Zero Digital Competence: Training Needs through Data Mining towards an Innovative Digital Training System

Competencia Digital Cero: Necesidades Formativas vía Minería de Datos hacia un Sistema de Formación Digital Innovador y Disruptivo

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ABSTRACT

This study identifies teaching training needs through text mining to underpin an innovative digital training system that contributes to reducing the digital skills gap, comparing pre- and post-pandemic periods. A sequential qualitative design was employed, with semi-structured interviews with 21 specialists from five Spanish-speaking countries (pre-pandemic phase, 2018-2020) and focus groups with 6 specialists (post-pandemic phase, 2023). Data were analyzed using text mining techniques (bigram analysis) and qualitative microanalysis, applying theoretical saturation criteria and methodological triangulation. The pre-pandemic analysis revealed concerns focused on curricular aspects, assessment of learning, and university structure. The post-pandemic study showed a shift toward technologies supporting data, a humanizing approach to learning, and solving real-world problems using artificial intelligence. The most significant bigrams ("virtual-reality," "soft-skills," "artificial-intelligence") confirm this evolution. The findings support a Digital Training System based on learning communities mediated by AI, personalized trajectories, and a technical-humanistic balance, transcending traditional models to address the digital skills gap in teaching in an innovative and contextualized manner.

RESUMEN

Este estudio identifica necesidades formativas docentes mediante minería de textos para fundamentar un sistema formativo digital innovador que contribuya a reducir la brecha de competencias digitales, comparando períodos pre y post-pandemia. Se empleó un diseño cualitativo secuencial con entrevistas semiestructuradas a 21 especialistas de cinco países hispanoamericanos (fase pre-pandemia, 2018-2020) y focus groups con 6 especialistas (fase post-pandemia, 2023). Los datos se analizaron mediante técnicas de minería de textos (análisis de bigramas) y microanálisis cualitativo, aplicando criterios de saturación teórica y triangulación metodológica. El análisis pre-pandemia reveló preocupaciones centradas en aspectos curriculares, evaluación de aprendizajes y estructura universitaria. El estudio post-pandemia evidenció un desplazamiento hacia tecnologías como apoyo de datos, enfoque humanizante del aprendizaje y solución de problemas reales mediante inteligencia artificial. Los bigramas más significativos ("realidad-virtual", "habilidades-blandas", "inteligencia-artificial") confirman esta evolución. Los hallazgos fundamentan un Sistema Formativo Digital basado en comunidades de aprendizaje mediadas por IA, trayectorias personalizadas y equilibrio técnico-humanístico, trascendiendo los modelos tradicionales para abordar la brecha de competencias digitales docentes de manera innovadora y contextualizada.

1. Introduction and Background

1.1. Introduction

The digital transformation of education has experienced an unprecedented acceleration since the onset of the COVID-19 pandemic, highlighting and deepening pre-existing gaps in teachers' digital competencies (Cabero-Almenara & Valencia-Ortiz, 2021; Fernández-Batanero et al., 2022). This phenomenon has underscored the urgency of rethinking traditional training systems, which have shown significant limitations in swiftly responding to the emerging needs of teachers in rapidly changing contexts (Castañeda et al., 2022).

This study aims to identify qualitative background on teachers' training needs through text mining techniques, analyzing data from participants of the "Competencia Digital Cero" movement at two key points: pre-pandemic (2018–2020) and post-pandemic (2023). This comparative analysis allows for an understanding of how the experience of forced digitalization has transformed teachers' priorities and training requirements, thus supporting the proposal of an innovative and disruptive Digital Training System (DTS).

The digital gap among teachers remains a persistent challenge in today's educational landscape. Area-Moreira et al. (2023) characterize it as a multidimensional phenomenon that goes beyond access to devices, encompassing instrumental (tool use), pedagogical (meaningful integration into teaching-learning processes), and ethical-reflective (critical stance toward digital transformation) dimensions. This gap, already identified before COVID-19 (Cabero-Almenara & Ruiz-Palmero, 2018), became dramatically visible during the pandemic and still persists, with traditional training systems having proven ineffective in reducing it (European Commission, 2023; Beltrán, 2023).

Recent research on teacher training in digital competencies shows a progressive shift from instrumental approaches toward more holistic and integrated perspectives (Garzón-Artacho et al., 2021; Esteve et al., 2022). However, as Reisoğlu and Çebi (2020) point out, a significant disconnect persists between conceptual frameworks and their practical implementation in training programs, which mostly remain anchored in rigid and decontextualized structures.

In this context, the "Competencia Digital Cero" initiative emerged in 2018 as a response to the limitations of traditional training systems in developing teachers' digital competencies. This movement operates under the principles of horizontality, contextualization, and collaborative learning—aligned with what Adell et al. (2018) describe as "emergent pedagogies" in digital environments. The experience accumulated by this practical community offers a valuable corpus of data for analyzing the evolution of teachers' training needs in the pre- and post-pandemic periods.

Analyzing these needs through text mining techniques represents an innovative methodological approach in the educational field. As Escudero et al. (2022) indicate, these techniques enable the identification of semantic patterns not evident through traditional analyses, which are especially valuable in understanding changes in perceptions and priorities. This methodology is complemented by conventional qualitative analyses that contextualize and interpret the identified patterns.

The general objective of this study is to identify teachers' training needs through text mining to support the design of an innovative and disruptive Digital Training System. The specific objectives are: 1) to comparatively analyze the training needs expressed by

teachers in pre- and post-pandemic periods; 2) to identify significant semantic patterns through bigram analysis; and 3) to propose a model for a Digital Training System based on the empirical evidence gathered.

The relevance of this research lies in its potential to inform the design of more agile, contextualized, and effective training systems for the development of teachers' digital competencies. In a historical moment of accelerated educational transformation, understanding the evolution of training needs and proposing disruptive models represents a significant contribution both for training institutions and educational policymakers (Portillo et al., 2020; Ramírez-Montoya et al., 2022).

1.2. State of the Art

Teacher training in digital competencies and innovative training systems are currently vibrant areas of research, particularly accelerated by the forced digitalization experience during the pandemic. The main developments are analyzed below in three interconnected dimensions: conceptual frameworks of teachers' digital competence, persistent gaps in its development, and emerging training systems.

1.2.1. Conceptual Frameworks of Teachers' Digital Competence

The construct of teachers' digital competence has undergone significant conceptual evolution, with the European Framework for the Digital Competence of Educators (DigCompEdu) progressively becoming an international benchmark (Cabero-Almenara & Palacios-Rodríguez, 2020). This framework organizes teachers' digital competence into six interrelated areas: professional engagement, digital resources, digital pedagogy, digital assessment, learner empowerment, and facilitation of students' digital competence.

Falloon (2020) proposes the Teacher Digital Competence (TDC) Framework, which emphasizes the contextual and situated nature of these competencies, distinguishing between technical, pedagogical, and evaluative skills. Meanwhile, Mishra and Koehler (2021) update their influential TPACK model (Technological, Pedagogical, and Content Knowledge), incorporating ethical and sociocultural dimensions that recognize the complexity of technology integration in diverse educational settings.

In the Spanish-speaking context, Pascual et al. (2022) identify the coexistence of multiple reference frameworks, highlighting the need for contextualization to specific realities. These authors emphasize that teachers' digital competencies are not a static set of skills but dynamic capacities that evolve in response to technological, pedagogical, and sociocultural transformations.

