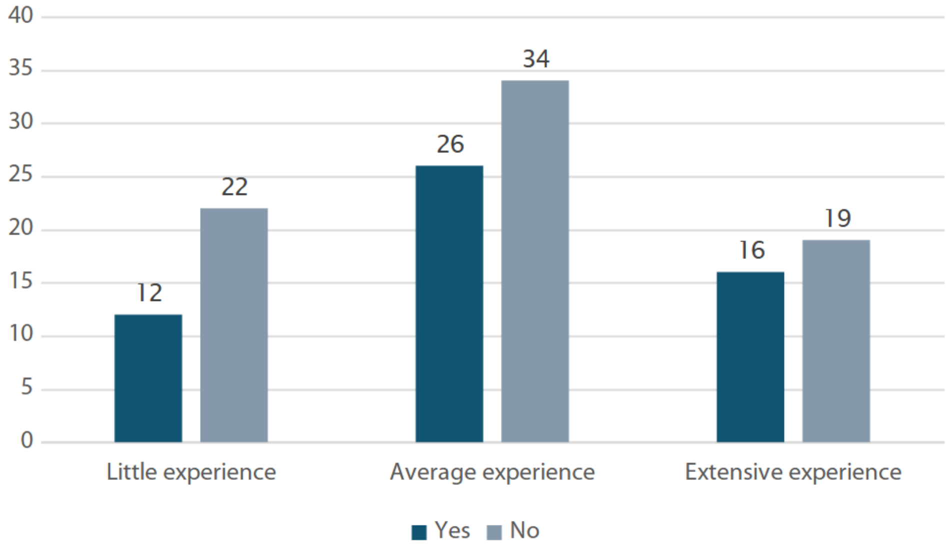

Figure 2. Use of GeoGebra according to level of experience

The reasons given by the teachers who claimed not to use GeoGebra to teach the limit concept were broken down into four categories (Figure 3): lack of technological resources (38.7%), lack of teaching experience or experience in teaching the limit concept (25.3%), lack of knowledge about the use of GeoGebra (24%) and didactic considerations, such as planning issues or student difficulties (8%). The others (6 teachers) did not give a reason or the response could not be classified.

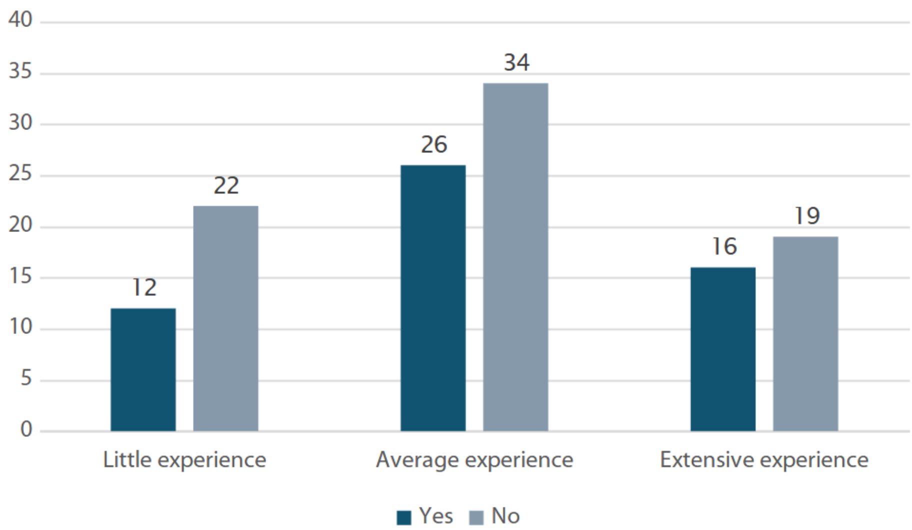

Figure 3. Reasons why GeoGebra is not used.

It is interesting to note that the teachers with extensive experience used didactic considerations to justify the lack of use of GeoGebra, while the other teacher groups rarely mentioned this type of considerations. It is also worth noting that lack of knowledge about the use of GeoGebra is a reason given at similar rates regardless of the level of experience (Figure 4).

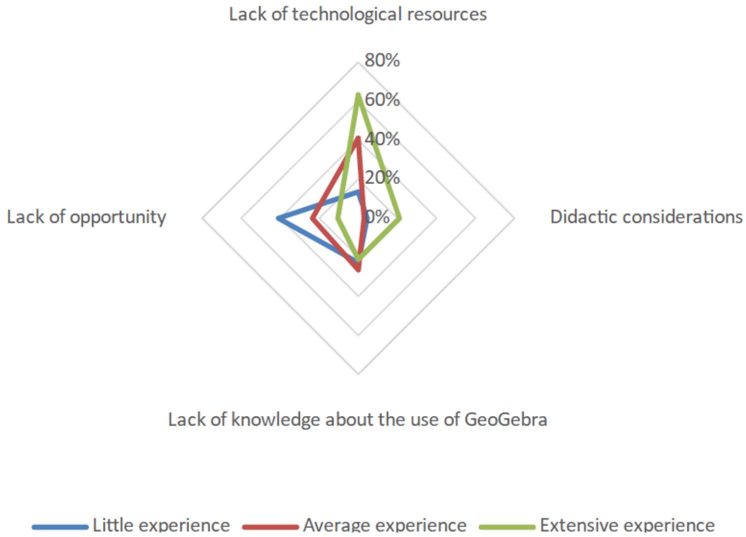

Figure 4. Reasons why GeoGebra is not used, according to level of experience.

3.2. Applet design

The number of teachers who created their own GeoGebra applets to teach the limit of a function is quite low, just 8 out of 129 participants. This means that, out of the 54 teachers who claimed to have used GeoGebra in this setting, more than 85% resorted to ready-made applets and have never designed or created a GeoGebra applet to teach the limit concept. Figure 5 shows the reasons why the teachers did not prepare their own applets.

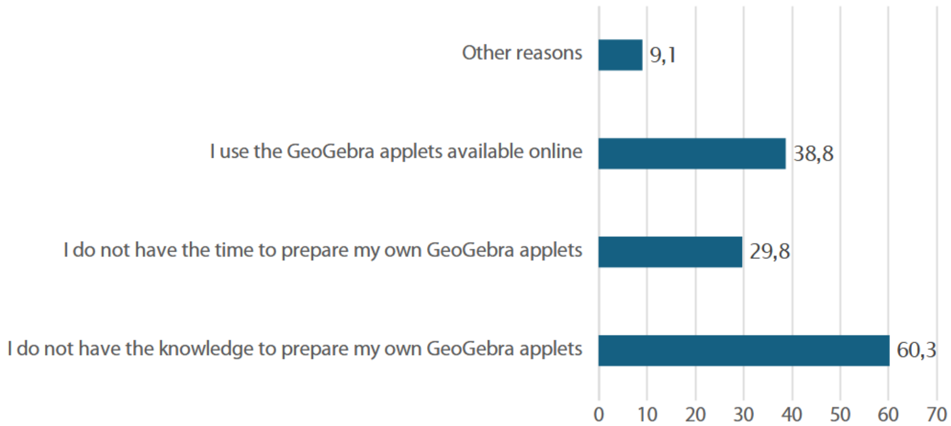

Figure 5. Reasons for not creating their own applets.

Thus, the main reason is lack of knowledge about the design and creation of GeoGebra applets (60.3%). The next most common reason is the use of GeoGebra applets that are available over the internet and, finally, the lack of time to prepare them. Other reasons given by the teachers for not preparing their own GeoGebra applets to teach the limit concept include the lack of teaching experience, lack of experience teaching this content and lack of technological resources to create and use them in the classroom.

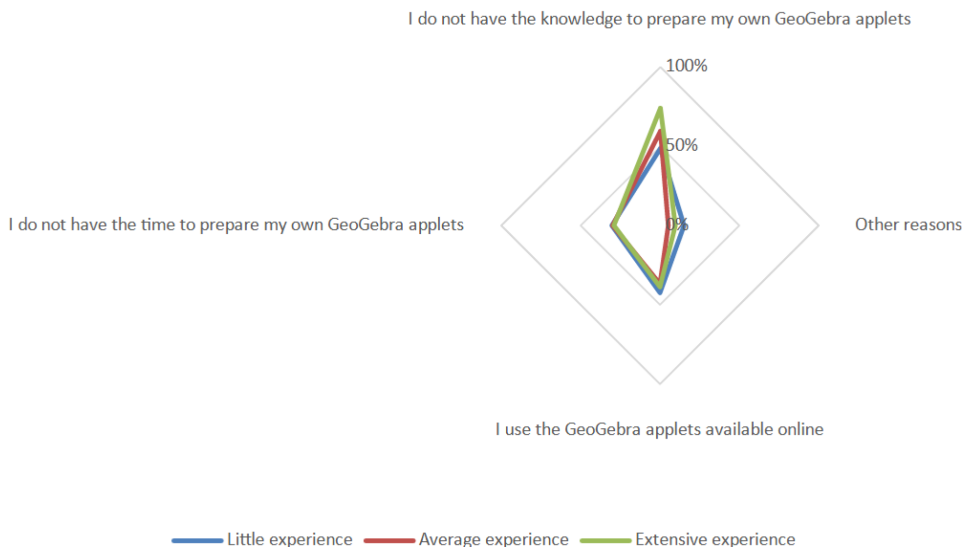

Figure 6. Reasons given for not preparing their own applets, according to level of experience.

