

Article

From Technological Exposure to Pedagogical Engagement: A Case Study of Pre-Service Teachers' Digital Profiles and Methodological Orientation

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Abstract

(1) Background: Pre-service teachers enter university with extensive digital experience, yet this familiarity does not guarantee pedagogically grounded ICT integration. (2) Objective: This study examines the sociodemographic profile, digital trajectory, ICT perceptions, and methodological orientation of 295 students in the Primary Education Degree and the Secondary Education Teacher Training Master's program at CES Don Bosco, a Spanish university. (3) Method: A quantitative, descriptive-correlational, cross-sectional design was used, combining non-parametric statistics with cluster analysis and multiple regression. (4) Results: Teaching specialization was significantly associated with age profile ($\chi^2(1) = 67.46, p < 0.001, \phi = V = 0.478$). Daily ICT exposure showed a weak, negligible association with tool familiarity ($\rho = 0.155, p = 0.008$), and no asymmetry emerged between the technological and methodological repertoires once expressed proportionally (Wilcoxon $Z = 1.32, p = 0.186, r = 0.08$). Cluster analysis identified two digital profiles differing not in tool familiarity but in how experience was acquired. Regression showed specific ICT training, not daily exposure, modestly predicted methodological orientation ($R^2 = 0.055$). (5) Conclusions: Findings do not support a large technology–pedagogy gap; deliberate training, not passive exposure, predicts methodological orientation. As a single-institution case study, results should not be generalized beyond this context.

Keywords: teacher education; educational technology; digital literacy; teaching methods; active learning; pedagogical innovation



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1. Introduction

The incorporation of information and communication technologies into educational systems has not been a linear or homogeneous process. It is the outcome of a gradual transformation that has progressively redefined expectations about teacher education and the competencies considered essential for professional practice in the twenty-first century (European Commission, 2020; UNESCO, 2021; OECD, 2023). The digitalization of education has moved beyond a question of technological access to become a demand for pedagogical competence, raising fundamental questions about the nature and quality of the initial preparation received by pre-service teachers (Basilotta-Gómez-Pablos et al., 2022;

Falloon, 2020). Falloon (2020) proposes a teacher digital competence framework that moves beyond technical and instrumental conceptualizations, arguing that teacher digital competence must incorporate curriculum-aligned, personal-ethical, and personal-professional dimensions, precisely those that initial training programmes tend to neglect when focusing predominantly on tool accumulation. This study addresses the curriculum-aligned and instrumental dimensions, as operationalized through the instruments employed, and this framework provides the conceptual anchor from which the technology–pedagogy asymmetry examined here is approached.

1.1. Informal Digital Familiarity and Its Limits Relative to Pedagogical Competence

The generation currently enrolled in education degrees and teacher training master’s programs has grown up in an environment of sustained digital immersion, with access to the internet from an early age and a daily integration of ICT that has no precedent among earlier cohorts (Sánchez-Cruzado et al., 2021; Normén-Smith et al., 2024). This early familiarity with technology does not, however, guarantee the development of a pedagogically grounded digital competence, understood as the ability to integrate ICT in a critical, reflective, and methodologically informed way within teaching and learning processes (Chugh et al., 2023; Antonietti et al., 2022). Buckingham (2006) warned that everyday access to and use of digital media do not automatically generate a critical understanding of them, and that developing genuine media literacy requires moving beyond instrumental technical mastery towards critical reading and reflective production. This warning remains fully pertinent in initial teacher education, where intensive personal use of ICT coexists with a frequently limited understanding of its pedagogical potential (Getenet et al., 2024). Recent studies with first-year pre-service teachers show that most define digital technologies more narrowly than expected, identifying them with specific everyday tools rather than with active learning environments or pedagogically intentional resources (Getenet et al., 2024).

This heterogeneity is reinforced by generational differences in technological access. Pre-service teachers who accessed the internet and digital tools at an earlier stage of their own development did so in a less developed technological landscape than their younger peers, producing differentiated digital trajectories even within the same university cohort (Schmid et al., 2021; Petko et al., 2025). ICT integration in initial teacher education is, in addition, neither systematic nor homogeneous. It varies according to the institution, the degree programme, and the digital profile of university lecturers (Drljić et al., 2025), a factor whose influence on students’ perceptions has been noted in the recent literature but rarely examined empirically (Awang et al., 2025). The digital resources most used by practicing teachers during periods of high technological demand are precisely those with the greatest accessibility and the least pedagogical complexity, such as management platforms and videos, while resources with greater formative potential, such as forums or online assessments, are the least valued (Mendez et al., 2022). This pattern of instrumental use may be reproduced in initial training if no deliberate intervention is made. Taggart and Roulston (2024) similarly describe teachers’ digital competence as occupying a “Goldilocks zone,” neither wholly deficient nor fully realized, a characterization consistent with the balanced but modest picture that emerges from the present study.

1.2. Digital Competence Frameworks and the Scope of the Present Study

The European Commission’s DigCompEdu framework (Redecker & Punie, 2017) organizes teacher digital competence across six areas: professional engagement, digital content, teaching and learning, assessment and feedback, empowering learners, and facilitating learners’ digital competence facilitating learners’ digital competence, complementing the broader citizen-oriented Digital Competence Framework, DigComp (European Commis-

sion & Joint Research Centre, 2022), from which DigCompEdu was adapted for the teaching profession. The TPACK model (Schmid et al., 2021) conceptualizes the intersection between technological, pedagogical, and content knowledge. The present study does not assess all six DigCompEdu areas or the full TPACK model. It focuses on two dimensions that can be operationalized through the instruments employed: the instrumental knowledge of educational digital tools, which relates most closely to the digital content area of DigCompEdu and to the technological component of TPACK, and the declared experience with active methodologies, which relates most closely to the teaching and learning area and to the pedagogical component of TPACK. The remaining four DigCompEdu areas, professional engagement, assessment and feedback, empowering learners, and facilitating learners' digital competence, fall outside the scope of this study and are addressed explicitly as a limitation. This is a design decision rather than an omission. It allows a precise empirical contrast between two specific dimensions of the model rather than a broad but superficial assessment of all six.

1.3. ICT Perceptions and Methodological Orientation Among Pre-Service Teachers

The relationship that pre-service teachers establish with ICT extends beyond its technical dimension to encompass perceptions and predispositions that shape their future pedagogical orientation. Recent literature evidences a growing awareness among prospective teachers of the need to transform inherited teaching practices, although this awareness does not always translate into a coherent methodological disposition (Abildinova et al., 2024; Awang et al., 2025). The adoption of active methodologies, including cooperative learning, project-based learning, gamification, Design Thinking, and the flipped classroom, depends not only on the technical training received but on attitudinal and institutional factors that modulate pre-service teachers' predisposition towards pedagogical innovation (Paniagua & Istance, 2018; Hernández-Barco et al., 2021; Ortiz-Colón et al., 2018; Panke, 2019; Aidoo et al., 2022; Martínez-Valdivia et al., 2023). This favorable predisposition frequently coexists with an ambivalent view of the lecture format. Pre-service teachers often reproduce the teaching models they experienced as students, even when they declare an innovative methodological orientation (Gil-Flores et al., 2024). The adoption of innovative methodologies is further conditioned by factors such as digital competence, intrinsic motivation, and openness to change, as well as by institutional leadership and organizational climate (Awang et al., 2025). Wang and Zhao (2023) document that perceived technological complexity and insecurity about ICT have significant negative effects on teachers' attitudes towards technology, which connects with Selwyn's (2023) call for a critical, sustainable, and pedagogically intentional use of educational technology. Consistent with the broader argument of this study, active-methodology training itself appears to strengthen digital competence more directly than passive exposure, as shown by Romero-García et al. (2020) in a sample of pre-service teachers.