1.2.2. Persistent Gaps in the Development of Teachers' Digital Competence

Despite the consolidation of robust conceptual frameworks, numerous studies show the persistence of significant gaps in the effective development of teachers' digital competencies. Area-Moreira et al. (2023), analyzing self-perceived competencies of 1,433

Spanish teachers, found that approximately 40% reported insufficient levels, particularly in the pedagogical and evaluative dimensions.

Fernández-Batanero et al. (2022), through a systematic review of 38 studies, confirmed that the greatest deficiencies are found precisely in the most complex competencies: designing digital learning experiences, technology-mediated assessment, and creating digital content. This uneven distribution shapes what Cabero-Almenara and Llorente-Cejudo (2020) call the "third digital divide" in teaching, characterized not by access or instrumental use, but by the capacity for transformative pedagogical integration.

The pandemic served as a catalyst that made these pre-existing gaps more visible. As Portillo et al. (2020) demonstrate in a study with 593 teachers from different educational levels, the emergency remote teaching experience revealed significant disparities not only between institutions but also among teachers within the same institution, creating a landscape of "digital inequality" that continues into the post-pandemic stage (Beltrán, 2023).

A particularly relevant aspect for our study is the identification of factors that determine teachers' resistance to technopedagogical innovation. López-Belmonte et al. (2020) identify the main barriers as: lack of specific training (45.2%), distrust toward innovative approaches (22.2%), reactive stances toward the use of technologies (17.2%), lack of resources (12%), and perceived incompatibility with student characteristics (3.4%). These findings suggest that training needs go beyond technical instruction, involving attitudinal, emotional, and epistemological dimensions.

1.2.3. Emerging Training Systems for the Development of Teachers' Digital Competencies

In light of the limitations of traditional training models, various researchers have documented the emergence of alternative systems with disruptive potential. González-Sanmamed et al. (2022) propose the concept of "digital learning ecologies" as an interpretive framework for these new training ecosystems. Their empirically validated model integrates resources, activities, relationships, and contexts into a dynamic network that transcends conventional institutional boundaries.

Gros and Noguera (2023) analyze digital learning communities among teachers, identifying them as particularly effective training spaces due to their ability to provide situated, collaborative, and contextualized learning. Their longitudinal study with 42 teachers shows how these communities foster not only technical skills development but, more importantly, the construction of shared pedagogical meanings around technology integration.

Artificial intelligence is emerging as a potentially transformative component of training systems. Fan et al. (2022) document experiences with adaptive recommendation systems to personalize learning pathways, demonstrating significant improvements when these systems address specific individual needs. However, as Williamson (2023) warns, implementing such systems must be grounded in sound pedagogical frameworks that avoid technological determinism and prioritize teacher agency.

Particularly relevant to our study is the experience of the "Competencia Digital Cero" initiative, launched in 2018 as a response to the limitations of traditional training systems.

This movement operates under the principles of horizontality, contextualization, and collaborative learning, aligned with what Raffaghelli (2020) describes as "transformative professional learning" in digital environments. The experience accumulated by this practical community offers a valuable corpus of data to analyze the evolution of teachers' training needs during the pre- and post-pandemic periods.

1.2.4. Text Mining Applied to the Analysis of Training Needs

The application of text mining techniques to the analysis of training needs represents an emerging field with significant potential. Escudero et al. (2022), in their systematic review of 87 studies, identify exponential growth in the use of these techniques in educational research, emphasizing their ability to process large volumes of information and detect patterns not evident through manual analysis.

Hidalgo-Ternero and Pérez-Cordón (2021) specifically examine the application of natural language processing in education, highlighting bigram analysis as a particularly valuable method for identifying semantic patterns in educational texts. This approach allows for the detection of recurring conceptual associations that reveal concerns, priorities, and underlying interpretive frameworks in teacher discourse.

Sharma et al. (2020) demonstrate the effectiveness of text mining in identifying significant communication patterns in educational contexts, showing how these techniques can complement traditional qualitative approaches. However, as Marín (2023) cautions, these methodologies present important limitations that must be acknowledged, particularly regarding the contextualization and interpretation of identified patterns.

This study is situated at the promising intersection of text mining, analysis of training needs, and the design of disruptive training systems, contributing to a growing field of research that seeks to empirically support the transformation of teacher training in the contemporary digital context.

2. Methodology

This study adopts a qualitative approach with a sequential comparative design, analyzing data collected in two clearly differentiated time periods: pre-pandemic (2018–2020) and post-pandemic (2023). This methodological approach enables the identification of changes in teachers' training needs resulting from the disruptive context caused by COVID-19, following the recommendations of Castañeda et al. (2022) for analyzing educational phenomena during periods of accelerated transformation.

2.1. Participants and Selection Criteria

2.1.1. Pre-pandemic Phase

The pre-pandemic phase involved 21 Spanish-speaking teaching specialists from the following countries: Argentina (1), Chile (5), Colombia (4), Spain (6), and Mexico (5). This

geographic diversity allowed the study to capture perspectives from various socio-educational contexts and digital policy frameworks, enriching the comparative analysis.

Regarding their professional affiliation, six specialists came from education-focused companies, while fifteen worked directly in public or private universities and national educational institutions. This heterogeneity enabled the contrast of views from both academic and educational business sectors.

Participants were selected using purposive criterion-based sampling (Flick, 2018), applying four fundamental parameters:

- **Verifiable teaching experience:** Minimum of 5 years in university or vocational education.

- **Specialization in digital training:** Demonstrated through publications, projects, or roles in teacher training and/or digital education.

- **Active involvement in educational innovation:** Participation in professional networks related to digital competencies and pedagogical innovation.

- **Contextual representativeness:** Inclusion of diverse institutional, geographic, and professional realities within the Spanish-speaking world.

The sample size (n=21) was determined using the theoretical saturation criterion (Strauss & Corbin, 2002), halting the inclusion of new participants once additional interviews no longer yielded substantially new categories or properties. This procedure follows the methodological recommendations of Guest et al. (2020) for qualitative studies based on semi-structured interviews in specialized fields.

2.1.2. Post-pandemic Phase

The post-pandemic phase included 6 education specialists from Chile (1), Spain (3), Mexico (1), and Peru (1), all engaged in academic and educational activities related to teacher training and digital education. Selection followed the same criteria as in the pre-pandemic phase, ensuring comparability between the two samples.

The smaller sample size in this phase (n=6) is explained by two methodological factors: 1) The greater depth and intensity of the focus group method compared to individual interviews, following Krueger and Casey's (2015) recommendations; y 2) Earlier saturation patterns, likely due to the shared experience of forced digitalization during the pandemic.

To compensate for this numerical difference and ensure the validity of findings, methodological triangulation was implemented by complementing the data with an open-ended questionnaire applied to participants from the "Mission 3" phase of the Competencia Digital Cero initiative.

2.2. Data Collection Techniques and Instruments

2.2.1. Pre-pandemic Semi-structured Interviews

A semi-structured interview protocol was designed with 12 open-ended questions organized into five thematic blocks:

- Teacher professional profile and expected transformations
- Emerging educational models
- Evolution of assessment systems
- Technological transformations and their impact on training
- Cultural changes and their influence on training needs

The protocol was validated by expert judgment (n=3) from individuals experienced in qualitative research and teacher training, achieving a content validity index of 0.87, considered optimal according to Lynn's (1986) criteria.

Interviews were conducted in person, recorded with informed consent, and fully transcribed for analysis. The average duration was 22 minutes, with a range from 9 to 58 minutes depending on the depth of the responses.

2.2.2. Post-pandemic Focus Groups

A specific protocol was designed with 13 open-ended questions that corresponded thematically to the pre-pandemic interviews, allowing comparability between the two phases. Additionally, questions were included regarding the specific impact of the pandemic on training needs.