The most striking feature of the graph above (Figure 6) is the fact that the teachers with the most extensive experience tend to assert lack of knowledge most often as the reason for not preparing their own applets. The teachers with little experience, in turn, give other reasons for not being able to create their own GeoGebra applets (such as lack of teaching experience) at a higher rate than teachers with average or extensive experience. For all the other reasons given, the percentages are virtually the same regardless of the level of experience.

3.3. Usage and usefulness

One of the questions in the questionnaire (Appendix I) addressed the importance given to the different features of the GeoGebra applets for use in teaching the limit of a function. Figure 7 shows the results obtained.

Examining this graph, it is clear that interactivity is the feature that the largest percentage of participants in this study (64.2%) ranked the highest when using the applets to teach the limit concept, followed by the possibility of combining several systems for representing the limit (54.7%). The possibility of jointly addressing several conceptual aspects of the limit appears to be less important, given that just 39.6% of the teachers decided to give it the highest score. In fact, the first two features share the same mean (5), while the mean of this latter feature of GeoGebra applets is 4. The other features that prompted the teachers to use GeoGebra applets in the process of teaching the limit concept include simplification of the process of visualising mathematics concepts for the students (in particular, the limit of a function) and ease of use.

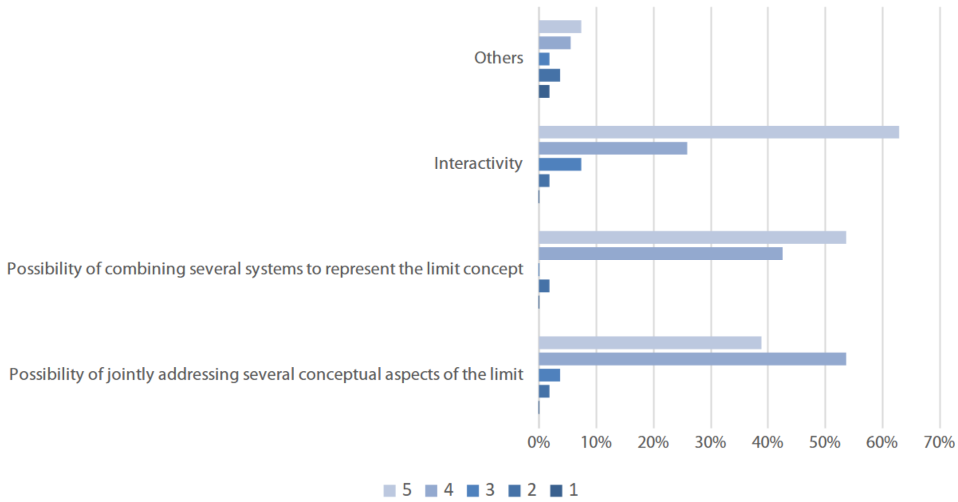

Figure 7. Importance of the applet features.

The graph below (Figure 8) shows that the percentage of teachers giving the highest score to each feature is quite similar, regardless of the level of teaching experience.

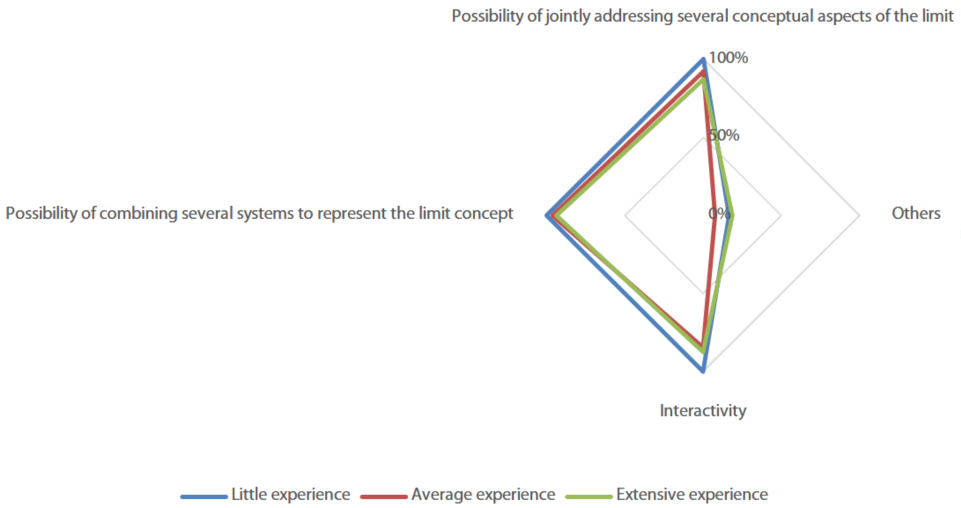

Figure 8. Percentage of highest scores according to level of experience.

There was also an open question to identify the reasons why using GeoGebra applets to teach the limit of a function was found to be useful. To analyse the responses to this question, three different classifications were made. With regard to the didactic criterion, nearly 39% of the teachers that use GeoGebra mention reasons related to teaching the limit concept, whereas more than 46% refer to issues about learning these concepts, focusing the attention on the students. Almost 30% of the teachers gave reasons that are not related to either of these two issues (Figure 9).

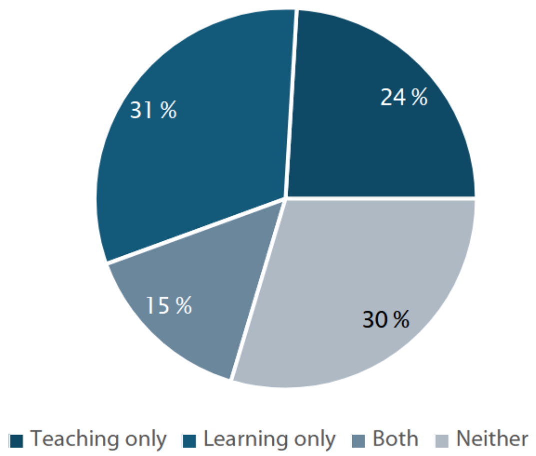

Figure 9. Didactic criteria on the usefulness of using GeoGebra.

The breakdown of the responses mentioning one or more of the main advantages of using GeoGebra has also been examined (Figure 10). The main advantage highlighted here is the visualisation capacity, recognised by more than 53% of the teachers, and how it aids in understanding the limit concept (31.5%). At the opposite end is the support in problem solving (11.1%) and emotional or motivational aspects (9.3%).

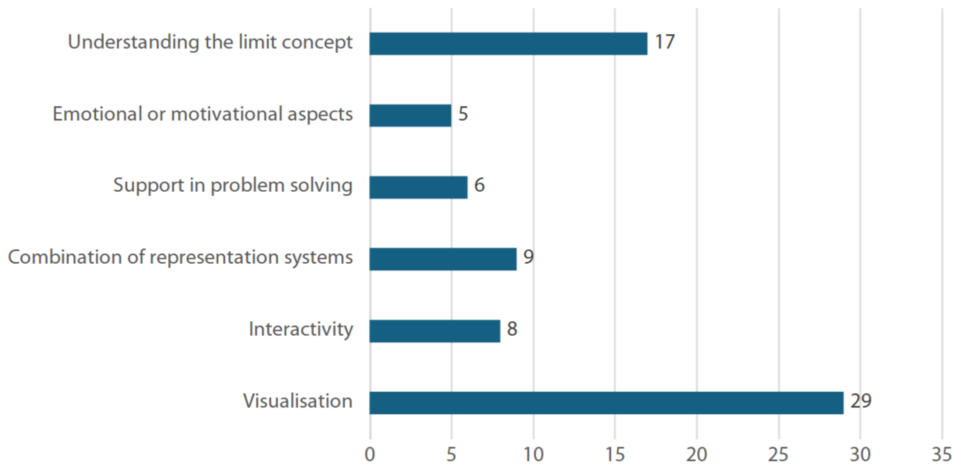

Figure 10. Advantages of using GeoGebra.

Figure 11 shows that the frequency with which these advantages of using GeoGebra are mentioned depends very little on teaching experience.

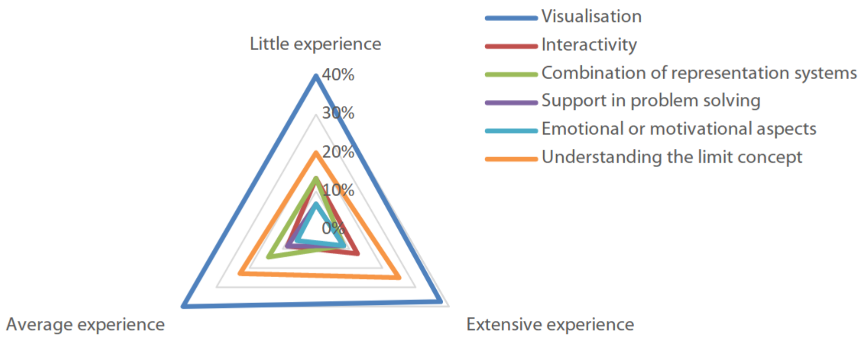

Figure 11. Advantages of using GeoGebra according to level of experience.