1.4. The Asymmetry Between Technological Exposure and Pedagogical Practice

What is already known is that pre-service teachers enter university with a broad repertoire of known digital tools and intensive habits of technological use (Chugh et al., 2023; Santos et al., 2022). What remains insufficiently documented is whether this instrumental repertoire corresponds to an equivalent repertoire of active pedagogical methodologies, or whether both develop as structurally distinct dimensions. The present study addresses this question through an empirical comparison, based on normalized proportions, between the two repertoires in a sample of pre-service teachers at a Spanish university, complemented by an exploratory analysis of differentiated digital profiles.

This asymmetry does not respond solely to a deficit of technological access. It reflects an insufficient pedagogical integration of technologies within university teacher education curricula, such that the mastery of educational applications does not correspond to an equivalent methodological repertoire (Chugh et al., 2023). Peng et al. (2024) show, in a sample of practicing teachers, that it is not the volume of tools known that predicts effective pedagogical integration, but the quality of the relationship the teacher establishes with them from a reflective pedagogical perspective. This finding points to the existence of differentiated technological profiles among pre-service teachers, which the present study explores through a cluster analysis.

1.5. Research Objectives

1.5.1. General Objective

To analyze the sociodemographic profile, digital trajectory, ICT perceptions, and future methodological orientation of students enrolled in the Primary Education Degree and the Secondary Education Teacher Training Master's programme.

1.5.2. Specific Objectives

- To describe the sociodemographic profile and digital trajectory of pre-service teachers, analyzing differences by sex and teaching specialization using contingency tests and Spearman correlations.
- To examine pre-service teachers' perceptions about ICT use and methodological change, comparing primary and secondary groups.
- To statistically contrast the asymmetry between technological exposure and pedagogical application using non-parametric tests, and to evaluate the psychometric properties of the instruments used.

1.6. Hypotheses

H₀₁. *Teaching specialization (primary or secondary) is not significantly associated with the age profile of pre-service teachers.*

H₁. *Teaching specialization (primary or secondary) is significantly associated with the age profile of pre-service teachers, given that both training pathways have structurally different entry requirements and durations.*

H₀₂. *Daily ICT exposure is not significantly correlated with self-reported breadth of ICT tool familiarity among pre-service teachers.*

H₂. *Greater daily ICT exposure does not necessarily translate into a higher level of self-reported breadth of ICT tool familiarity among pre-service teachers.*

H₀₃. *There is no significant asymmetry between the repertoire of ICT tools known to pre-service teachers and the repertoire of active methodologies they report practicing.*

H₃. *An asymmetry exists between the repertoire of ICT tools known to pre-service teachers and the repertoire of active methodologies they report practicing, measured through proportions normalized to the number of options in each list.*

RQ₁. *Do pre-service primary and secondary teachers differ in their future methodological orientation and in their perceptions of ICT?*

1.7. Theoretical Model

The study is structured around four analytical dimensions. The first dimension comprises the socio-demographic profile, treated as an independent variable: sex, age, year of study, and type of teacher. The second dimension comprises digital trajectory,

also treated as an independent variable: age of first internet access, stage of onset of ICT use, social media use, daily ICT hours, and percentage of courses integrating ICT. The third dimension comprises digital competence and attitudes, treated as independent and mediating variables: self-reported knowledge of ICT tools, the number of educational applications known, the perception of methodological change scale, and the need for methodological change. The fourth dimension is the future methodological orientation, treated as the main dependent variable: the number of methodologies practiced and the methodological orientation scale.

The central proposition of the model is that an asymmetry operates between the third and fourth dimensions, understood not as an individual deficit but as a structural feature of initial training programs resulting from insufficient pedagogical integration of ICT in the university curriculum (Chugh et al., 2023; Falloon, 2020; Ertmer, 1999). The socio-demographic profile is associated with digital trajectory (H_1). Daily digital exposure, part of the second dimension, does not strongly predict tool familiarity in the third dimension (H_2). Primary and secondary pre-service teachers are expected to differ in their perceptions within the third dimension (RQ_1). The instrumental repertoire (Dimension 3) and the methodological repertoire (Dimension 4) are partially independent, an asymmetry documented through the proportional comparison in H_3 and further examined through cluster analysis and multiple regression (see Figure 1).

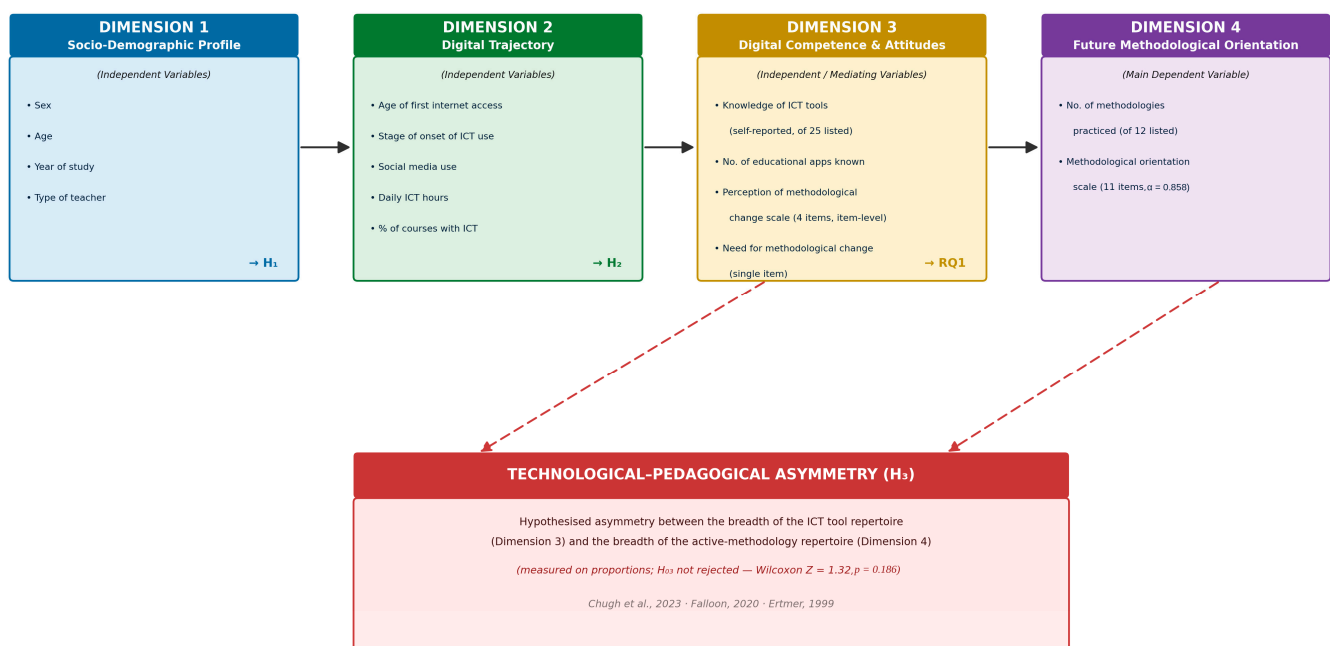


Figure 1. Theoretical model of the study. Solid arrows indicate analytical relationships between dimensions; dashed arrows indicate the hypothesized convergence on the central asymmetry construct. The findings of this study come from a convenience sample drawn from a single university, with a marked imbalance between specializations (Primary 81.7%, Secondary 18.3%). Accordingly, the study is presented as a case-based approximation to this phenomenon rather than as a representative characterization of teacher education in Spain. This limitation is developed further in the Section 4.1 (Chugh et al., 2023; Falloon, 2020; Ertmer, 1999).

2. Materials and Methods

This study adopts a quantitative, non-experimental, cross-sectional, and descriptive-correlational approach. The choice of a quantitative methodology responds to the need to systematically characterize the digital profile and future methodological orientation of pre-service primary and secondary teachers, enabling the measurement of variables, the

identification of associations among them, and the comparison between groups through statistical inference. The non-experimental nature of the design is determined by the absence of variable manipulation, since the aim is to analyze the phenomenon as it naturally occurs in the context of initial teacher education. The cross-sectional dimension reflects that data collection took place at a single point in time, providing a synchronic picture of the reality under study. Finally, the correlational component responds to the need to explore the degree and direction of association between sociodemographic variables, digital trajectory, and future methodological orientation, without implying the establishment of causal relationships among them. Given the marked imbalance between the two teaching specializations in the sample (Primary Education, $n = 241$; Secondary Education, $n = 54$), the findings of this study are presented as a case-based approximation to a single institutional context rather than as a representative characterization of teacher education in Spain, a scope that is developed further in the Section 4.1.