Two focus groups were conducted, each with 3 participants, facilitated by the same researcher who conducted the individual interviews. The sessions were held virtually via Zoom, recorded with informed consent, and fully transcribed. The durations were 130 and 90 minutes, respectively.

2.2.3. Complementary Questionnaire

A questionnaire with three open-ended questions was administered to participants from the "Mission 3" phase of the *Competencia Digital Cero* initiative:

How do you imagine the future of teacher training?

What do you want to learn today?

Would you like to add any ideas or suggestions about our Mission 3?

This complementary instrument broadened the post-pandemic database and triangulated the findings from the focus groups with a wider sample.

2.3. Data Analysis

A mixed analytical approach was implemented, integrating text mining techniques with traditional qualitative analysis, following the methodological integration recommendations by Escudero et al. (2022) for educational research.

2.3.1. Text Mining: Bigram Analysis

Text mining analysis followed a systematic procedure structured in five phases:

1. **Text corpus preparation:** A corpus was created for each interview, excluding interviewer interventions. The text was normalized through cleaning processes (removal of punctuation, conversion to lowercase) and lemmatization (reducing words to their canonical form).

2. **Stopword removal:** A Spanish stopword list with 310 terms was applied, consisting of grammatical particles or connectors with no relevant semantic value.

3. **Bigram extraction:** Bigrams (pairs of related words) were identified in each interview, following the methodology proposed by Chen et al. (2006). Bigrams are language models that help determine dependencies between terms and enable automatic text categorization.

4. **Adaptive bigram filtering:** Due to semantic richness variability across interviews, differentiated frequency thresholds were applied:

   a. High semantic richness: minimum frequency of 5

   b. Medium semantic richness: minimum frequency of 3–4

   c. Low semantic richness: minimum frequency of 2

   This flexible approach enabled the identification of relevant semantic patterns across all interviews, adapting to their natural informational density.

5. **Semantic network visualization:** Visual representations of the most significant bigrams were generated, facilitating the identification of both central nodes and peripheral relationships in the specialists' discourse.

The computational analysis was conducted using the R programming language, version 4.1.1, employing the "tm" package for text processing, "igraph" for network visualization, and "tidytext" for structured text analysis.

2.3.2. Qualitative Microanalysis

To complement the computational analysis, line-by-line microanalysis was applied, as proposed by Strauss and Corbin (2002), enabling the emergence of categories and relationships among them. This method was applied to both the focus group transcripts and the responses from the complementary questionnaire.

The microanalysis process included:

1. **Open coding:** identification of concepts within the data
2. **Axial coding:** establishing relationships among categories
3. **Selective coding:** integration and theoretical refinement

2.4. Validation and Methodological Rigor

To ensure methodological rigor, the criteria proposed by Lincoln and Guba (1985) for qualitative research were applied:

- **Credibility:** Implementation of methodological triangulation (interviews, focus groups, questionnaire) and analytical triangulation (text mining and traditional qualitative analysis).

- **Transferability:** Detailed description of participants, contexts, and procedures to support judgments about the applicability of findings to other contexts.

- **Dependability:** Maintenance of a detailed audit trail of all methodological and analytical decisions.

- **Confirmability:** Use of textual citations to support interpretations and validation of preliminary analyses with a sample of participants.

2.5. Ethical Considerations

The research was conducted following ethical principles for social science research (AERA, 2011). All participants signed informed consent forms that explained the study's objectives, the voluntary nature of their participation, their right to withdraw at any time, and confidentiality guarantees. Data were handled in accordance with personal data protection regulations, using coding systems that prevented participant identification.

3. Analysis and Results

3.1. Pre- and Post-Pandemic Perspectives on Teacher Training Needs.

3.1.1. Analysis and Results from Pre-Pandemic Interviews.

Text mining was carried out separately for each pre-pandemic interview in order to enable semantic pattern comparison. A corpus was created for each interview, excluding interviewer interventions. A list of 310 Spanish stop-words was compiled, consisting of grammatical particles or connectors without semantic meaning.

From the analysis of the 21 interviews, bigrams were obtained with minimum frequencies of two, three, four, and five, depending on the semantic richness of each interview. Interviews with greater semantic richness were filtered using a minimum frequency of five, since non-trivial patterns were consolidated to the point of having high frequencies such as 12 and 13. In contrast, in interviews with lower semantic richness, the bigram filter was set at two, to allow more flexibility in identifying non-trivial semantic patterns. Table 1 shows the distribution of interviews according to bigram filter criteria.

Table 1

Interview Distribution and Bigram Filters

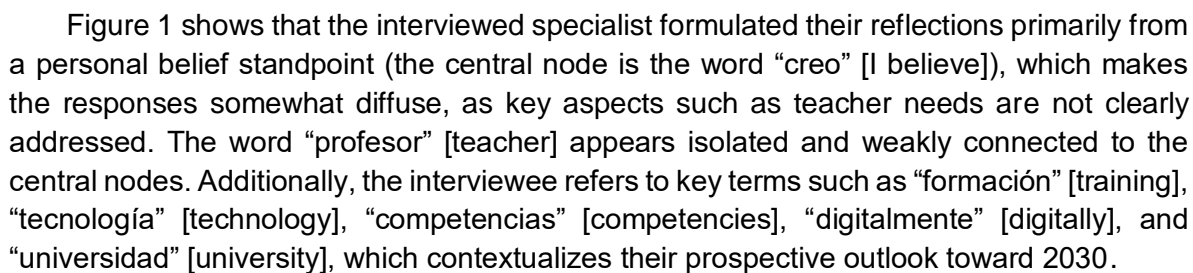| Bigram Filter	Number of Interviews	Range of Maximum Frequencies	Interview IDs
Minimum frequency 2	5	3 to 5	2, 3, 8, 12 y 21
Minimum frequency 3	7	5 to 7	13, 14, 15, 16, 17, 18 y 19
Minimum frequency 4	2	6 to 7	10 y 11
Minimum frequency 5	7	8 to 13	1, 4, 5, 6, 7, 9 y 20
Total	21		

According to Table 1, five interviews showed low semantic richness, requiring the bigram filter threshold to be lowered to a minimum frequency of two in order to identify non-trivial semantic patterns. Furthermore, the patterns found were not consolidated, and within these five interviews, the maximum bigram frequencies ranged only from three to five. In contrast, seven interviews presented a large number of consolidated non-trivial patterns, with minimum bigram frequencies of five and maximums of up to thirteen.

The visual representation of the bigrams from the seven interviews with the highest semantic richness is shown in Figures 1 to 7.

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Figure 1

*Bigrams from Interview 1, with Frequencies Ranging from 5 to 10*

Figure 1 shows that the interviewed specialist formulated their reflections primarily from a personal belief standpoint (the central node is the word "creo" [I believe]), which makes the responses somewhat diffuse, as key aspects such as teacher needs are not clearly addressed. The word "profesor" [teacher] appears isolated and weakly connected to the central nodes. Additionally, the interviewee refers to key terms such as "formación" [training], "tecnología" [technology], "competencias" [competencies], "digitalmente" [digitally], and "universidad" [university], which contextualizes their prospective outlook toward 2030.