When it comes to the number of advantages indicated by each teacher in relation to the use of GeoGebra to teach the limit concept, none gave more than 3 advantages. The most experienced teachers tend to consider 3 simultaneous advantages more often than their colleagues (Figure 12).

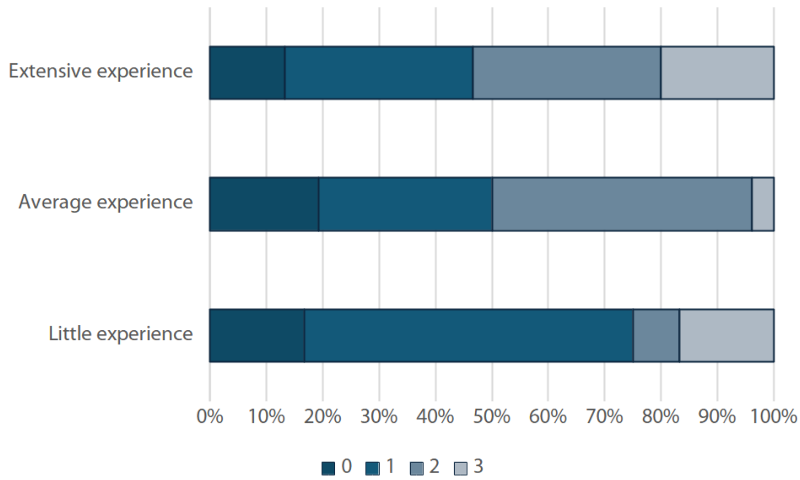

Figura 12. Número de ventajas del uso de GeoGebra según la experiencia.

Thirdly, the responses about interest in using GeoGebra to teach the limit concept were classified according to the mathematical processes defined by the NCTM. Representation ranks much more highly than the others, mentioned by more than 54% of the teachers (Figure 13). However, communication is not mentioned as a process considered by any of the teachers that use GeoGebra.

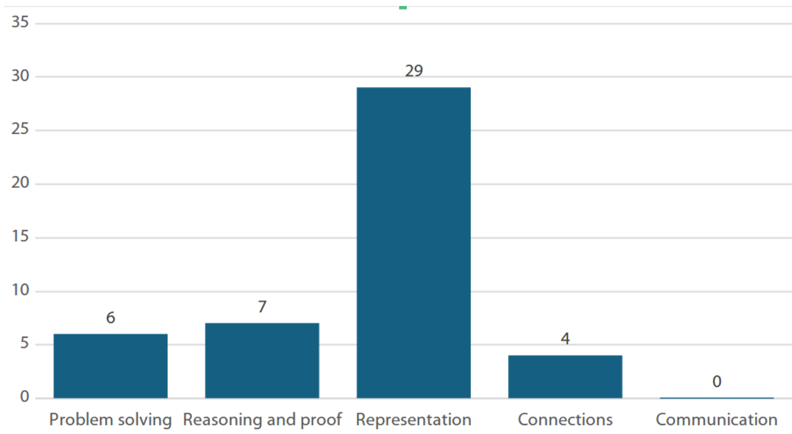

Figure 13. Mathematical processes (NCTM) considered for the use of GeoGebra.

Interestingly, teachers with little experience do not mention reasoning and proof among the processes considered. It is also striking that teachers with average experience find connections to be unimportant and those with little experience find problem solving to be less important than their colleagues, who consider it more important (Figure 14).

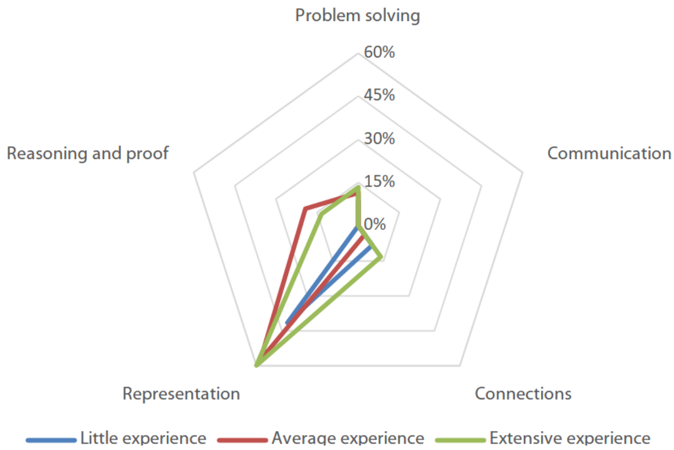

Figure 14. Mathematical processes (NCTM) considered according to level of experience.

With regard to the number of mathematical processes considered, just one teacher, with average experience, mentions 3 processes simultaneously, while more than 3 processes are not mentioned at all. On the other hand, approximately 30% of the teachers do not mention any processes (Figure 15).

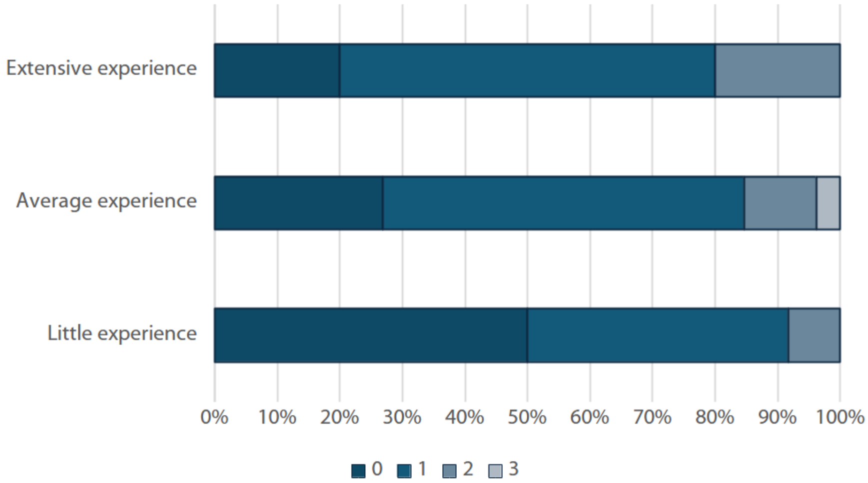

Figure 15. Number of mathematical processes (NCTM) considered according to level of experience.

3.4. Timing of use

Firstly, the participants were asked about the different stages in the process of teaching the limit concept at which the GeoGebra applets were used. The findings show that 83.3% felt that the right time to use them is when giving examples, while 77.8% use them to solve exercises. This was followed by the introduction of concepts and solving contextualised problems, while just over one quarter (25.9%) use GeoGebra applets in the evaluation (Figure 16).

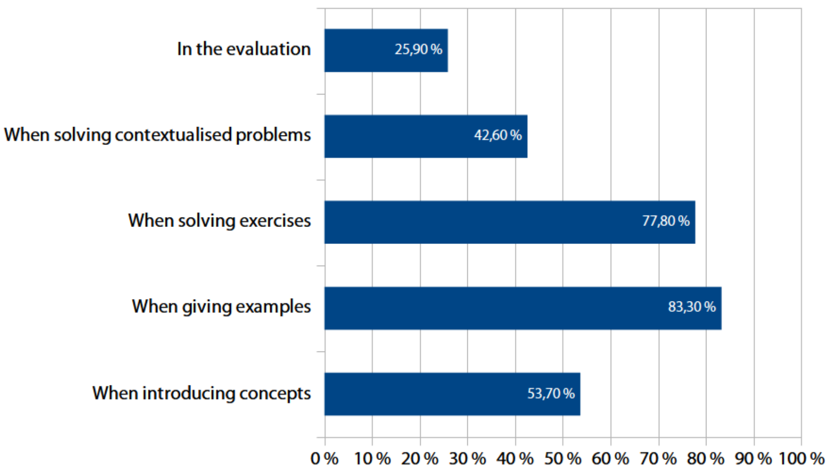

Figure 16. Timing of GeoGebra use.

The analysis of the stages in the process of teaching the limit concept at which the teachers use GeoGebra applets, according to their level of experience, shown in Figure 17 indicates that teachers with little experience rarely use this tool in the evaluation process. There is also a striking difference between the percentage of teachers with extensive experience (similar to those with little experience) and those with average experience when introducing concepts and solving contextualised problems.