Given that the normality assumption could not be confirmed for the main study variables, as evidenced by the Kolmogorov–Smirnov and Shapiro–Wilk tests, which rejected normality in both the female and male groups ($p < 0.001$), non-parametric statistical techniques were adopted throughout all analyses, including Spearman’s rank correlation coefficient, the Mann–Whitney U test, the Wilcoxon signed-rank test, and Pearson’s chi-square tests of independence. The internal consistency of the measurement scales was assessed using Cronbach’s alpha coefficient, complemented by exploratory factor analysis where reliability proved insufficient for a unidimensional interpretation. In view of the disparity in group sizes between specializations, group comparisons were supplemented with Welch’s t -test, robust to unequal variances and unequal sample sizes, together with Hedges’ g as a bias-corrected estimate of effect size, and a sensitivity analysis reporting the minimum detectable effect (MDE) given the achieved sample sizes. To identify differentiated digital profiles among participants, a two-step cluster analysis was conducted, and a multiple linear regression model was estimated to examine the predictors of future methodological orientation.

2.1. Research Design

For data collection, an ad hoc questionnaire was developed comprising 46 items, including an informed consent item for participation in the research. The decision to design an original instrument responds to the absence of validated questionnaires that addressed in an integrated manner the dimensions under study: the sociodemographic profile and digital trajectory of pre-service teachers, their perceptions about ICT use in the classroom, and their future methodological orientation, consistent with calls for integrating digital competence assessment into teacher education programs through sensitively designed instruments (Müller et al., 2021). This design choice, together with the reliance on self-reported responses throughout the instrument, is acknowledged as a methodological limitation and is addressed in detail in Section 4.1. The instrument was structured into four thematic blocks: sociodemographic and educational background data; technological trajectory and digital exposure; digital competence and ICT attitudes; and predisposition towards active teaching methodologies. Sociodemographic and digital trajectory questions were formulated as single-response and multiple-response items, whereas the attitudes and methodological orientation blocks were measured using five-point Likert scales, where 1 corresponded to strong disagreement or never, and 5 to strong agreement or always. The full questionnaire is available as Supplementary Material.

In order to ensure the conceptual adequacy and clarity of the items, the instrument was subjected to a content validation process through expert judgement. This process involved ten specialists from the academic domain, specifically nine doctors and one full professor

with experience in Education, Journalism, Sociology, and Psychology, who independently rated each item of the questionnaire block addressed to pre-service teachers in terms of item relevance and wording (Content Validity Index, CVI = 0.897) and adequacy of the response scale (CVI = 0.895), calculated as the average item-level CVI (I-CVI) across the panel (Polit & Beck, 2006). Both values exceeded the conventional acceptability threshold of 0.78 recommended for expert panels of eight or more members (Lynn, 1986). Items with comparatively lower agreement, mainly those addressing the perceived persistence of traditional teaching formats despite ICT adoption, were revised for clarity prior to the pilot study, and experts' qualitative observations, such as the inclusion of a "none of the above" response option in multiple-selection items, were incorporated into the final version of the instrument.

Following the expert committee review, a pilot study was conducted with a group of 20 students from the Primary Education Degree, with the aim of verifying item comprehension, administration feasibility, and the overall consistency of the instrument. The results of this phase confirmed the suitability of the questionnaire for full-scale data collection, with no structural modifications required.

Study Variables

The variables included in this study are organized into four analytical blocks corresponding to the research objectives, as presented in Table 1.

Table 1. Operational Definition of Study Variables.

Block	Variable	Operational Definition	Measure	Scale
Socio-demographic	Sex	Self-perceived gender of the participant	Categorical item	Nominal
	Age	Age in completed years	Self-report	Continuous
	Year of study	Academic year in which the participant is enrolled	Categorical item	Ordinal
	Type of teacher	Primary Education Degree or Secondary Education Teacher Training Master's	Dichotomous item	Nominal
Digital trajectory	Age of internet access	Age of first unrestricted internet access	Categorical item	Ordinal
	Stage of ICT onset	Educational stage in which ICT use for educational purposes began	Categorical item	Ordinal
	Social media use	Ownership and frequency of social media use	Dichotomous item	Nominal
	Daily ICT hours	Daily time devoted to ICT use	Numerical item	Continuous
	% of courses with ICT	Estimated % of courses taken with ICT integration	Numerical item	Continuous
Digital competence & attitudes	Knowledge of ICT tools	Self-reported knowledge of 16 educational ICT tools	Multiple-selection list	Nominal
	No. of educational apps known	Total number of educational applications known by the participant	Numerical item	Discrete
	ICT attitudes scale	Attitudes and beliefs about ICT use (4 items, $\alpha = 0.467$)	Likert scale	Ordinal (1–5)
	Perception of methodological change	Perception of methodological change, lecturing, and ICT overuse (5 items)	Likert scale	Ordinal (1–5)

Table 1. *Cont.*

Block	Variable	Operational Definition	Measure	Scale
Future methodological orientation	No. of methodologies practiced	Number of active methodologies practiced or studied during initial training	Numerical item	Discrete
	Methodological orientation scale	Predisposition towards active and innovative teaching methodologies (11 items, $\alpha = 0.858$)	Likert scale	Ordinal (1–5)

Note. ICT = information and communication technologies.

The third block comprises the digital competence and ICT attitudes variables. Self-reported familiarity with a set of twenty-five educational ICT tools was measured, along with the total number of educational applications known by the participants; this indicator reflects self-reported breadth of tool familiarity rather than functional competence in their use, a distinction addressed in Section 4.1. Two conceptually distinct constructs were measured within this block, following the terminological clarification requested during peer review: a four-item Likert scale addressing perceptions of methodological change in teaching (referring to perceived change since primary education, replacement of the lecture format, ICT overuse in the classroom, and concern about domestic use), whose internal consistency was assessed using Cronbach's alpha and yielded a value of $\alpha = 0.467$, indicating insufficient homogeneity for treatment as a unidimensional composite; and, separately, a fifth item addressing the perceived need for methodological change, analyzed independently. Given the low reliability of the four-item scale, subsequent analyses treated these items individually rather than as a composite score, complemented by an exploratory factor analysis reported in Section 3.

The fourth block integrates the future methodological orientation variables, which constitute the core of the analysis. The number of active methodologies practiced or studied during initial training was included, along with an eleven-item Likert scale of future methodological orientation. This scale showed high internal consistency ($\alpha = 0.858$), establishing it as a reliable measure of pre-service teachers' predisposition towards active and innovative pedagogical approaches.

2.2. Procedure

Data collection was carried out through a self-administered digital questionnaire hosted on the Google Forms (Google LLC, Mountain View, CA, USA), platform and distributed to participants via institutional email. The application period ran from March to June 2023, with a total duration of three months, which was considered sufficient to ensure an adequate response rate without compromising the temporal homogeneity of the collected data.

The instrument was administered during class time, in the university classroom setting, which ensured homogeneous application conditions for all participants. Prior to completion, a presentation session of approximately ten minutes was conducted, explaining the research objectives, the structure of the questionnaire, and the instructions for correct completion. The estimated response time was thirty minutes, although in practice the majority of participants finished in less time.

Participation was entirely voluntary and anonymous. Before completing the questionnaire, participants were informed of the research objectives and purpose, as well as the confidentiality of data processing, and provided their explicit consent through the initial item of the instrument, in accordance with the principles set out in the Declaration of Helsinki. Inclusion criteria for participation were: enrolment in the Primary Education

Degree or the Secondary Education Teacher Training Master's; being at least 18 years of age at the time of data collection; and voluntary acceptance of participation via informed consent. No upper age limit was established.