Figure 2

Bigrams from Interview 4, with Frequencies Ranging from 5 to 13

Figure 2 shows that this interview contained a richer set of relevant patterns, unlike Interview 1, as it does not reflect a discourse based on personal belief (the term "creo" [I believe] is absent). The main nodes indicate that the prospective perspective is closely linked to Mexican educational policy (connection between "política" [policy], "México," and "educación" [education]), and to issues related to "programas" [programs], "proceso(s)" [processes], and the "realidad" [reality] of using "tecnología" [technology], "computadora" [computer], and "conectividad" [connectivity]. Less directly connected but still related to the central nodes is the discussion of the "brecha digital" [digital divide], "acceso" [access] to "tecnológico" [technological] tools, and the "estudiante" [student]. Notably, aspects related to "formación docente" [teacher training] are practically disconnected from the prospective perspective presented.

Figure 3

Bigrams from Interview 5, with Frequencies Ranging from 5 to 9
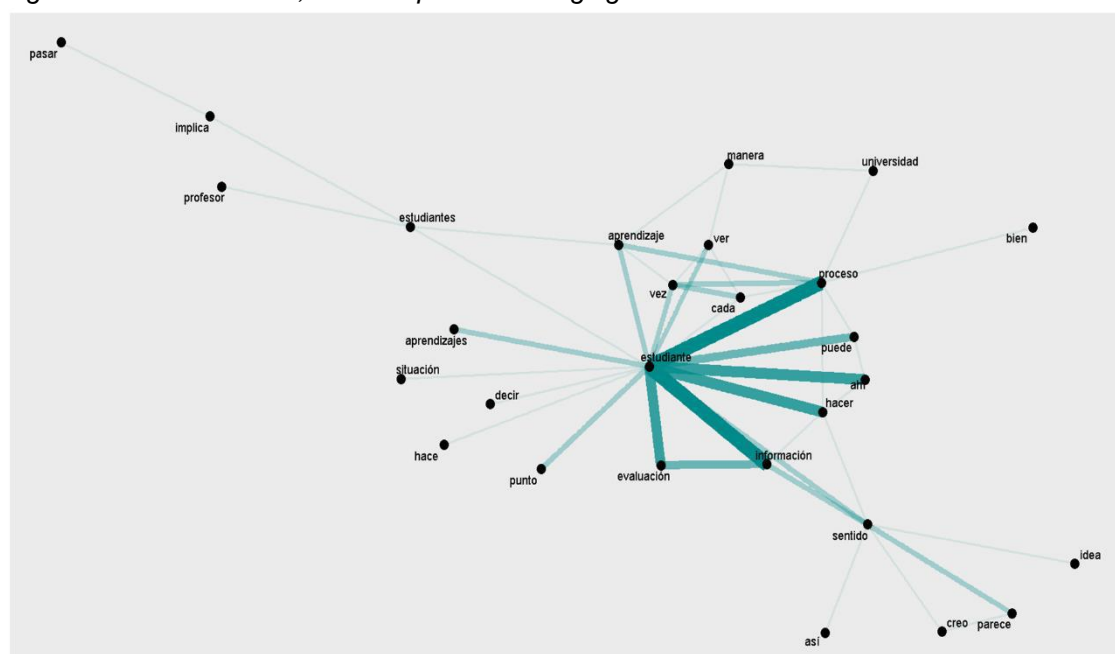
In Interview 5, it is clear that the focus of the dialogue was the "estudiante" [student], projecting a perspective in which the most important aspects are the "aprendizajes" [learning outcomes], the possible forms of "evaluación" [assessment] of those learnings, and the use of "información" [information] to provide "sentido" [meaning] and to understand their "manera" [way] of "ver" [viewing] the "universidad" [university]. Tangentially, a certain role of the "profesor" [teacher] in the "aprendizaje" [learning] process is also observed, but the main focus remains on the "estudiantes" [students].
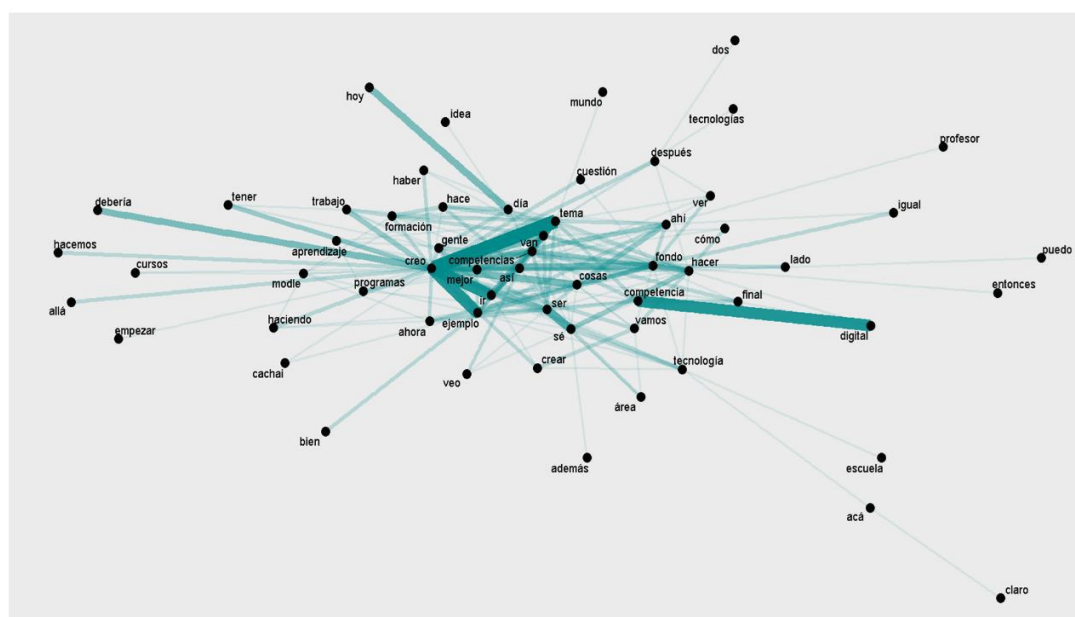
Figure 4