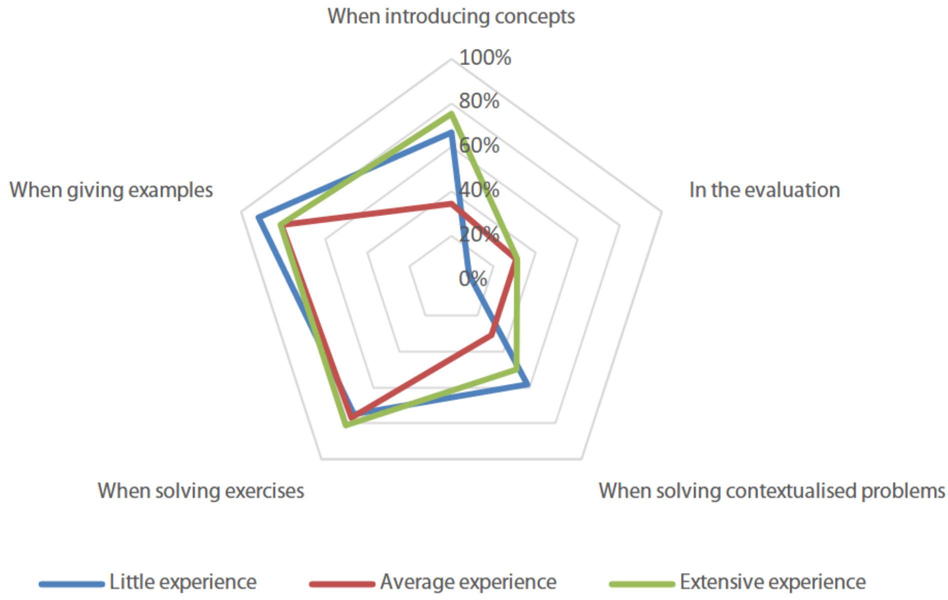

Figure 17. Timing of GeoGebra use according to level of experience.

When it comes to the stages in the process of teaching the limit concept at which this type of resource is used (Figure 18), it is worth noting the limited number of teachers who use GeoGebra applets at the five stages proposed, due to the fact that a low percentage of teachers use GeoGebra in the evaluation.

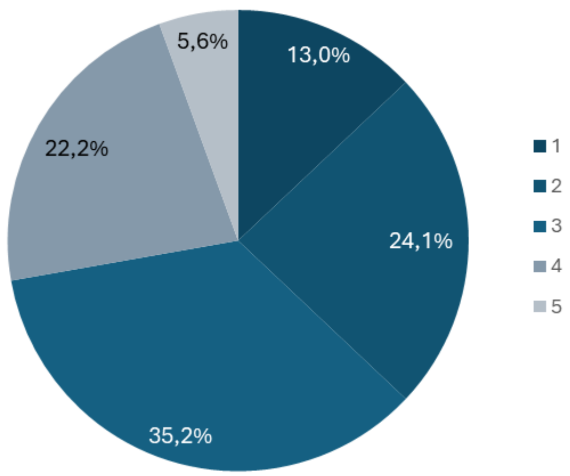

Figure 18. Number of stages at which GeoGebra is used.

However, bearing in mind the teachers' level of experience, none of those with little experience mention all five stages of the limit teaching process to introduce the use of GeoGebra. In particular, just one of these teachers uses GeoGebra in the evaluation (Figure 19).

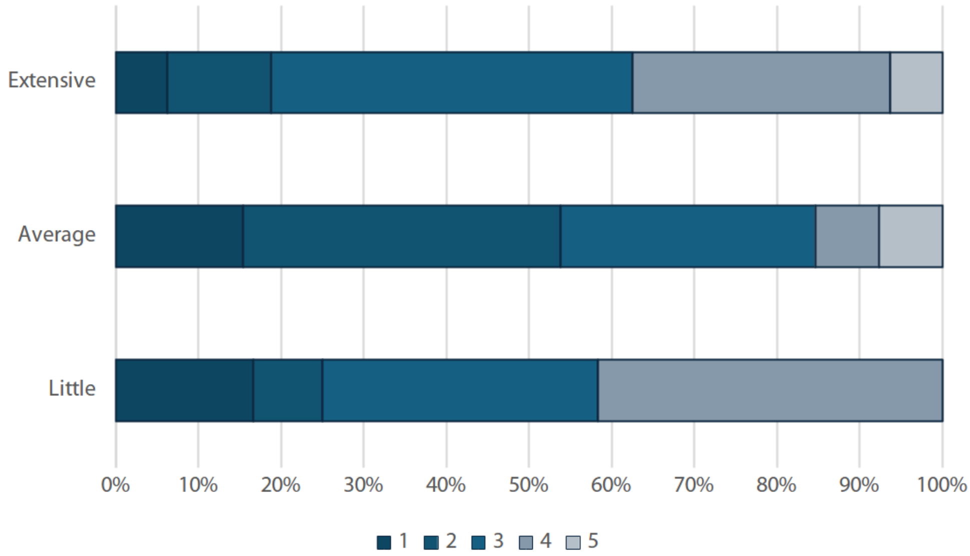

Figure 19. Number of stages at which GeoGebra is used according to level of experience.

4. Discussion and Conclusions

Just 42% of the teachers were found to have used GeoGebra in the process of teaching the limit of a function. Furthermore, the percentage of teachers that use GeoGebra in this context increases with the amount of teaching experience, although this percentage is lower in all cases than that of teachers who do not use GeoGebra in teaching the limit concept. The reasons given by those teachers that do not use GeoGebra include, most notably, the lack of technological resources, although it is worth mentioning that nearly one quarter of these teachers assert that they lack sufficient knowledge to use the tool (Wassie and Zergaw, 2019; Saralar-Aras, 2022).

In turn, the number of teachers who claim to create their own applets is extremely low (15%). The reason given for this is, in most cases, related to lack of training in use of the software (Musa et al., 2021; Saralar-Aras, 2022; Wassie and Zergaw, 2019), which highlights, in terms of the model by Koehler et al. (2013), the importance of having adequate technical knowledge (TK) as a prerequisite for proper integration of the software into teaching practice. In addition, a good number of teachers stated that they used applets available online. In this regard, Barreras et al. (2022) note that the applets available to the public often have certain shortcomings, such as limited options for representations and inefficient promotion of conceptual images or actions, as defined by Przenioslo (2004). This means that teachers need to be "critical when selecting external online resources" (Barreras et al., 2022, p. 79), evidencing the importance of moving beyond mere technological knowledge when it comes to teacher training (McGrath et al., 2011). In turn, nearly one third of the participants mentioned lack of time to prepare their own materials, a limiting factor that has also been identified in contexts such as modelling in the classroom (Schmidt, 2011) or implementation of problem-based learning (Nurlaily et al., 2019), so it is interesting to note that the different factors mentioned by the teachers seem to intersect with the introduction of diverse tools, instruments or methodologies in the classroom.

When using GeoGebra applets, the feature most highly valued by teachers is interactivity, followed by the possibility of combining several systems to represent the limit concept. Both interactivity (Sari, 2017) and the combination of several representation systems (Blázquez and Ortega, 2001) have been identified in the literature as features that can help students understand the limit concept. Furthermore, Barreras et al. (2022) note that both of these features are essential when it comes to selecting GeoGebra applets available online. It is striking that there are very few differences in the features highlighted by the teachers across the different levels of experience.

To analyse the usefulness of using GeoGebra, a three-tiered analysis was performed. Firstly, more than 46% of the teachers that use GeoGebra focus the attention on the students, indicating reasons related to learning about the limit of a function, whereas nearly 39% refer to matters related to teaching the concept. Secondly, regardless of their level of experience, the teachers highlight two main advantages in the use of GeoGebra: visualisation and comprehension of the limit concept. The striking thing in this sense is that the advantages cited least are problem solving (11%) and emotional or motivational aspects (9%), given the existence of research like that by García et al. (2021), which shows that the use of GeoGebra enhances student motivation. Thirdly, representation stands out in the analysis of the mathematical processes (NCTM) that are fostered by the use of GeoGebra. Despite the advantages found in the use of GeoGebra in processes like communication, reasoning and proof and problem solving (Romero et al., 2015), none of the surveyed teachers feel that this tool helps in the development of the communication process.

Finally, in terms of timing, the teachers stated that they used GeoGebra most often to give examples, which is related to the illustrative stage, as defined by Lasa and Wilhelmi (2013). Solving exercises, which is related to the exploratory stage, was ranked second. The demonstrative stages, which could be partially linked to the introduction of concepts, are addressed by just over one half of the participants that use GeoGebra. In addition, we believe that there could be a certain correlation between the stages at which GeoGebra is introduced in the classroom and some of the reasons indicated by McCulloch et al. (2018) for using technology in the classroom. Thus, using it to solve exercises or contextualised problems is linked to opportunities to practice, usage in introducing concepts is linked to making sense of mathematical ideas or procedures and using it to give examples is related to opportunities to build understanding. Despite the fact that some research has shown that it is possible to design valid evaluation instruments using GeoGebra (Rosyidi et al., 2024), we have observed that GeoGebra is used the least at the evaluation stage. This is consistent with studies like that by McCulloch et al. (2018), who showed that teachers do not identify GeoGebra as a technological tool for evaluation. In addition, we have seen that teaching experience is a factor that influences the idea of using GeoGebra for this purpose. This seems to suggest that training in this regard, which is related to what Koehler et al. (2013) referred to as technological pedagogical knowledge (TPK), could promote this use of GeoGebra as an evaluation tool, which could have a positive impact on student motivation (Carvalho et al., 2023).

Based on this research, the authors propose expanding the study to obtain a larger sample of teachers so that the findings are more statistically representative. Furthermore, this study is part of a research project that entails a transfer of the findings, focused on teacher training in the use of GeoGebra in secondary education.

5. Acknowledgments

This work has been partially funded by a UNIR2024 Internal Project granted to the Research Group on Didactics of Mathematics and Experimental Sciences (DIMACE) at UNIR. Additionally, the third author has been funded by the S60_23R «Research in Mathematics Education» group of the Government of Aragon.