Once the data collection period had closed, the database was cleaned by excluding records with incomplete responses or outliers. The final valid sample for statistical analysis comprised 295 participants.

At the time the study was designed, no ethics committee competent to evaluate this research was yet operating within the collaborating institutions. Data collection therefore proceeded under the confidentiality and voluntary consent safeguards described above, consistent with the ethical principles of the Declaration of Helsinki, while formal ethical evaluation was pursued in parallel. The study was conducted through a research collaboration between Universidad Villanueva and CES Don Bosco, independent institutions at which the author holds research affiliations. Following the establishment of a Research Ethics Committee, the research protocol, the measurement instrument, the information sheet, and the informed consent form were submitted for retrospective evaluation and received a favorable resolution from the Research Ethics Committee of Universidad Villanueva, dated 16 December 2025 (ref. 2025-49), confirming the ethical adequacy of the procedure followed.

2.3. Participants

The study sample comprised 295 pre-service primary and secondary teachers, recruited through non-probabilistic convenience sampling from a single institutional context. Data collection was conducted across all available groups during the application period, thereby maximizing the internal representativeness of the sample within this specific context; however, given the non-probabilistic nature of the sampling procedure and its concentration in a single institution, the sample cannot be assumed to be representative of pre-service teacher populations beyond this context, a limitation addressed further in Section 4.1.

Of the total participants, 241 were enrolled in the Primary Education Degree (81.7%) and 54 in the Secondary Education Teacher Training Master's (18.3%). Based on institutional enrolment records for the corresponding academic year, the reference population comprised approximately 350 students enrolled in the Primary Education Degree and 60 in the Secondary Master's, yielding estimated participation rates of 68.9% and 90.0% respectively, indicating high response levels in both groups, particularly in the Master's program. This marked imbalance between groups reflects the actual enrolment structure of the two training pathways at the institution and is treated as a structural feature of the sample rather than a sampling artifact; its statistical implications are addressed through the robustness checks described in Section 2.4 (Welch's *t*-test, Hedges' *g*, and sensitivity analysis).

Regarding the sociodemographic profile, the sample showed a female predominance, with 187 women (63.4%), 102 men (34.6%), and 6 participants identifying with another gender category (2.0%). The mean age of the full sample was 21.66 years. Statistically significant differences were observed between the two groups: pre-service primary teachers showed a lower mean age ($M = 21.23$; $SD = 3.71$), while all secondary pre-service teachers were concentrated in the 21-years-and-above group, an association that was statistically significant and of moderate-to-large magnitude ($\chi^2(1) = 67.46$, $p < 0.001$, $\phi = V = 0.478$). The Kolmogorov–Smirnov and Shapiro–Wilk normality tests rejected the normality assumption for the age distribution in both the female and male groups ($p < 0.001$), leading to the adoption of non-parametric tests in subsequent analyses.

Regarding distribution by year of study, 16.6% of participants were enrolled in Year 1, 22.4% in Year 2, 27.8% in Year 3, 14.9% in Year 4, and the remaining 18.3% were Secondary Teacher Training Master's students (see Table 2).

Table 2. Sociodemographic and Educational Characteristics of Participants ($N = 295$).

Variable	Category	<i>n</i>	%	<i>M</i>	<i>SD</i>	95% CI
Sex	Female	187	63.4	21.23	3.71	[20.70, 21.76]
	Male	102	34.6	22.36	3.41	[21.70, 23.02]
	Other	6	2.0	23.00	1.10	[21.85, 24.15]
Type of teacher	Primary	241	81.7	—	—	—
	Secondary	54	18.3	—	—	—
Year of study	1st	49	16.6	—	—	—
	2nd	66	22.4	—	—	—
	3rd	82	27.8	—	—	—
	4th	44	14.9	—	—	—
	Secondary Master's	54	18.3	—	—	—
Total		295	100.0	21.66	3.61	—

Note. *M* = arithmetic mean; *SD* = standard deviation; 95% CI = 95% confidence interval, computed using the normal approximation for groups with $n \geq 30$ and Student's *t*-distribution for the "Other" gender category ($n = 6$).

2.4. Data Analysis

Statistical analyses were conducted using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). In a first phase, a descriptive analysis of all study variables was performed, computing absolute and relative frequencies for categorical variables, and measures of central tendency and dispersion, specifically the arithmetic mean, median, standard deviation, and the P25, P50, and P75 percentiles, for continuous and discrete variables, in order to provide a comprehensive characterization of the sample and the main variables of interest.

Prior to applying inferential tests, the normality assumption for the age variable was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Results evidenced a violation of this assumption in both the female and male groups ($p < 0.001$), which led to the adoption of a non-parametric statistical approach for all subsequent comparative and correlational analyses.

All hypothesis tests were conducted as two-tailed, with a significance level set a priori at $\alpha = 0.05$. A non-directional approach was adopted given the exploratory, single-institution nature of the study and the absence of sufficiently robust prior evidence in this specific context to justify a one-tailed test.

Associations between categorical variables were examined using Pearson's chi-square test of independence. Effect sizes were estimated using the Phi coefficient (ϕ) and Cramér's *V*, given that, for 2×2 contingency tables such as those used in the present study, both statistics are equivalent, and Cramér's *V* offers a more directly comparable interpretation across studies, as it is normalized to the interval [0, 1] regardless of table dimensions (Cohen, 1988). Associations between ordinal and continuous variables were examined using Spearman's rank correlation coefficient (ρ), consistently denoted throughout the manuscript, with results presented in a correlation matrix indicating bilateral significance levels.

To compare scores on the study scales between pre-service primary and secondary teacher groups, the Mann–Whitney *U* test for independent samples was applied, given the previously noted violation of the normality assumption. Effect sizes were quantified using the $r = Z/\sqrt{N}$ statistic, following Cohen's (1988) guidelines, which establish thresholds of 0.10, 0.30, and 0.50 for small, medium, and large effects, respectively. Given the marked dis-

parity in group sizes between specializations ($n = 241$ and $n = 54$), group comparisons were supplemented with Welch's t -test, robust to unequal variances and unequal sample sizes, together with Hedges' g as a bias-corrected estimate of effect size for small and unequal samples, and a sensitivity analysis reporting the minimum detectable effect (MDE) given the achieved statistical power, in order to assess whether the observed group imbalance compromised the reliability of the comparative findings.

To statistically contrast the relative weight of the repertoire of known educational ICT tools against the repertoire of active methodologies known or practiced during initial training, both indicators were first transformed into proportions relative to the total number of options available in each list (25 tools and 12 methodologies, respectively), yielding a common 0–1 scale that allows for a direct comparison between repertoires of different length. The Wilcoxon signed-rank test for related samples was then applied to these paired proportions, given that both indicators were measured on the same participants and the normality assumption was not met. This procedure allowed for the formal quantification of the relative asymmetry between technological and methodological repertoires (H_3), beyond mere descriptive comparison of raw counts.

The internal consistency of the measurement scales included in the instrument was assessed using Cronbach's alpha coefficient, with item-total corrected correlations also examined to identify potentially problematic items that might be compromising the internal homogeneity of each scale. Additionally, McDonald's omega (ω) is reported as a supplementary measure of composite reliability, given that, unlike Cronbach's alpha, it does not assume tau-equivalence among items and provides a more precise estimate of internal consistency in the presence of heterogeneous factor loadings (McDonald, 1999; Revelle & Zinbarg, 2009). For the four-item scale on perceptions of methodological change, which showed insufficient reliability for treatment as a unidimensional composite ($\alpha = 0.467$), an exploratory factor analysis was conducted to examine its underlying structure, and subsequent analyses treated the corresponding items individually rather than as a composite score, applying a Holm–Bonferroni correction to control the family-wise error rate across the resulting multiple comparisons.

To identify differentiated digital profiles among participants, a two-step cluster analysis was conducted using standardized indicators of technological exposure and tool familiarity, with cluster quality evaluated through the silhouette coefficient of cohesion and separation. To examine the joint predictive contribution of sociodemographic, digital trajectory, and ICT exposure variables on future methodological orientation, a multiple linear regression model was estimated, with model assumptions verified prior to interpretation.