Bigrams from Interview 6, with Frequencies Ranging from 5 to 9
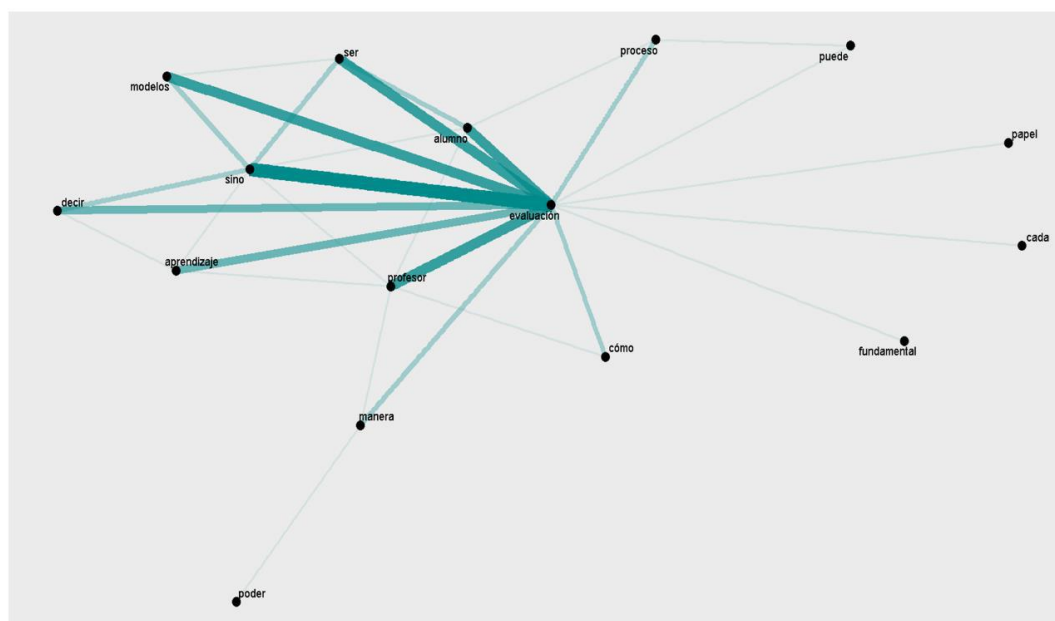
In Interview 6, a perspective centered on "evaluación" [assessment] is observed, rather than on the student, as in Interview 5. In this sense, the interview projects aspects related to the assessment of "aprendizaje" [learning], the "alumno" [student], the role of the "profesor" [teacher], and different "modelos" [models] of evaluation.
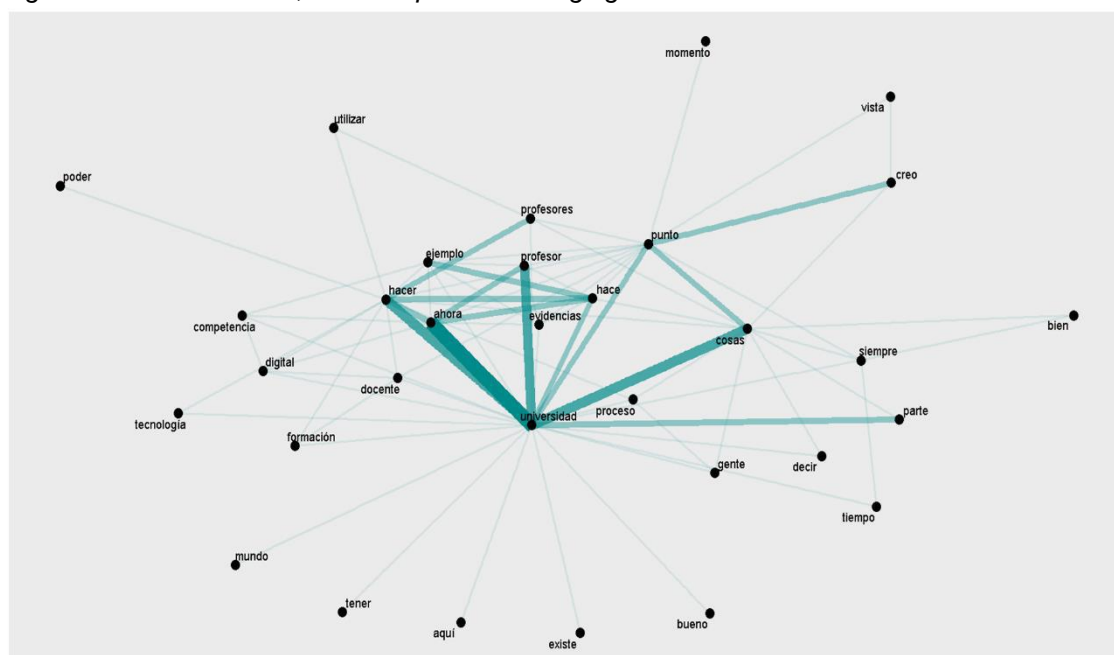
Figure 5

Bigrams from Interview 7, with Frequencies Ranging from 5 to 12

In Interview 7 (Figure 5), as in Interview 1, the prospective perspective is primarily framed from a personal standpoint, with the term "creo" [I believe] as the most prominent node. However, this interview addresses a broader range of topics, including "competencias" [competencies], "formación" [training], "aprendizaje" [learning], "trabajo" [work], and "cursos" [courses]. Likewise, although indirectly linked to the main nodes, the topic of "competencia digital" [digital competence], "tecnologías" [technologies], and "escuela" [school] is repeatedly addressed.

Figure 6

Bigrams from Interview 9, with Frequencies Ranging from 5 to 8

The significant patterns observed in Figure 6 indicate that, in Interview 9, the center of the prospective perspective is the "universidad" [university]. Various related topics are discussed, such as the "profesor(es)"/"docente(s)" [teacher(s)/educator(s)], "formación" [training], "competencia digital" [digital competence], and "tecnología" [technology].

Figure 7

Bigrams from Interview 20, with Frequencies Ranging from 5 to 10
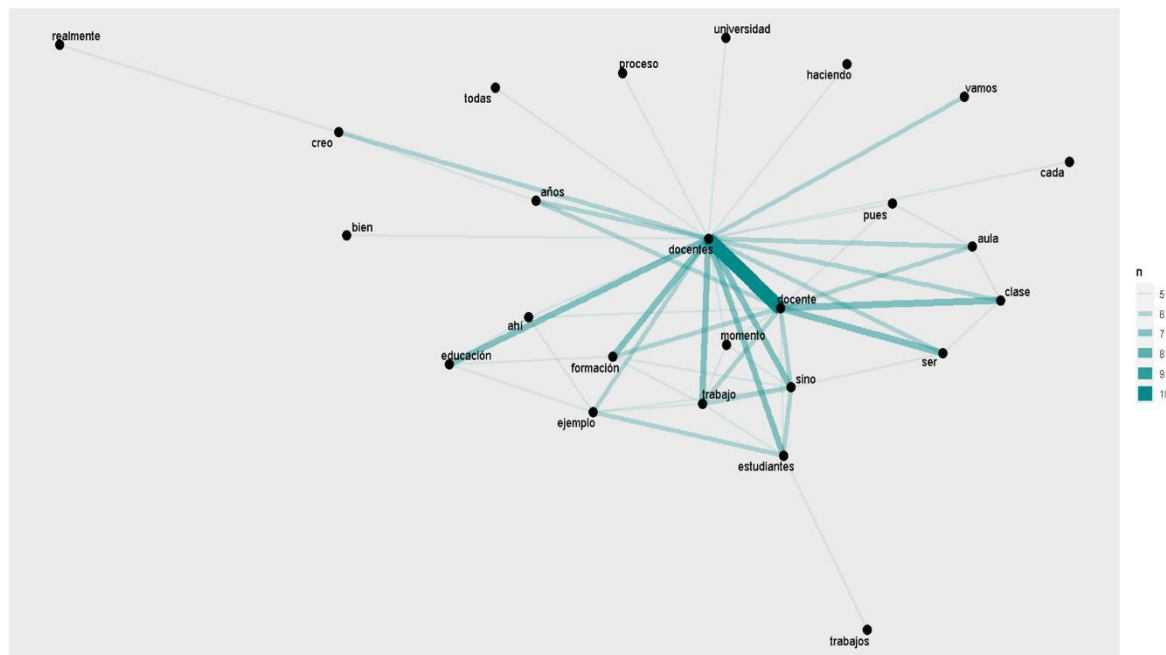
Finally, Figure 7 shows that, in Interview 20, the focus of the dialogue is on the "docente(s)" [teacher(s)], relating to topics such as "educación" [education] and "formación" [training], their "trabajo" [work], the "estudiantes" [students], "clases" [classes], and the "universidad" [university].

3.1.2. Analysis and Results from the Post-Pandemic Focus Group.

Microanalysis

The line-by-line microanalysis based on Strauss and Corbin (2002) allowed for the identification of six thematic categories and a series of specific subtopics (see Table 2).

Table 2

Thematic Categories and Subtopics Resulting from the Microanalysis

Thematic Category	Subtopics
1. How digital technologies could support education.	Technologies support data collection. Technology helps when integrated, not when it replaces. Technology won't help if evaluation doesn't improve. Teachers are irreplaceable in assessment.
2. On improving the competency-based approach, or proposing a better model.	The system continues to demand a numerical evaluation model, not a competency-based one. Assessment should be more qualitative. Informal assessment is gaining social traction.