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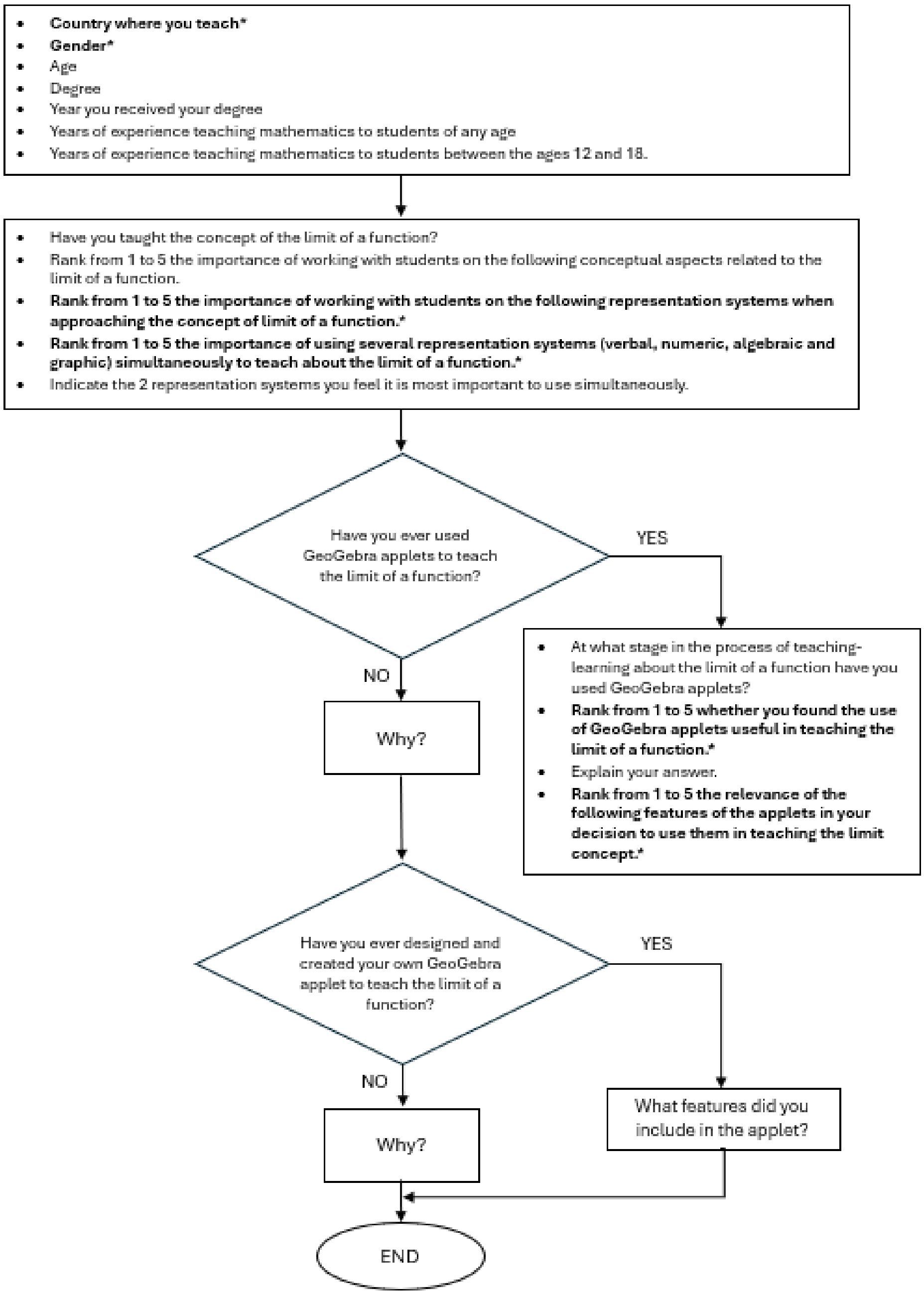
APPENDIX I. Questionnaire flow chart.



* Questions modified according to expert opinions.

Revista Latinoamericana de Tecnología Educativa, 24(1)
https://doi.org/10.17398/1695-288X.24.1.101

RELATEC
Revista Latinoamericana de Tecnología Educativa

Received: October 31, 2023
Reviewed: June 10, 2024
Accepted: October 11, 2024

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ARTICLE / ARTÍCULO

Digital technologies in music education. Using Digital Audio Workstations (DAW) with Project-Based Learning (PBL)

Tecnologías digitales en la educación musical. El uso de Estaciones de Trabajo de Audio Digital (DAW) con Aprendizaje Basado en Proyectos (ABP)

María Elena Cuenca-Rodríguez, Ignacio Pascual-Moltó & Raquel Pastor-Prada

Abstract: *BandLab* and *Walk Band* are two mobile and web-based applications that let users create and record their own songs, providing them with a variety of virtual instruments, samples, loops and drum machines. These applications can be used as educational tools to encourage musical learning and creativity in secondary and higher education students. This article discusses the advantages and challenges of using these applications in education and offers some recommendations for their pedagogical use. The objective is to show how *BandLab* and *Walk Band* can contribute to the development of musical, artistic and digital proficiency in students as well as create collaborative learning communities. A literature review on previous uses of multitrack sequencers is also done, and some examples of didactic proposals on music creation and musical arrangements are offered on how to integrate these applications in the music curriculum in secondary education and in interdisciplinary projects in higher education. Finally, some challenges and opportunities are presented for research and educational innovation through the use of these technologies in the field of music creation.

Keywords: Music Education, Educational Technology, Digital Audio Workstations, Project-Based Learning.

Resumen: *BandLab* and *Walk Band* are two mobile and web-based applications that allow users to create and record their own songs, with a variety of virtual instruments, samples, loops and drum machines at the user's disposal. These applications can be used as educational tools to foster musical learning and creativity in secondary and higher education students. This article discusses the advantages and challenges of using these applications in the educational context and offers some recommendations for their pedagogical use. The objective is to show how *BandLab* and *Walk Band* can contribute to the development of musical, artistic and digital competences in students, as well as to the creation of collaborative learning communities. A literature review on previous uses of multitrack sequencers is also carried out and some examples of didactic proposals on music creation and musical arrangements are offered to integrate these applications in the music curriculum in Secondary Education and in interdisciplinary projects in Higher Education. Finally, some challenges and opportunities for research and educational innovation in the field of music creation through these technologies are presented.

Palabras clave: Educación Musical, Tecnología Educativa, Estaciones de Trabajo de Audio Digital, Aprendizaje Basado en Proyectos.

1. Introduction

Musical creation is one of the proficiencies developed in music education. It exists in the Music subject in Compulsory Secondary Education (Educación Secundaria Obligatoria, hereinafter ESO) (Royal Decree 217/2022) and in subjects within Teaching degrees in the Music Education major in Early Childhood Education and in the one for Primary Education at universities (Ministry of Education and Science Order ECI/3857/2007). There have already been authors such as Nielsen (2013) or Ocaña-Fernández et al. (2020) who have emphasized the change of attitude in students and the creative development that comes from collective musical creation in both educational stages. The use of digital resources can facilitate and enrich this process by offering tools and possibilities that expand the repertoire and types of musical expression (Lam, 2023). According to Calderón-Garrido et al. (2019), digital technology has influenced the practices in musical creation and composition that are done in the classroom, incorporating new hardware, software and 2.0 tools in teaching and learning processes. These authors note that, in the case of secondary education, a transversality of learning appears, although certain usage to reinforce traditional content is also present, which can mean missing out on new possibilities. Moreover, Tejada Giménez (2004, p. 21) suggests that «music technology can improve processes and reduce learning times.»

Both Sastre (2013) and Ellis (1995) emphasize the potential of new technologies in music education, the former focusing on collaborative creation and the latter on software development to support creativity in compositions. Cayari (2014) expands this debate by highlighting the role of music video creation in the development of musical and technological skills. Cano (2018) further explores the use of music information retrieval technologies in music education, including applications that allow separation of the voice accompaniment alone, or the automatic transcription of certain instruments. These studies collectively underscore the potential of technology to improve music creation and education, in the same way that Brown (2014) stressed that they could help in learning and teaching a wide range of didactic activities.

On the other hand, Giráldez (2012) adds some questions about the integration of technologies in music education, such as the advantages, objectives, the relationship with new musical practices and the training of teachers. Also Hernández-Sellés et al. (2015) present a corpus of web 2.0 applications for musical creation and consumption and analyze a sample of these to determine their specific educational characteristics and uses. All these proposals highlight the notable advance in the acquisition of musical skills from the practice, improvisation and musical creation itself with Learning and Knowledge Technologies (hereinafter LKT) (Dammers, 2010; Rosen et al., 2013).

1.1. BandLab and Walk Band as didactic applications to create musical arrangements

As can be seen, the use of digital resources for the composition and creation of musical arrangements in secondary and higher education is a topic that has aroused the interest of diverse researchers. These resources can provide benefits for students as well as teachers, provided they are used with clear pedagogical criteria that is appropriate for each context (Brown, 1999).