2.5. Use of Artificial Intelligence

In the preparation of this manuscript, generative artificial intelligence tools were employed, specifically Claude Sonnet 5 (Anthropic, PBC, San Francisco, CA, USA), for exclusively instrumental purposes in support of writing and document organization. Their use was limited to reviewing and improving the clarity and expository coherence of the text, providing guidance on the methodological structuring of the manuscript, and refining the linguistic formulation of certain sections in order to enhance readability and terminological consistency.

No generative artificial intelligence system was used for data production, statistical analysis, interpretation of empirical results, or generation of figures, tables, or original scientific content. All theoretical decisions, analyses, interpretations, and conclusions of the study were carried out entirely by the authors.

3. Results

3.1. Sociodemographic Profile and Digital Trajectory

The sample showed a predominantly female profile (63.4% women, 34.6% men, 2.0% other gender categories), with a mean age of 21.66 years ($SD = 3.61$) and marked age differences by teacher type: all prospective secondary teachers were aged 21 or above, compared to a more varied distribution among primary pre-service teachers ($\chi^2(1) = 67.46$, $p < 0.001$, $\phi = V = 0.478$. (see Table 3).

Table 3. Distribution of Pre-Service Teachers by Grouped Age and Type of Teacher ($N = 295$).

Age Group	Primary	Secondary	Total
≤ 20 years	149 (61.8%)	0 (0.0%)	149 (50.5%)
≥ 21 years	92 (38.2%)	54 (100.0%)	146 (49.5%)
Total	241 (100.0%)	54 (100.0%)	295 (100.0%)

Note. Percentages in the Primary and Secondary columns are calculated from the total for each type of teacher. Percentages in the Total column are calculated from $N = 295$. $\chi^2(1) = 67.46$, $p < 0.001$, $\phi = V = 0.478$.

Participants showed early and near-universal technological immersion (see Table 4): 85.1% had unrestricted internet access before age 15, and 99.0% held social media accounts. Academic ICT use began predominantly during lower secondary education (57.6%), rather than primary school (32.9%) or later stages (9.5% combined).

Table 4. Early Access and Educational ICT Use Among Pre-Service Teachers ($N = 295$).

Variable	Category	<i>n</i>	%
Age of first unrestricted internet access	≤ 11 years	78	26.4
	12 years	82	27.8
	13–14 years	91	30.9
	≥ 15 years	44	14.9
Stage of onset of educational ICT use	Primary	97	32.9
	Lower secondary (ESO)	170	57.6
	Upper secondary/VET	15	5.1
	University	13	4.4
Has social media accounts	Yes	292	99.0
	No	3	1.0

Note. Percentages are calculated from the total number of valid cases ($N = 295$).

Daily ICT use was concentrated at moderate-to-high levels ($M = 2.65$, $SD = 0.92$; $P_{25} = 2$, $P_{50} = 3$, $P_{75} = 3$), whereas ICT integration in university coursework was markedly heterogeneous ($M = 2.40$, $SD = 1.49$): 20.7% of participants reported no ICT integration in any course, while 30.8% and 25.1% reported approximately 50% and 40% of courses using ICT, respectively. This dispersion indicates that ICT integration in university training does not follow a systematic pattern.

3.2. Correlations Between Sociodemographic and ICT Use Variables

To explore the relationships between sociodemographic variables and those of digital trajectory and use, a Spearman correlation matrix was computed for the nine variables in this block admitting an ordinal or continuous interpretation, with results presented in Table 5. The variable capturing self-reported knowledge of specific ICT tools was excluded from this matrix, as it was coded as a nominal identifier of response patterns rather than an ordinal or quantitative indicator, and is therefore not suitable for rank-based correlation.

Table 5. Spearman Correlation Matrix for Sociodemographic and ICT Use Variables ($N = 295$).

Variable	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
1. Age	—							
2. Sex	0.27 **	—						
3. Year of study	0.61 **	0.15 **	—					
4. Type of teacher	0.52 **	0.07	0.69 **	—				
5. Age of internet access	0.23 **	0.10	0.09	−0.03	—			
6. Stage of ICT onset	0.36 **	0.30 **	0.24 **	0.11	0.48 **	—		
7. Daily ICT hours	−0.16 **	−0.02	0.12 *	0.15 *	−0.12 *	−0.10	—	
8. % courses with ICT	−0.00	−0.01	0.00	0.13 *	0.03	0.03	0.15 **	—
9. No. of educ. apps	0.13 *	−0.06	0.15 *	0.21 **	0.04	−0.00	0.15 **	0.03

Note. ρ = Spearman's rank correlation coefficient. Values on the diagonal and upper triangle are omitted by symmetry. * $p < 0.05$. ** $p < 0.01$ (two-tailed).

The highest correlations correspond to academic and formative variables: age with year of study ($\rho = 0.61, p < 0.001$) and type of teacher ($\rho = 0.52, p < 0.001$), consistent with the structural age differences between training pathways documented in Section 3.1, and year of study with type of teacher ($\rho = 0.69, p < 0.001$), reflecting shared academic progression. A moderate association was found between age of internet access and the stage of onset of educational ICT use ($\rho = 0.48, p < 0.001$), and age correlated with age of first internet access ($\rho = 0.23, p < 0.001$), consistent with a generational effect in technological access.

Daily ICT hours showed weak but statistically significant associations with year of study ($\rho = 0.12, p = 0.046$), type of teacher ($\rho = 0.15, p = 0.013$), and number of educational applications known ($\rho = 0.15, p = 0.008$). Although statistically significant, these associations were small in magnitude, indicating that daily ICT use time does not translate proportionally into greater pedagogical integration of technology, a pattern examined further in relation to H_2 in Section 3.3.

3.3. Asymmetry Between Technological and Methodological Repertoires

Self-reported knowledge of educational ICT tools showed a profile strongly oriented towards general-purpose productivity and communication tools rather than education-specific platforms (see Table 6). Microsoft PowerPoint (98.0%), Kahoot! (95.9%), Microsoft Word (94.9%), Google Meet (90.5%), and Google Documents (89.5%) were the most widely known tools, while more specialized educational platforms such as Playposit (2.0%), Trello (2.4%), and Mendeley (5.1%) showed markedly lower recognition.

To statistically contrast the relative weight of the technological and methodological repertoires, both indicators were transformed into proportions relative to their respective list lengths (25 tools, 12 methodologies), yielding a comparable 0–1 scale (see Table 7). The Wilcoxon signed-rank test applied to these paired proportions did not reach statistical significance, $Z = 1.32, p = 0.186, r = 0.08$, indicating a negligible effect. Of the 295 participants, 51.5% showed a proportionally higher familiarity with tools than with methodologies, compared to 48.5% with the reverse pattern, an essentially balanced distribution. The null hypothesis H_{03} was therefore not rejected: within this sample, no reliable asymmetry was found between the breadth of the technological repertoire and the breadth of the methodological repertoire once both are expressed on a comparable scale.

The null hypothesis H_{02} was rejected: daily ICT exposure showed a weak, statistically significant, but substantively negligible association with tool familiarity ($\rho = 0.155, p = 0.008, r^2 \approx 0.024$), in the opposite direction to that hypothesized by H_2 . The small effect size ($r^2 \approx 0.024$) indicates that daily exposure accounts for a marginal share of the variance in tool familiarity, suggesting that mere technological exposure does not translate into meaningfully greater instrumental knowledge. The null hypothesis H_{02} was therefore

rejected, although not in the direction anticipated by H₂; the negligible magnitude of the association is consistent with the broader argument that exposure alone does not generate pedagogically relevant digital competence.

Table 6. Distribution of Self-Reported Knowledge of Educational ICT Tools (N = 295).