Thematic Category	Subtopics
3. On teacher training and technology.	More learning takes place online than at university.
	Growth of online learning.
	Companies offering online training are expanding.
	A transition from in-person to online learning is underway.
	Online education is more up to date than in-person education.
	Teacher training in classroom practice is complex;
	The shift to digital is necessary but slow.
	The curriculum must be updated because digital competencies are not included.
	Teachers are in a vulnerable position, as their jobs are at risk if they do not update their skills.
	Teachers are forced to learn ICT for educational purposes.
	Teachers are required to use ICT tools.
	There is a lack of ability to use technology in the classroom.
	Using technology to teach.
4. Free global education model.	Prejudices about free offerings: - Free means low quality. - Paying provides a certain guarantee of service quality. - Free implies less commitment.
	Provide personalized feedback (performance compared to one's own progress).
	Peer assessment.
	In some places (Argentina), free education is highly regarded.
	Free training is undervalued when it comes to employability.
	Assessment is practical.
	Even in competency-based assessment, a numeric value is still required.
	Current training focuses on understanding curricular content.
	In 5 to 10 years, it will be necessary to understand the learner as a person.
5. Training needs for the next 5 years	We already know what needs to be done—now it's time to act.
	The focus should be on the human being.
	Training is not addressing the human dimension.
	Efforts aim to solve problems, but there is no guidance on identifying what the problems are.
	Current practices will continue, but informal education (such as short courses) will gain strength.
6. What will prevail in 2030 regarding teacher training?	The year is too near to expect a radical change.
	Greater attention to the human dimension.
	Corporate universities.
	Prepare learners to solve real-world problems.
	More focus on attitudes and coexistence.

The themes addressed post-pandemic are deeply influenced by the experiences lived during the pandemic. There is greater emphasis on topics related to the use of technology compared to the pre-pandemic interviews, where—although technology was discussed—the focus was directed toward other aspects of teacher training, such as student-centered learning or public education policy.

- **Bigrams from Specific Post-Pandemic Questions.**

The following questions were included in the short questionnaire:

1. How do you imagine the future of teacher training?

2. What do you want to learn today?

3. Would you like to add any ideas or suggestions about our Mission 3? We're listening. Now is your moment.

Figure 8

*Bigrams from the question "How do you imagine the future of teacher training*

Teachers envision the future of teacher training as being centered on "continuous" and "ongoing" "training" for the development of "digital" "competencies." This vision is reinforced by references to elements such as "virtual" "reality," "augmented" "reality," and "artificial" "intelligence." Notably, there is also a general emphasis on the development of competencies in terms of "soft" "skills.".

The preferences regarding content are clearly focused on the "use" of "technological" "digital" "tools," such as "ICTs," "artificial" "intelligence," and "virtual" "reality." However, it is worth noting that there remains a strong preference for "soft" "skills," which aligns overall with the future-oriented perspective on teacher training.
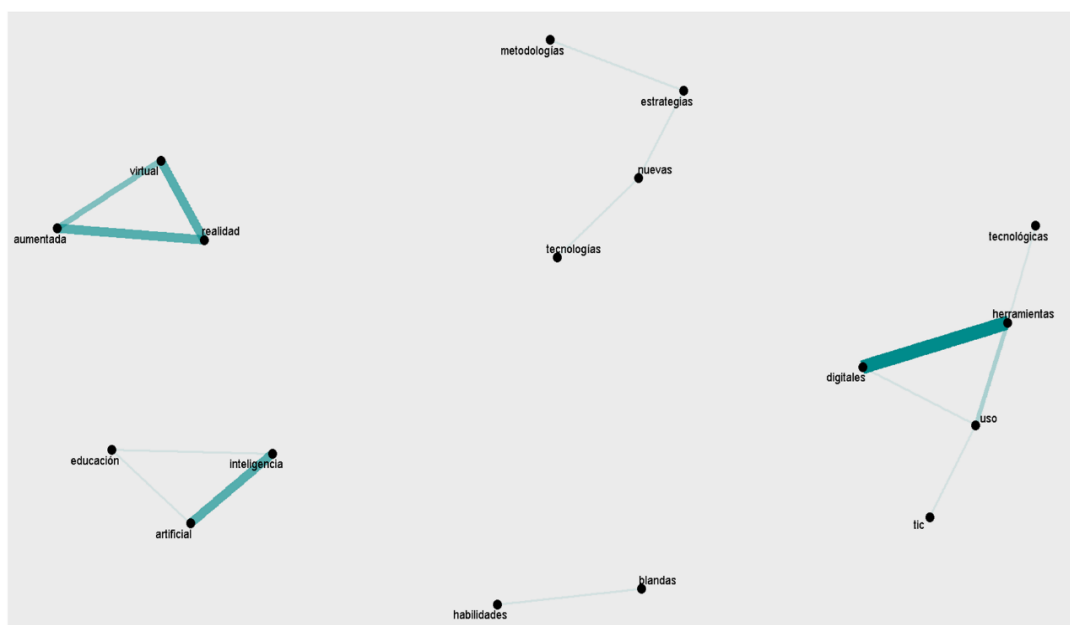
Figure 9

Bigrams from the question "What do you want to learn today?
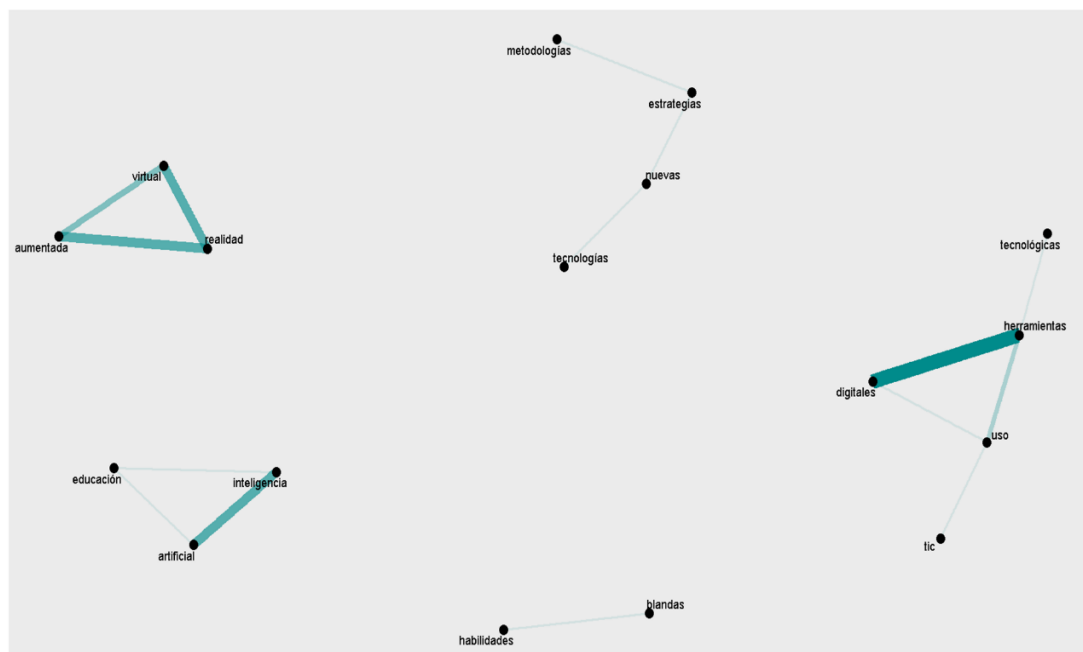
Figure 10

Bigrams from the question "Would you like to add any ideas or suggestions about our Mission 3? We're listening. Now is your moment."