Among these tools is the use of totally free-of-charge multitrack sequencers like *BandLab* and *Walk Band*. *BandLab* is an online platform that lets musicians and fans easily create, collaborate and share music for free. *BandLab* also offers an educational version that adapts to the needs of teachers and students in the school context. *Walk Band*, on the other hand, is a mobile application that allows music to be created with different virtual instruments such as piano, guitar and drums, among others. These tools offer instruments, effects and a sound library for students to experiment with various parameters such as timbre, rhythm, harmony and melody. Students can explore different genres, styles and musical techniques, compose, record, do arrangements and/or edit their own songs or pieces. These days students are quite used to the amount of sound manipulation that takes place in the different processes of musical production in popular music genres (Faure Carvallo et al., 2020), so for them it is familiar and affordable to explore effects and modifications of the audio when doing projects on specific songs.

Both applications facilitate collaboration, communication and feedback between students and teachers, allowing for projects, assignments, grading and group messages. *BandLab* for Education provides greater privacy and security for minors, protecting their intellectual property and image rights. These free, easy-to-use tools promote the creation of music learning communities both inside and outside of the classroom, while promoting the integration of music into other areas of the curriculum such as languages, sciences or mathematics, creating interdisciplinary projects.

Nevertheless, there are some challenges or limitations to consider. These include the need for a stable Internet connection, compatibility or performance problems with certain browsers or devices – especially older or low-memory ones – and possible distractions or conflicts between students if the activity is not supervised and class standards are not established. Additionally, there is the need for prior training or constant support for teachers and students who are not familiar with technology or music production. Moreover, use of these programs is not a substitute for the experience of playing a real instrument. Still, they can be tools that encourage learning the language of music, literacy in music scores or auditory training.

Below, some didactic proposals that have been done with these programs will be explained to show the varied uses that have been applied in the field of formal education with the goal of acquiring musical and digital proficiencies.

1.2. Studies that have used multitrack sequencers for musical creation in the educational setting

Many authors have researched the impact on music education that teaching this discipline through digital media such as online multitrack sequencers can have. *BandLab*, *Walk Band* or similar platforms – such as GarageBand or Soundtrap – facilitate music creation and arranging in different educational settings, such as schools, universities and online communities (Hamilton, 2021). In this sense, *BandLab* has been introduced in higher education experiments such as those by Hamilton (2021, p. 28), applied to knowledge in music classrooms of styles such as hip hop, which raises the value of music that has been marginalized for racist reasons in much media. In a preliminary study, the authors of this article have also verified the didactic possibilities that *BandLab* or *Walk Band* can have in the context of ESO, such as an increase in musical creativity, motivation and cooperation between students (Pascual Moltó et al, 2021). Other authors who have put it into practice in their music classes have been Fick and Bulgren (2022), and they present a model for tablet-based music production instruction through five gradual steps: sequencing, recording, editing, effects processing, and mixing. Mash (1991) emphasizes that the possibility of combining the recording of live instrumental performances with the MIDI sequencing environment in an intuitive graphic interface in these types of applications poses new challenges for music studies. Moreover, Peters (2015) recommends using semi-structured and playful activities done by students by means of introducing musical production skills. The end result should be focused on considering programs such as *BandLab* or *Walk Band* as tools to develop creativity with methods based on Project-Based Learning (PBL).

On the other hand, recent studies such as one from Carroll and Harris (2022) highlight that the use of digital tools focused on musical creation encouraged positive changes in the training of music teachers in stages such as early childhood education and primary education, as they got involved in using these in educational practice when numerous advantages in skills acquisition were observed. In addition, Watson (2011) points out that use of these DAW (Digital Audio Workstations) on a pedagogical level is an essential curricular material for the subject of music.

Likewise, Thorgersen and Mars (2021) study how different teachers from the previously mentioned stages and ESO in Sweden shared advantageous learning situations – such as the use of these DAW – with their music students during the COVID-19 pandemic in 2020 with satisfactory results. In turn, Merchán-Sánchez-Jara and González-Gutiérrez (2023) created a structured and sequential model for the collaborative composition of musical productions in the field of urban popular music through the DAW within the university setting in musical training of ESO teachers. Casanova López and Serrano Pastor (2016, p. 420) also used *Walk Band* during the second year of a project in musical training and Learning and Knowledge Technologies (LKT, hereinafter) in higher education of future music teachers, observing an increase in motivation, interest and the effort to learn during the sessions. In addition, Díez Latorre (2018) noted that the pedagogical training of many teachers is deficient and they simply teach the use of software without giving much importance to its usefulness on an educational level. Other projects related to instrumental training through technological resources did not incorporate musical production programs and were limited exclusively to sound recording (Berrón-Ruiz et al., 2023).

The use of *BandLab* as well as *Walk Band* is quite low in Spanish music schools. The uses made of these applications didactically in the field of higher education at the international level are also anecdotal. There are some proposals developed in a book by Giráldez et al. (2015) where innovative examples are collected on the use of DAW in the school environment to encourage musical creation and arrangements with loops and to develop rhythmic skills through drum machines. Tejada and Thayer Morel (2019a; 2019b) and Thayer Morel et al. (2021) used the same action-research proposal in different universities, which consisted of technological training that was provided in the initial training of music education teachers in secondary education, where they used multitrack sequencers to record instruments. Even though these proposals work different types of software, none focuses on the didactic, systematic and sequential use of specific DAW. This is why it is necessary to propose more experiences adapted to the field of music teaching through these programs in ESO and in higher education.

1.3. Objectives

After having given a series of advantages, challenges and disadvantages on the use of multitrack sequencers such as *BandLab* and *Walk Band* in the field of music education, the aim of this article is to find out the degree to which ESO and higher education students acquire musical and digital skills through activities done with the above-mentioned DAW and Project-Based Learning (PBL). As specific objectives (SO), the following are proposed:

SO1. Describe the proposal for musical activities and analyze results from the students during the process of musical creation with the DAW

SO2. Develop a SWOT report based on collecting data from final debates with the student body to observe their perception of the digital tools introduced for musical creation

SO3. Observe the differences in implementation of these resources and the results achieved between the groups of students in ESO, the Bachelor's degree and the Master's degree.

2. Methodology

In order to achieve the goals proposed in this study, an action-research design was chosen along with the collection and processing of data from two different case studies: one carried out in compulsory secondary education (ESO) and the other in higher education (specifically, Bachelor's and Master's degree students, which will be detailed below).

In the didactic proposals, the teaching strategies of Project-Based Learning (PBL) and the cooperative method with students were implemented. In this sense, the methodology was very similar to the one used in various studies (Mendoza Ponce and Galera Nuñez, 2011; Lage Gómez and Zahonero Rovira, 2012; and Tejada and Thayer Morel, 2019b) that highlight the importance of student commitment and creativity in the process of musical learning, using cooperative learning. This encouraged an innovative and inclusive process for all group members, who organized themselves to do all the project's tasks with guidance from the respective teachers.

2.1. Context of participants

The context in which the didactic proposal was carried out is that of different educational centers at different educational stages. Thus it was decided to extract three differentiated groups to observe the differences between them in the results section:

- For ESO, there were 50 students from two different primary school 6th grade classrooms (1st ESO in Spain) at the IES Clot de l'Illot school, 2 boys and 28 girls. This will form category A, where *Walk Band* will be used in ESO. These students come from lower and middle class families and have not received any prior technological or digital media training. None of them had previously experimented with digital tools, such as multitrack sequencers, in the music subjects they had previously studied.

- For the higher education proposal, there were 58 students from the Universidad Autónoma of Madrid (UAM, hereinafter), who come from two different categories: the Bachelor's degree and the Master's degree. These students come from middle class families and have previous knowledge in LKT subjects and digital media from the degrees they are studying or have studied in the past. None of them had previously experimented with digital tools, such as multitrack sequencers, used in music studies.

  a) 30 students (23 women and 7 men between the ages of 22 and 39 in the 4th year of the Bachelor's degree in Teaching Primary Education (with a specialization in Music Education). These participants will be category B, where *BandLab* will be used.

  b) 28 students (11 women and 17 men between the ages of 24 and 44) in the Master's degree in Teacher Training for Compulsory Secondary Education and High School (Máster en Formación del Profesorado de Educación Secundaria Obligatoria y Bachillerato, hereinafter MESOB). This will form category C, where *BandLab* will also be used.

Each program has been assigned to each stage, due to the difficulty and range of resources of each one: While *Walk Band* has a simpler interface adapted to adolescents, *BandLab* is a more complex program with a wider range of resources. Students in these educational stages have also been chosen to observe the different behaviors and results when facing the use of very similar applications. All the groups participated willingly in the activities proposed, based on creating musical arrangements with these DAW.

In each process, permission was requested from the managerial team at both centers, as well as the ethics committee of the UAM, to carry out the research. This entity advised on the applicability, both legally and for safety, in the selected sample. The families of underage students were also given information and informed consent was requested in order to participate in the research experiment. The data processing has been completely anonymized, without revealing any identity of the students and respecting the Organic Law 3/2018 on Personal Data Protection and the guarantee of digital rights.

2.2. Procedure and timing of study

The teachers, authors of this article, used the didactic proposal based on *Walk Band* in ESO and Band Lab for higher education during six consecutive sessions of 50 minutes each. Each teacher – in ESO as well as higher education – followed the ensuing schematic model (each one adapted to the functionality and difficulty of each stage):

- Session 1: The program's functionality and its didactic applicability for musical creation was explained.