Tool	% Known	Tool	% Known
Microsoft PowerPoint	98.0%	Socrative	42.7%
Kahoot!	95.9%	Moodle	33.9%
Microsoft Word	94.9%	Photomath	33.9%
Google Meet	90.5%	Scratch	33.9%
Google Documents	89.5%	Google Scholar	20.3%
Google Classroom	87.5%	Wordpress	19.0%
Zoom	84.4%	Educaplay	17.6%
Microsoft Excel	82.7%	Blackboard	17.3%
Genially	82.4%	Minecraft	8.1%
Google Forms	70.5%	Education Edition	5.1%
Acrobat (PDF)	63.1%	Mendeley	5.1%
Microsoft Outlook	62.4%	Trello	2.4%
Microsoft Teams	53.2%	Playposit	2.0%

Note. N = 295. Percentages calculated from total valid responses, excluding the “other tools not listed” option. Tools are listed in descending order of self-reported knowledge.

Table 7. Descriptive Statistics for the Proportion of Known ICT Tools and the Proportion of Known/Practiced Methodologies, Relative to List Length (N = 295).

Variable	M	Md	SD
Proportion of known ICT tools (of 25)	0.534	0.52	0.156
Proportion of known/practiced methodologies (of 12)	0.505	0.50	0.234

Note. N = 295. Wilcoxon signed-rank test on paired proportions: $Z = 1.32$, $p = 0.186$, $r = 0.08$.

3.4. ICT Perceptions, Future Methodological Orientation, and Scale Reliability

Table 8 shows pre-service teachers' responses on the perception of methodological change scale. The item generating the greatest consensus concerned the perceived need for methodological change, with 79.0% of participants expressing at least moderate agreement, and 68.5% expressed great concern about the consequences of excessive ICT use at home. In contrast, items on the persistence of the lecture format despite ICT adoption and on perceived ICT overuse in the classroom showed markedly more balanced, polarized distributions, with no clear consensus among pre-service teachers.

Given that this four-item scale showed insufficient internal consistency to be treated as a unidimensional composite ($\alpha = 0.467$, $\omega = 0.445$; see below), group comparisons by teaching specialization were conducted at the item level rather than on a composite score, applying the Mann–Whitney U test to each item with a Holm–Bonferroni correction for multiple comparisons (see Table 9). Three items showed no significant difference between primary and secondary pre-service teachers after correction. One item, concerning whether ICT use has kept the lecture format intact, showed a statistically significant difference ($U = 7955.0$, $Z = 2.66$, $p = 0.008$, $p_{\text{Holm}} = 0.031$, $r = 0.155$), with secondary pre-service teachers more likely to agree that ICT has not displaced traditional lecturing, an association of small magnitude. On the future methodological orientation scale, no significant difference was found between groups ($U = 4996.0$, $Z = 0.47$, $p = 0.638$, $r = 0.030$), indicating a homogeneous predisposition towards active methodologies regardless of specialization.

Table 8. Pre-Service Teachers' Perceptions About ICT Use and Methodological Change ($N = 295$).

Item	Disagreement (%)	Intermediate Agreement (%)	High Agreement (%)
Methodological change since primary education	7.8	29.8	62.4
ICT have kept the lecture format intact	32.2	32.5	35.3
Overuse of ICT in the classroom	36.9	29.2	33.9
Concern about excessive ICT use at home	13.6	18.0	68.5
Need for methodological change in the classroom	21.0	44.1	34.9

Note. Disagreement = strongly /slightly disagree; Intermediate agreement = somewhat agree; High agreement = quite/strongly agree. Percentages are calculated from $N = 295$.

Table 9. Item-Level Mann–Whitney Comparisons by Teaching Specialization for the Perception of Methodological Change Scale, with Holm–Bonferroni Correction ($N = 295$).

Item	<i>U</i>	<i>Z</i>	<i>p</i>	<i>p</i> (Holm)	<i>r</i>	Sig.
Methodological change since primary	6072.0	−0.80	0.422	0.844	0.047	No
ICT kept lecture intact	7955.0	+2.66	0.008	0.031	0.155	Yes
Overuse of ICT	6923.0	+0.76	0.449	0.844	0.044	No
Concern about excessive use at home	7149.0	+1.20	0.229	0.687	0.070	No

Note. Mann–Whitney *U* tests comparing primary ($n = 241$) and secondary ($n = 54$) pre-service teachers, with Holm–Bonferroni correction applied across the four comparisons.

This result was corroborated with Welch's *t*-test, robust to the marked group-size imbalance ($n_1 = 208$, $n_2 = 46$ after listwise deletion): $t = 0.75$, $p = 0.456$, Hedges' $g = 0.112$. The sensitivity analysis indicated a minimum detectable effect of $d = 0.456$ at 80% power for this comparison, well above the observed effect size, so this null result should be interpreted as inconclusive given the available power rather than as evidence of true equivalence between groups. The single significant item-level difference identified above (ICT kept lecture intact) was likewise corroborated with Welch's *t*-test ($t = 2.84$, $p = 0.006$, Hedges' $g = 0.375$), confirming that this finding is not an artifact of the sample imbalance; the remaining three items showed no significant difference under either test (all $p > 0.28$, $|Hedges' g| < 0.17$).

Regarding the psychometric properties of the instruments, the perception of methodological change scale, comprising four items, showed low internal consistency ($\alpha = 0.467$, $\omega = 0.445$; see Table 10). Corrected item-total correlations revealed marked heterogeneity: the item on the persistence of the lecture format obtained a near-zero correlation with the corrected total score ($r^{ITC} = 0.034$), and its removal would raise alpha to 0.588, indicating that it does not share the construct measured by the remaining items. An exploratory factor analysis confirmed that this heterogeneity reflects genuine multidimensionality rather than random noise, extracting two components rather than a single underlying factor, consistent with the low omega value ($\omega = 0.445 < \alpha$), which indicates that the items do not share a common latent dimension. Given this evidence, the scale's total score is not interpreted as a reliable unidimensional measure, and the item-level analysis above is treated as the primary source of evidence for this construct.

Table 10. Item-Level Reliability Statistics for the Perception of Methodological Change Scale ($N = 295$).

Item	M	SD	r^{ITc}	α If Item Deleted
Methodological change since primary education	2.83	0.946	0.198	0.455
ICT have kept the lecture format intact	2.08	1.008	0.034	0.588
Overuse of ICT in the classroom	2.01	1.150	0.463	0.174
Concern about excessive ICT use at home	2.97	1.170	0.410	0.235

Note. M = arithmetic mean; SD = standard deviation; r^{ITc} = corrected item-total correlation; α if item deleted = Cronbach's alpha if the item is removed. Overall: $\alpha = 0.467$, $\omega = 0.445$.

In contrast, the future methodological orientation scale, comprising eleven items, showed high and robust internal consistency ($\alpha = 0.858$, $\omega = 0.861$; see Table 11). All items exceeded the recommended minimum threshold of corrected item-total correlation ($r^{ITc} > 0.30$), and no item would improve the overall alpha if removed. The near-equivalence between alpha and omega confirms that the scale meets the tau-equivalence assumption and measures a genuinely homogeneous construct. The methodology with the highest mean score was cooperative learning ($M = 3.46$, $SD = 0.798$), while the lecture format obtained the lowest score ($M = 2.54$, $SD = 0.860$), confirming a predominantly active and innovative methodological orientation among the pre-service teachers studied.

Table 11. Item-Level Reliability Statistics for the Future Methodological Orientation Scale ($N = 254$).

Item	M	SD	r^{ITc}	α If Item Deleted
Competency-based learning	2.90	0.667	0.601	0.844
Thinking-based learning	3.05	0.704	0.636	0.841
Problem-based learning	3.05	0.779	0.439	0.855
Project-based learning	3.24	0.727	0.664	0.839
Cooperative learning	3.46	0.798	0.579	0.844
Service-learning	3.02	0.805	0.592	0.843
Lecture-based instruction	2.54	0.860	0.460	0.854
Design Thinking	2.72	0.914	0.640	0.839
Flipped Classroom	2.98	0.788	0.553	0.846
Gamification	2.71	0.835	0.489	0.851
Integrated curriculum teaching	2.76	0.755	0.432	0.855

Note. M = arithmetic mean; SD = standard deviation; r^{ITc} = corrected item-total correlation; α if item deleted = Cronbach's alpha if the item is removed. $N = 254$ valid cases (listwise); the reduction from $N = 295$ reflects listwise deletion, since 41 participants had at least one missing value across the eleven items of this scale. Overall: $\alpha = 0.858$, $\omega = 0.861$.