The main nodes continue the trend of focusing on digital tools and competencies, explicitly acknowledging the importance of a project like CDO, and expressing gratitude and curiosity about future workshops.

4. Discussion

The results of this study reveal significant transformations in teacher training needs between the pre- and post-pandemic periods, providing empirical foundations for the conceptualization of an innovative Digital Training System (SFD). In this section, we critically analyze the findings, contrast them with previous research, assess methodological limitations, and develop an operational model of the proposed system along with its practical implications.

4.1. Evolution of Teacher Training Needs: From Structural to Transformational

The bigram analysis highlights a paradigmatic shift in teacher training needs. During the pre-pandemic period, semantic networks were predominantly organized around institutional (university), policy (regulations, programs), and assessment (models, instruments) dimensions, with technology occupying peripheral positions. This configuration aligns with what Cabero-Almenara and Palacios-Rodríguez (2020) define as the instrumental approach to digital competence, in which technology is viewed as a tool subordinate to pre-existing structures.

In contrast, the post-pandemic analysis reveals a reconfiguration where bigrams like "artificial-intelligence," "virtual-reality," and "soft-skills" emerge as key organizing elements of the discourse. This shift goes beyond the mere increase in the perceived value of digital competencies, as documented by studies such as Portillo et al. (2020), to reveal a qualitative change in the very conceptualization of these competencies: from instrumental to transformational.

The emergence of the bigram "soft-skills" is particularly noteworthy, as it reveals a conceptual integration of technical and socio-emotional competencies—something absent in the pre-pandemic discourse. This finding expands on Fernández-Batanero et al.'s (2022) understanding of the multidimensional nature of digital teaching competence by empirically identifying the integration of socio-affective dimensions as a post-pandemic emergent component. The pandemic appears to have catalyzed not only an intensification in the use of technologies—as documented by numerous studies (Marín et al., 2021)—but also a deep reconceptualization of the relationship between technology and humanism in teacher training.

4.2. Epistemic Patterns in the Conceptualization of Training Needs

A particularly relevant finding from our analysis concerns the underlying epistemic patterns in the conceptualization of training needs. The pre-pandemic predominance of bigrams centered on "I believe" (Figures 1 and 5) suggests an experiential-subjective anchoring in the identification of needs, whereas the post-pandemic networks show greater articulation with established theoretical constructs (digital competencies, soft skills, artificial intelligence).

This epistemic evolution suggests that the forced digitalization experience during the pandemic not only changed perceptions of specific technologies but also transformed the conceptual frameworks through which training needs are interpreted. Teachers appear to

have shifted from primarily experiential positions to more structured and theorized interpretive frameworks—a phenomenon identified by Area-Moreira et al. (2023) as "forced epistemic maturation" in contexts of digital disruption.

This transformation has fundamental implications for training system design, suggesting a shift from models based on the transmission of instrumental competencies toward ecosystems that facilitate the collective construction of interpretive frameworks on the integration of technology and pedagogy. Our findings thus extend the conclusions of González-Sanmamed et al. (2022) on digital learning ecologies by empirically demonstrating that these must respond not only to technical needs but also to transformations in teachers' epistemic frameworks.

4.3. Methodological Limitations and Analytical Complementarity

The bigram analysis has proven effective in identifying significant semantic patterns in teachers' discourse regarding training needs. However, we concur with Escudero et al. (2022) in acknowledging the limitations inherent to this methodological approach. The bigram technique, by nature, captures binary lexical associations but not necessarily complex argumentative structures or contextual nuances.

This limitation is particularly relevant in our case, where categorizing texts through bigrams proved insufficient to fully capture the multidimensional complexity of expressed training needs. As Hidalgo-Ternero and Pérez-Cordón (2021) warned, text mining techniques must be complemented by interpretative approaches that contextualize the patterns identified.

Triangulation with qualitative microanalysis has partially compensated for these limitations, revealing dimensions that bigrams alone could not capture—such as attitudinal ambivalence toward emerging technologies or ethical concerns about artificial intelligence in education. This methodological complementarity reinforces Sharma et al.'s (2020) argument on the need for hybrid approaches that combine the processing power of computational techniques with the contextual sensitivity of qualitative analysis.

Acknowledging these limitations does not invalidate the findings; rather, it defines their interpretive scope and supports our proposal for a training system that integrates both computational analysis and qualitative approaches for the ongoing identification of teacher training needs.

4.4. Digital Training System: Operational Model and Practical Implications

Grounded in empirical findings on the evolution of training needs, we propose a Digital Training System (SFD) structured around four interrelated components that go beyond traditional training models. Figure 11 illustrates the conceptual and operational architecture of the proposed system.

Figure 11

Diagram of the Digital Training System. Own elaboration

Diagram of the Digital Training System (DTS)
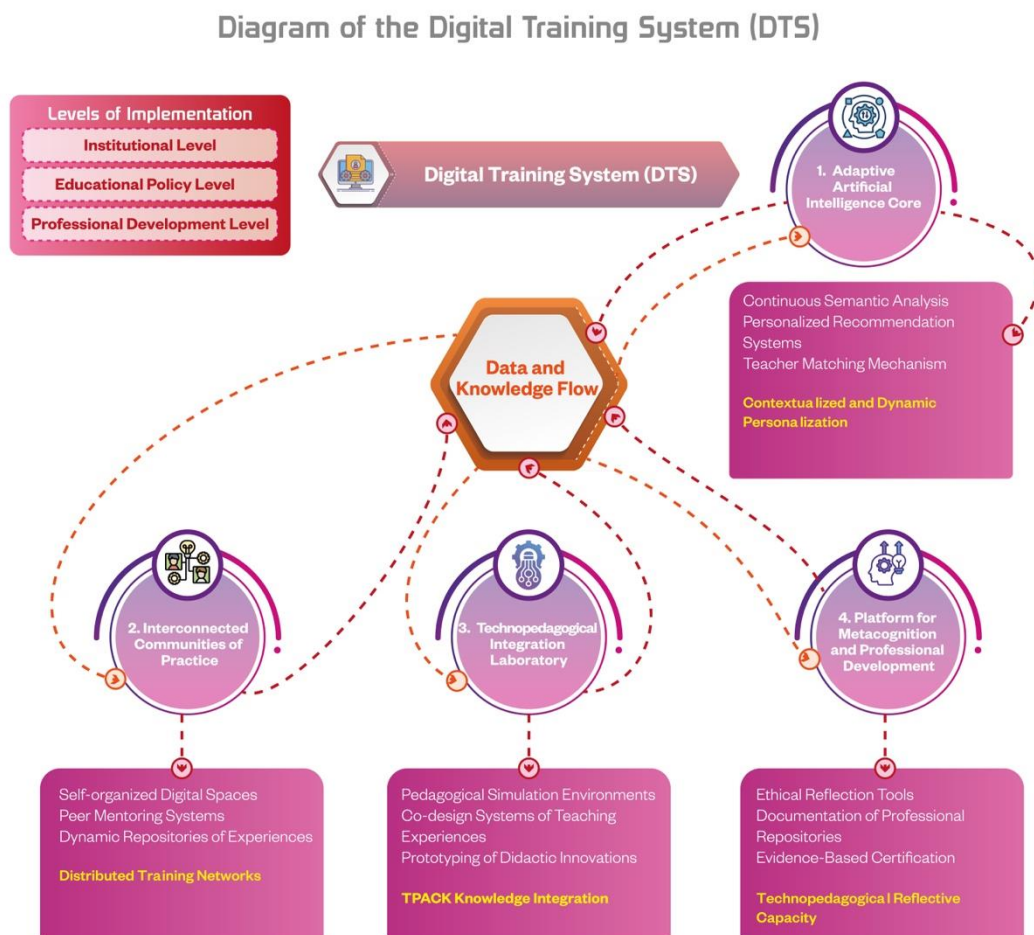
4.4.1. Components of the Digital Training System

1. **Adaptive Artificial Intelligence Core**: Directly addresses the identified need for personalized training by implementing:

   o Semantic analysis algorithms to continuously identify emerging needs

   o Recommendation systems that create personalized learning paths based on teacher profiles

   o Matching mechanisms between teachers with complementary profiles

This component goes beyond mere automation of training content, addressing what Fan et al. (2022) identify as the main challenge in digital training systems: contextualized and dynamic personalization.