- Session 2: The teacher created various exercises with the PBL methodology for acquisition of musical and digital skills through the use of DAW. These are explained below in the results section.

- Sessions 3-5: The students – having previously practiced in Session 2 with the prior activities – had to develop a project to create song arrangements, following the steps in a previous example that was structured and explained sequentially by the teachers. The teachers then guided the students' didactic process using advice and problem solving on a technical and musical level.

– Session 6: The results were observed and suggestions for improvement were provided on both the musical production and performance levels. In the case of higher education, use of the DAW applied to music teaching in primary and secondary education was also discussed.

2.3. Design and instruments

The design of the research is based on an educational activity in the classroom aimed at acquiring greater musical and digital skills through DAW. To do this, the experiment will have a social approach, done through collaborative teaching and project-based learning via technology.

For data collection, instruments designed to achieve the proposed objectives have been used. On the one hand, observations and annotations in log books of each of the strengths, weaknesses, opportunities and threats (SWOT report) in each group. On the other, the results of each of the projects have been analyzed, critically observing the positive and negative aspects in regard to musical and technical production in each of the groups. Finally, a last discussion group served to recognize the usefulness and employability of these tools to encourage musical creativity.

3. Results

The following results are divided into three sections. First, to achieve SO1, implementation of *Walk Band* is described and analyzed in regard to developing musical creativity and the exercises done in primary school 6th grade students (1st ESO) at the IES Clot de l'Illot school, plus the results of projects done with *BandLab* by students in the Bachelor's degree in Teaching Primary Education (with a specialization in Music Education) and by students of the MESOB. Next, to achieve SO2, results of the SWOT analysis on the use of these tools to encourage musical creativity are developed. Finally, to achieve SO3, the differences in the results after implementation of the DAW among the different groups of students will be studied.

3.1. Exercises with Walk Band in ESO

Utilizing the *Walk Band* application during the period it was in use managed to strengthen the content and processes typical of music studies in ESO. This has been verified through fulfillment of the exercises and observation of the questions and problems that arose in doing the exercises. The teacher guided the students throughout the entire process. This series of exercises has also encouraged learning mathematical and digital skills, among others, given that students learn to make good use of LKT (in this case, their smartphones).

Figure 1. Drum fragment proposed to the class.

In the case of rhythm, it is worth noting that the length of the different musical figures was worked on using the drum machine tool. Once given the explanation to remember the different values of the musical figures, the students were able to transcribe the simple drum score (Figure 1), taking into account that each of the four squares of the same color is equivalent to a sixteenth note (Figure 2).

Figure 2. Diagram of the drum machine belonging to the previous score.

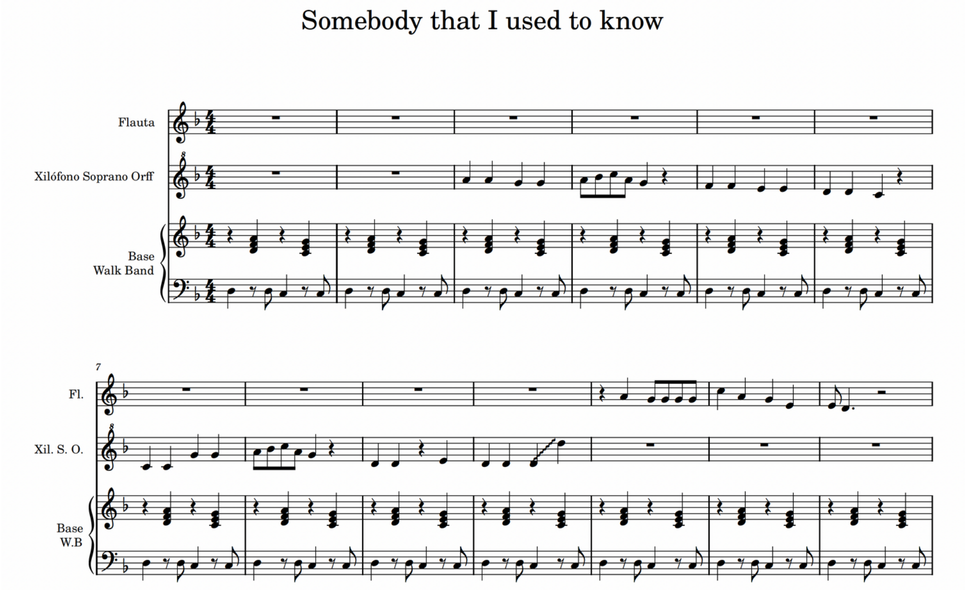
By using this drum machine, they have visually understood how fractional numbers work, thus improving this basic knowledge for mathematical competency.

Moreover, by using the virtual bass tools and the possibility of playing chords on the virtual guitar, students were able to make the base of the first section of the song by Gotye: «Somebody that I used to know» (Figure 3).

Figure 3. Arrangement by author of the song "Somebody that I used to know" by Gotye.

In this way, the goal is to promote both learning of the use of the bass clef in bass instruments as well as differentiation between the formation of a major chord (formed by a major and minor triad) or the formation of a minor chord (the inverse). Subsequently, the union of the bass with the guitar chords made with the application's virtual instruments served as a basis for the live performance of both the xylophone score in the introduction of the song and the singer's melody, performed on the flute. The score of the final performance can be seen in Figure 4.

Figure 4. Final score comprising the base made with *Walk Band*, along with the score of the acoustic



instruments played by the students.

One of the results from a group of ESO students has been this preliminary project that you can listen to in Example 1 in the repository uploaded to Zenodo[1].

Throughout the entire process, the students worked collaboratively and expressed interest in doing each activity, each of them developing a part and interpreting it later with their peers. At the same time, they acquired the numerous skills mentioned above along with interpersonal and digital ones.

3.2. Projects with BandLab in the Bachelor's degree

Next, projects are shown that have been developed based on the previous examples done by the teacher. The students in the Bachelor's degree in Teaching Primary Education as well as those in the MESOB in postgraduate education had no learning difficulties in gradually following the steps.

[1] https://doi.org/10.5281/zenodo.8364525

Figure 5. Final score of «Love Me Do» showing the interpretation done with *BandLab*.

First, a series of examples were taught that the students themselves used to put their performance skills into practice using MIDI instruments from the *BandLab* for Education program. Initially, they had to prepare the song «Love Me Do» by The Beatles with MIDI instruments and real recorded instruments. This was based on the above score (Figure 5), which they progressively prepared by introducing more and more instrumental parts. One member of the group prepared the Classic Rock drums by pressing the computer keys A (bass drum), F (snare drum) and P (cymbal) simultaneously (Figure 6); another member rehearsed the electric bass part, Electric Bass Legato, with a four-note melodic ostinato (sol, re, do, re).

A third member then rehearsed the accompanying guitar chords, recording the performance of a ukulele available in the music classroom, which was done with a Zoom H6 recorder microphone, also available in the classroom. Another member interpreted the accompanying melody of the harmonica on a MIDI instrument, and the last members sang lead and the secondary vocal part of the song (Figure 5). The students chose the instruments, adjusting their choices to the tone closest to the instrumental template used by The Beatles. The result made by the group 1 students of the Bachelor's degree in Teaching Primary Education can be heard in Example 2 in the Zenodo repository.

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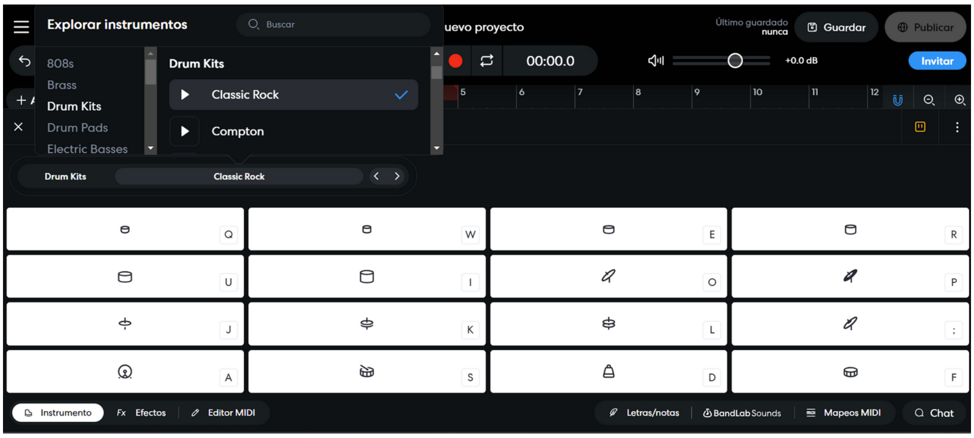

Figure 6. Pads from the drum part as MIDI instrument in *BandLab*.

After the initial example proposed by the teacher, the students had to develop and create new projects from already created songs in popular music. Each of the parts could be extracted by ear, or the score could be searched from numerous arrangements found on the Noteflight, MuseScore or IMSLP websites. From this, each member of the group was involved in developing the melody, harmony and rhythm of each instrument as well as singing the vocal part. The results of the groups in the Bachelor's degree in Teaching Primary Education can be observed in Examples 2 to 5.