3.5. Digital Profiles: Cluster Analysis

To explore whether pre-service teachers could be grouped into differentiated digital profiles, a two-step cluster analysis was conducted using four standardized indicators: proportion of known educational ICT tools, daily hours of ICT use, percentage of university courses integrating ICT, and number of ICT-related training actions undertaken. The analysis yielded a two-cluster solution of moderate quality (silhouette coefficient = 0.244), comprising 134 participants (46.7%) in Profile A and 153 (53.3%) in Profile B.

Contrary to what might be expected, the two profiles did not differ appreciably in the proportion of known ICT tools (Profile A = 0.531; Profile B = 0.532), indicating that tool familiarity is broadly homogeneous across the sample and does not, by itself, distinguish meaningful subgroups. The profiles differed instead in how digital experience was acquired: Profile A combined lower ICT integration in university coursework ($M = 1.19$, approximately 25% of courses) with a higher number of self-initiated training actions ($M = 3.48$), whereas Profile B combined higher curricular ICT integration ($M = 3.45$, approximately 50–75% of courses) with markedly fewer additional training actions ($M = 1.14$).

and somewhat higher daily ICT use ($M = 2.93$ vs. 2.29). This pattern suggests that curricular ICT exposure and self-initiated training may function as partially substitutive rather than complementary pathways to digital experience, though this interpretation remains exploratory given the modest cluster quality (see Table 12).

Table 12. Digital Profiles Identified Through Cluster Analysis: Descriptive Statistics by Cluster ($N = 287$).

Variable	Profile A M (SD)	Profile B M (SD)
Proportion of known ICT tools	0.53 (0.17)	0.53 (0.14)
Daily ICT hours	2.29 (0.84)	2.93 (0.89)
% courses with ICT integration	1.19 (1.25)	3.45 (0.68)
No. of ICT training actions	3.48 (2.53)	1.14 (1.40)
n	134 (46.7%)	153 (53.3%)

Note. $N = 287$. Two-step cluster solution; silhouette coefficient of cohesion and separation = 0.244. Proportion of known ICT tools computed over 25 listed tools.

3.6. Predictors of Future Methodological Orientation: Multiple Regression

To examine the joint contribution of sociodemographic, digital trajectory, and ICT exposure variables to future methodological orientation, a multiple linear regression was estimated, with age, sex, teaching specialization, daily ICT hours, percentage of ICT-integrated courses, proportion of known educational tools, and number of ICT training actions entered as predictors ($N = 287$). The overall model was statistically significant but explained a modest proportion of variance, $R^2 = 0.055$, adjusted $R^2 = 0.031$, $F(7, 279) = 2.32$, $p = 0.026$. Residual diagnostics indicated no serious violations of model assumptions (Jarque–Bera $p = 0.189$; Durbin–Watson = 1.66), and variance inflation factors remained below 1.4 for all predictors, ruling out multicollinearity concerns.

Two predictors reached statistical significance (see Table 13). The number of ICT-related training actions undertaken was a significant positive predictor ($B = 0.037$, $p = 0.014$), as was the proportion of known educational ICT tools ($B = 0.442$, $p = 0.043$). Age, sex, teaching specialization, daily ICT hours, and percentage of ICT-integrated courses were not significant predictors. This pattern indicates that specific, self-initiated ICT training and instrumental tool familiarity contribute modestly but significantly to future methodological orientation, whereas mere daily exposure to technology does not, reinforcing the distinction between exposure and pedagogically meaningful engagement with ICT already noted in relation to H_2 .

Table 13. Multiple Regression Predicting Future Methodological Orientation ($N = 287$).

Predictor	B	SE	t	p	95% CI
(Constant)	2.562	0.254	10.09	<0.001	[2.062, 3.062]
Age	0.002	0.011	0.23	0.817	[−0.019, 0.023]
Sex	−0.083	0.064	−1.29	0.197	[−0.208, 0.043]
Teaching specialization	−0.132	0.101	−1.30	0.194	[−0.332, 0.068]
Daily ICT hours	0.036	0.038	0.95	0.343	[−0.039, 0.110]
% courses with ICT	0.040	0.023	1.77	0.078	[−0.005, 0.084]
Proportion of known ICT tools	0.442	0.218	2.03	0.043	[0.013, 0.870]
No. of ICT training actions	0.037	0.015	2.48	0.014	[0.008, 0.067]

Note. $N = 287$. Dependent variable: mean score on the future methodological orientation scale. $R^2 = 0.055$, adjusted $R^2 = 0.031$, $F(7, 279) = 2.32$, $p = 0.026$.

4. Discussion

The results of this study do not support a large, unequivocal asymmetry between technological exposure and pedagogical application among pre-service teachers. Once

the repertoires of known ICT tools and known or practiced active methodologies were expressed on a comparable proportional scale, no reliable asymmetry emerged (H_{03} was not rejected; Wilcoxon $Z = 1.32$, $p = 0.186$, $r = 0.08$), with the sample split almost evenly between those proportionally stronger in tools (51.5%) and those stronger in methodologies (48.5%). This null result is itself informative: it suggests that the intuitive narrative of pre-service teachers being “digitally fluent but methodologically underequipped” oversimplifies a more balanced reality, at least regarding the breadth of what is known or practiced (Kirschner & De Bruyckere, 2017). This reframing is consistent with Chugh et al.’s (2023) observation that ICT integration in higher education tends to remain instrumental, but qualifies it: the imbalance appears to lie less in the sheer number of tools versus methodologies known, and more in how that knowledge is acquired and applied, a distinction developed further below.

Regarding H_2 , daily ICT exposure showed a weak, statistically significant, but substantively negligible association with tool familiarity ($\rho = 0.155$, $p = 0.008$, $r^2 \approx 0.024$), in the opposite direction to that hypothesized. Rather than exposure translating into no gain, it translates into a trivial one. This finding aligns with Falloon’s (2020) argument that teacher digital competence requires ethical, reflective, and pedagogically grounded engagement with technology, which mere time spent using devices does not confer. The regression analysis reinforces this distinction: specific, self-initiated ICT training actions and instrumental tool familiarity were modest but significant predictors of future methodological orientation ($B = 0.037$, $p = 0.014$, and $B = 0.442$, $p = 0.043$, respectively), while daily hours of ICT use and percentage of ICT-integrated courses were not ($R^2 = 0.055$). Peng et al. (2024) similarly found that digital competence and attitudes, rather than mere familiarity or exposure, were the strongest predictors of effective ICT integration among in-service teachers; the present findings extend this pattern to the pre-service stage.

The cluster analysis identified two digital profiles of comparable size (46.7% and 53.3%) that did not differ in tool familiarity, but differed markedly in how digital experience was acquired: one profile combined lower curricular ICT integration with a higher number of self-initiated training actions, while the other combined higher curricular ICT integration with markedly fewer additional training actions. This pattern suggests that curricular exposure to ICT and self-initiated professional development may function as partially substitutive rather than complementary pathways, a possibility that, to our knowledge, has not been directly documented in the pre-service teacher literature and merits confirmatory research beyond the exploratory scope of this study.

At the item level, RQ_1 revealed a single significant difference between primary and secondary pre-service teachers: those training for secondary education agreed more strongly that ICT use has not displaced the lecture format ($r = 0.155$, $p_{\text{Holm}} = 0.031$), while no differences emerged on the remaining three perception items or on the future methodological orientation scale. This selective pattern is consistent with the more subject-centered, lecture-oriented culture typically associated with secondary teaching, and echoes Gil-Flores et al.’s (2024) finding that methodological transformation in ICT-rich environments depends on organizational conditions as much as on individual predisposition.