2. **Interconnected Communities of Practice**: Addresses the post-pandemic emerging need for collaborative learning by means of:

   - Self-organized digital spaces by domains of interest

   - Peer mentoring systems with complementary expertise

   - Dynamic repositories of pedagogical experiences and solutions

This component operationalizes what Gros and Noguera (2023) conceptualize as "distributed learning networks," where knowledge emerges from horizontal interactions rather than vertical transmissions.

3. **Technopedagogical Integration Lab**: Responds to the identified need to link practice with theory through:

   - Simulation environments for pedagogical experimentation

   - Co-design systems for digital learning experiences

   - Prototyping and testing tools for didactic innovations

This component brings to life the proposal by Mishra and Koehler (2021) regarding learning environments that integrate technological, pedagogical, and disciplinary knowledge simultaneously.

4. **Metacognition and Professional Development Platform**: Addresses the emerging need for techno-humanist integration through:

   - Reflection tools on the ethical impacts of educational technologies

   - Documentation systems for professional development pathways

   - Certification mechanisms based on evidence of contextualized performance

This component addresses what Area-Moreira et al. (2023) identify as the most neglected dimension in digital teacher training: the reflective capacity regarding the pedagogical and ethical implications of technology integration.

4.4.2. Practical Implications for Implementation

The effective implementation of the proposed Digital Training System (SFD) requires specific actions at different levels.

At the institutional level:

- Create specialized technopedagogical design units that integrate expertise in AI, instructional design, and subject-specific teaching methods

- Develop institutional recognition systems for competencies acquired through the SFD

- Implement hybrid physical-virtual spaces to facilitate interaction among communities of practice

At the educational policy level:

- Establish regulatory frameworks to facilitate the certification of competencies acquired through non-traditional training systems

- Develop targeted funding programs for educational AI infrastructure

- Create centralized repositories of anonymized data to feed adaptive AI systems

At the level of teacher professional development:
- Implement initial AI literacy programs in education to overcome entry barriers

- Develop specific "connector" roles between communities of practice

- Establish incentives for teachers who actively contribute to shared repositories

These concrete practical implications address the need identified by Ramírez-Montoya et al. (2022) to transform conceptual models into operational roadmaps that guide effective transformations in training systems.

4.5. Contribution to the Existing Literature and Future Projections

This study contributes to the literature on digital teacher training in three key areas:

1. **Methodologically**: It demonstrates the potential and limitations of text mining for analyzing training needs, highlighting the need for hybrid methodological approaches that integrate computational and qualitative techniques.

2. **Conceptually**: It empirically identifies a paradigmatic shift in teacher training needs, from models centered on institutional structures toward integrated technopedagogical and humanistic approaches.

3. **Practically**: It proposes a Digital Training System model with specific components and actions that go beyond conceptual proposals to offer concrete implementation pathways.

Future research projections include the development of specific prototypes of the proposed Digital Training System (SFD) components, longitudinal studies on its impact in different educational contexts, and comparative analyses with other emerging training

models. Particularly promising is the exploration of hybrid systems that integrate computational and qualitative approaches for the ongoing identification of training needs in rapidly evolving technological contexts.

5. Conclusions

This research has identified teacher training needs through text mining in order to support an innovative Digital Training System (DTS), by comparatively analyzing pre- and post-pandemic periods. The results allow for drawing significant conclusions related to the proposed objectives.

The comparative analysis of training needs between the pre- and post-pandemic periods shows a substantial transformation. Pre-pandemic semantic patterns revealed five priority axes: curricular aspects, learning assessment, institutional structure, technology as a tool, and instrumental digital competence. Teachers' concerns were mainly articulated from institutional, evaluative, or student-centered perspectives, with technology occupying peripheral positions in the semantic networks.

In contrast, the post-pandemic analysis identified a central repositioning of technology—not as a subordinate tool but as a transformative ecosystem. The most significant bigrams ("virtual-reality", "soft-skills", "artificial-intelligence") reflect a reconceptualization where previously disconnected technical, pedagogical, and humanistic dimensions now converge. Particularly noteworthy is the emergence of the "soft-skills" bigram, absent in pre-pandemic discourse, reflecting a new prioritization of socioemotional competencies integrated with technical capabilities.

The complementary qualitative microanalysis revealed emerging categories that both reinforce and nuance this transformation: technological resistance as a determining factor, the perception of professional vulnerability in the face of accelerated digitalization, the growing appreciation of informal learning over traditional academic pathways, and an increasing concern for the humanization of digital educational environments.

Regarding the methodology used, we conclude that bigram analysis constitutes a valuable yet insufficient approach on its own to capture the multidimensional complexity of teacher training needs. Text mining techniques enabled the identification of significant semantic patterns, particularly useful for detecting terminological and conceptual evolutions. However, these techniques showed limitations in capturing contextual nuances, attitudinal ambivalences, and complex argumentative structures—elements that the qualitative microanalysis was able to complement. This methodological complementarity stands out as a significant methodological finding for future studies in this field.

The proposed Digital Training System, grounded in these empirical findings, transcends traditional models by integrating four interrelated operational components: a core of adaptive artificial intelligence, interconnected communities of practice, a technopedagogical integration lab, and a platform for metacognition and professional development. This system responds to the detected evolution in training needs by prioritizing adaptive personalization, situated and collaborative learning, integrated technopedagogical experimentation, and ethical reflection on educational digitalization.

Among the most relevant practical implications derived from this proposal are: the need for specific institutional units that integrate expertise in AI, technopedagogical design, and subject-specific didactics; regulatory frameworks that formally recognize competencies acquired in non-conventional training systems; and specific initial literacy programs in educational AI to overcome entry barriers.

The limitations of this study include the exploratory nature of bigram analysis in the field of training needs, its restriction to Spanish-speaking contexts, and methodological differences between pre-pandemic (in-person) and post-pandemic (virtual) data collection, which—although justified by circumstances—introduce additional contextual variables.

Future lines of research should delve into the pilot implementation of the components of the proposed Digital Training System, evaluating their effectiveness in different institutional contexts; developing more sophisticated hybrid methodological approaches for the analysis of training needs; and comparatively analyzing the evolution of teacher training needs across different educational levels and disciplinary areas.

In summary, this research significantly contributes to the understanding of how the pandemic not only accelerated ongoing processes of educational digitalization but also qualitatively transformed teacher training needs, demanding disruptive systems that can respond to these new priorities in an agile, contextualized, and humanizing way. The proposed Digital Training System constitutes an innovative starting point for rethinking teacher training in the post-pandemic era, fostering meaningful integration between technology, pedagogy, and humanism.

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