The results are as follows: Example 3 is composed of a piece entirely interpreted on MIDI brass wind instruments and percussion from *BandLab*. To do this, the students composed the rhythmic base and reproduced the melody and harmony with a MIDI controller that played back each instrumental part with the song «Hit the Road Jack» by Ray Charles. Example 4 has interpretation of the choral song «Akai hana» from Japanese folk tradition. It is a piece with a lead vocalist and accompaniment (two voices per part, each recorded individually), plus parts with alto xylophone and bass xylophone as rhythmic and harmonic base. It is a fairly simple arrangement for the final courses in primary education. Example 5 is Coldplay's song «Paradise» recorded by a group of students who sang together in unison over a base with drum, bass and piano with MIDI instruments.

3.3. BandLab projects in the Master's degree

The project that was implemented with the students in the MESOB Master's degree was very similar to the one done in the Bachelor's degree in Teaching Primary Education except that the song arrangements had a higher level of difficulty. The results from the MESOB Master's students can be heard in Examples 6 to 10 in the Zenodo repository.

Example 6 is «Stand by Me» by Ben E. King. This is the song proposed by the group of students, who mixed MIDI instruments – drums, bass and piano – and recordings – maracas and vocals – in their interpretation. Example 7 is James Brown's «I Feel Good» with numerous MIDI instruments added (drums, bass, trumpet and sax) plus recorded vocals. Meanwhile, in Example 8 – Bruno Mars' «Uptown Funk» – they decided to introduce a drum machine, with a clapping rhythm and, after that, bass drum and snare drum. The keyboard and bass were added as MIDI instruments, and they also decided to add a lead vocal part and recorded chorus effects. Example 9 has an interpretation of «Accidentally in love» by Counting Crows, from the Shrek soundtrack. It is a complex composition of MIDI instruments – drums, acoustic guitar, riff guitar and synthesizers – accompanied by lead and back-up vocals and a voice doing a downward octave, a sample of a clear example of a complete arrangement from the original song. Finally, Example 10 – Bob Marley's «One Love» – is also a sample of great instrumental development, adding melodies sung with three voices along with the recorded solo trumpet part plus bongo, organ, guitar, two keyboards and bass as part of harmonic crafting on MIDI instruments, as well as the MIDI drums as a rhythmic base.

Among the effects introduced in each song, students added compressors, equalizers, reverberation and normalization on virtually all tracks to achieve optimal results, similar to those done in a record production process.

3.4. SWOT analysis of debate on the didactic activity in ESO, the Bachelor's degree and Master's degree

After analysis of the last of the sessions, where a debate was held and new data was collected on the opinions and impressions of the students, the SWOT report was prepared on the use of DAW in the music classroom to achieve SO2. Following are the overall results for the three groups of participants:

- Strengths: Multitrack sequencers let you create original pieces or make complex musical arrangements by combining different audio tracks, effects and resources. Also, they encourage collaborative work, creativity and motivation in the students by offering them a means of personal and artistic expression. Likewise, they facilitate assessment and self-evaluation, allowing musical productions to be recorded and listened to. Both platforms are also very intuitive and permit rapid and progressive acquisition of musical and digital skills.

- Weaknesses: Multitrack sequencers require certain technical and musical knowledge for their use, which can be an entrance barrier for some students and teachers.

- Opportunities: The use of multitrack sequencers opens up new pedagogical and didactic possibilities, integrating not only these digital and musical skills into the curriculum but also others related to linguistic communication, mathematics, learning how to learn, and autonomy and personal initiative. They also favor inclusion and diversity, adapting to the needs and preferences of each student. Finally, they promote connection with the social and cultural environment, encouraging the exchange and dissemination of the musical work created.

- Threats: The use of multitrack sequencers can cause a loss of musical identity as they favor the imitation or plagiarism of existing work. They can also create unfair competition among students by valuing the quality of the final product over the learning process. Moreover, they can pose a legal risk if copyright is not respected.

Next, to fulfill SO3, is analysis of the differences found between groups:

a) The teacher needs to guide the process more closely when it comes to stages like ESO and also in the Bachelor's degree. In the Master's degree, almost all the students had greater autonomy in performing musical arrangements due to their greater knowledge of music and digital tools associated with production.

b) Through different methodologies used didactically – one with *Walk Band* for ESO and the other with *BandLab* for higher education – it was observed that the results are equally satisfactory in different ways: On the one hand, involving the entire class to do an arrangement of the same song in *Walk Band*; on the other, interpretive options and scores were researched by the groups to do different arrangements of various songs with *BandLab*.

c) Creating musical arrangements of songs has had very diverse results: simple adaptations in the case of ESO but with results that imply a clear acquisition of musical and digital skills, and more elaborate arrangements in the case of the Bachelor's degree students or even more complex ones in the case of the Master's students, with many more instrumental layers.

4. Discussion

Initially, it was shown how musical creation is an essential item in music education curricula, both in secondary education and higher education (Royal Decree 217/2022; Order ECI/3857/2007). In line with what has been noted in various research (Calderón-Garrido et al., 2019; Hamilton, 2021), teacher intervention developed through the use of LKT has been able to enrich the possibilities for musical expression and composition within an educational process.

In this sense, the results are consistent with other studies (Carroll and Harris, 2022; Casanova López and Serrano Pastor, 2016; Giráldez, 2012) in which the use of LKT in the initial training of teachers benefits their learning competencies, as well as their motivation and interest in the need for specific pedagogical training in this field (Author1 et al., 2021; Lam, 2023). It has been shown how, specifically, they have acquired musical and digital skills through the PBL methodology implemented, as also shown by Nielsen (2013) and Ocaña-Fernández et al. (2020) in their respective studies on musical creation via technological means.

Similarly, the data collected during the process confirms the benefits of digital resources for development of musical skills, such as instrumental practice and rhythmic skills (Giráldez et al., 2015). In this sense, it has been shown how technology can be used to improve music studies, facilitating creation and collaboration between students and teachers, as advocated by Brown (1999). Moreover, in the didactic proposal it has also been observed how these exercises with DAW favor the acquisition of other interdisciplinary competencies, like mathematical or interpersonal skills, which shows the transversality of the learning acquired, as noted by Calderón-Garrido et al. (2019).

Moreover, the different work done by the students highlights the opportunity to work with popular and traditional repertoires they feel close to and that are affordable (Faure Carvallo et al., 2020). Likewise, it is worth noting the design of teacher interventions through semi-structured activities that get progressively complex (Fick and Bulgren, 2022), which allows students autonomous learning that is playful and collaborative, being able to develop creative group processes (Hernández-Sellés et al., 2015; Peters, 2015).

Therefore, it seems that the integration of resources such as *Walk Band* (2024) or *BandLab* (2024) in music education, both in ESO and in higher education, allows numerous skills to be developed in students. However, as Díaz Latorre (2018) argues, teachers must take into account the didactic objectives and not use this tool as an end in itself but rather as a resource for musical learning. For this reason, it is necessary to increase the didactic proposals that result in meaningful learning of musical concepts and procedures adapted to the different educational areas, as indicated by Giráldez et al. (2015) and Tejada and Thayer Morel (2019a and 2019b).

5. Conclusions

The above-mentioned results are clearly satisfactory for the reduced number of sessions, six, in which this didactic proposal was implemented. We can conclude by stating that this is a clear example of didactic sequencing and Project-Based Learning in which students notably collaborated to attain highly significant results.

Moreover, thanks to this proposal, numerous musical, digital and interpersonal skills were acquired that clearly showed the benefits in using DAW in the educational context. All of this makes these future music teachers – in the Bachelor's degree in Teaching Primary Education as well as in the MESOB – capable of using multitrack sequencers, in these stages of compulsory education, as digital tools for the development of musical expression and creativity. Although these resources require certain technical and musical knowledge for their operation, they also allow the creation of original pieces, complex arrangements and encourage collaborative work, creativity and motivation in the students. Therefore, teachers should be trained in these digital methodologies so they can be implemented in music classrooms.

As has been seen, there is still very little research referring to the pedagogy of these digital tools used primarily in music production but which are very useful and didactic for learning music. In addition, *BandLab* (2024b) and *Walk Band* (2024) are tools that facilitate assessment and self-evaluation, which allows the teaching-learning process to be observed progressively. This experiment has also shown the different degrees of interaction with the applications: While in ESO the arrangements were quite simple and supervised by the teacher, in the Bachelor's and Master's degrees greater development was shown both in the complexity of the arrangement (with many instrumental layers) and in the addition of effects that improved the musical production and final result.

Among the limitations of the study is the lack of a greater number of participants in the different groups and the short time available to implement the didactic proposal, due to the demands of the curriculum itself. It is hoped in the future to do mixed research – with quantitative and qualitative questions – on a larger group of students from various educational stages, including primary education. Said study will focus on the increase in musical abilities through the DAW used in the music classroom in basic education and the pedagogical benefits of the PBL methodology in the production of musical creation projects.

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ISSN

1695-288X

Journal design and web maintenance

Jesús Valverde Berrocoso

FECYT-291/2024
Fecha de certificación: 14 de julio de 2016 (5ª convocatoria)
Válido hasta: 24 de julio de 2025