These findings raise a question that the data alone cannot answer directly, but which the broader pattern of results makes difficult to avoid: why does curricular ICT integration in university coursework fail to translate into a correspondingly stronger methodological orientation, and why might it even substitute for, rather than complement, self-initiated training? Three institutional factors offer plausible explanations, without being directly tested here. First, curriculum overload in initial teacher education programs leaves limited space for the sustained, hands-on practice that active methodologies require, favoring content coverage over pedagogical experimentation (Ertmer, 1999; Ngao et al., 2022);

this pattern echoes [Ley et al.'s \(2021\)](#) account of how schools struggle to move beyond superficial technology adoption towards genuine knowledge appropriation. Second, pre-service teachers' methodological orientation is shaped in part by the teaching practices they observe in their own university lecturers; when lecturers themselves rely predominantly on transmissive formats despite using ICT as a delivery tool, students receive an implicit model of technology as a complement to, rather than a vehicle for, methodological change, a dynamic documented among teacher educators by [Ngao et al. \(2022\)](#). Third, institutional structures that treat ICT integration as a technical requirement to be reported (e.g., the percentage of courses "using ICT") rather than a pedagogical capacity to be developed may inadvertently reward superficial adoption. These institutional-level explanations, rather than deficits in individual pre-service teachers, are consistent with the modest and selective pattern of associations found throughout this study, and point towards curriculum redesign, and specifically towards strengthening pedagogical modeling by teacher educators, as a more promising lever than expanding technological content.

These findings should be interpreted within the boundaries of a single-institution case study rather than as evidence of a generalizable structural feature of teacher education. Within this boundary, however, the pattern observed carries a concrete implication for curriculum design: rather than expanding the technological content of the curriculum, programs may benefit more from restructuring practicum and methodology courses to require documented, supervised practice with active methodologies mediated by ICT, coupled with explicit expectations that teacher educators model such practices in their own teaching rather than using ICT solely as a content-delivery channel. Embedding this requirement into accreditation or curriculum review criteria, rather than leaving it to individual lecturer discretion, would address the institutional-level mechanisms identified above more directly than isolated training interventions.

The psychometric contrast between the two measurement scales adds a further interpretive layer. The high internal consistency of the future methodological orientation scale ($\alpha = 0.858$, $\omega = 0.861$) confirms that pre-service teachers in this sample hold a coherent, genuinely active pedagogical orientation. The four-item perception of methodological change scale, by contrast, did not share a common latent dimension ($\alpha = 0.467$, $\omega = 0.445$), with the item on the persistence of the lecture format functioning as an essentially independent perceptual domain ($r^{ITC} = 0.034$). This is not primarily a psychometric limitation; it reflects genuine multidimensionality in how pre-service teachers relate to educational technology. [Wang and Zhao \(2023\)](#) show that ICT attitudes are shaped by partially independent dimensions such as perceived complexity and technostress, and [Tzafilkou et al. \(2023\)](#) argue that global ICT attitude instruments systematically underperform because the underlying construct is not unidimensional. Developing a coherent methodological orientation therefore appears more tractable, and more measurable, than shaping a unified attitudinal stance towards ICT.

4.1. Limitations

The most significant limitation of this study concerns its scope of generalizability. The sample was drawn through non-probabilistic convenience sampling from a single institutional context, with a marked imbalance between teaching specializations (Primary Education, $n = 241$; Secondary Education, $n = 54$). Accordingly, these findings should be interpreted as evidence from a single-institution case study and cannot be generalized beyond this institutional context; they do not warrant conclusions about pre-service teacher education in Spain more broadly. The cross-sectional design further precludes causal inference and does not allow tracking of how digital trajectories and methodological

orientations evolve over the course of initial training, an inherent limitation of descriptive-correlational designs.

A second limitation concerns the reliance on self-reported measures throughout the instrument. Familiarity with educational ICT tools and methodologies was assessed through self-declared recognition rather than through direct or performance-based assessment. Indicating awareness of a tool by name does not equate to functional competence in its pedagogical use, and the same caveat applies to the number of active methodologies participants reported knowing or having practiced, which may reflect exposure to terminology rather than sustained classroom application. The proportional indicators used to examine H₃ should therefore be interpreted as measures of the breadth of self-reported familiarity, not of depth of mastery or actual instructional use, and the absence of a significant asymmetry between these indicators should not be read as evidence that technological and pedagogical competence are equally well developed.

A further limitation concerns the scope of the digital competence dimensions assessed. The instruments employed operationalize two of the six areas defined by the DigCompEdu framework (Redecker & Punie, 2017): digital content knowledge, approximated through self-reported familiarity with educational ICT tools, and teaching and learning, approximated through experience with active methodologies. The remaining four areas, professional engagement, assessment and feedback, empowering learners, and facilitating learners' digital competence, fall outside the scope of the present study. Relatedly, the four-item scale addressing perceptions of methodological change showed insufficient reliability to be treated as a unidimensional composite ($\alpha = 0.467$, $\omega = 0.445$) and was therefore analyzed at the item level; future studies in this area would benefit from validated multidimensional instruments designed specifically to capture ICT attitudes, such as the scale proposed by Tzafilkou et al. (2023), rather than ad hoc item sets.

Finally, two aspects of the analytical approach warrant caution in interpretation. First, the institutional-level explanations discussed above, including curriculum overload and the modeling role of teacher educators, are offered as plausible interpretations of the observed patterns rather than as directly tested mechanisms; this study did not collect data on teacher educators' own practices or on curricular structure beyond students' self-reported perceptions, and future research should incorporate these dimensions directly. Second, the digital profiles identified through cluster analysis showed only moderate solution quality (silhouette coefficient = 0.244) and should be regarded as an exploratory, hypothesis-generating result rather than a confirmed typology; replication with latent profile analysis on independent samples is needed before these profiles are treated as stable.

4.2. Future Research Directions

The research directions opened by these results are diverse and complementary. First, longitudinal studies tracking pre-service teachers' technological and methodological trajectories throughout initial training and, especially, during the practicum period, when they have the greatest opportunity to contrast their declared methodological orientation with the demands of real classroom practice, would help clarify whether the balanced pattern observed here between tool familiarity and methodological breadth persists, narrows, or diverges over time.

Second, the digital profiles identified through cluster analysis in this study, differentiated by the relative weight of curricular ICT integration versus self-initiated training rather than by tool knowledge, merit further investigation through latent profile analysis on larger and more balanced samples, which would allow for more precise characterization and stronger confirmation of their stability. Such research should attend to the updated TPACK framework proposed by Petko et al. (2025), which extends the original model

to integrate contextual and dispositional dimensions not fully captured by instrumental indicators alone.

Third, the validation and improvement of ICT attitude measurement instruments in initial teacher education contexts remains an unresolved methodological need, particularly given the multidimensionality documented in this study for the perception of methodological change scale. The work of [Getenet et al. \(2024\)](#) with first-year pre-service teachers, and the validated scale proposed by [Tzafilkou et al. \(2023\)](#), offer instrument design models that integrate digital literacy, self-efficacy, and attitudes in an articulated manner and could serve as references for developing psychometrically more robust instruments in the Spanish context.

Fourth, the institutional-level mechanisms proposed to explain the patterns observed here—curriculum overload, the modeling role of teacher educators, and the treatment of ICT integration as a reportable metric rather than a pedagogical practice—were not directly tested in this study and warrant dedicated empirical attention. Research combining classroom observation, teacher educator surveys, or curriculum content analysis, following the qualitative approach used by [Ngao et al. \(2022\)](#) with teacher educators, would allow these explanations to move from plausible interpretation to tested mechanism.

Extending this research to other university centers and national contexts would allow determination of the extent to which the patterns identified in this single-institution case study generalize to broader trends in initial teacher education, and would contribute to empirically grounding curriculum reform proposals with greater scope and external validity.

Finally, given that data collection took place in 2023, before the widespread adoption of generative artificial intelligence tools in higher education, future studies should extend this line of research to examine how pre-service teachers' familiarity with and pedagogical use of generative AI tools relates to their methodological orientation, an increasingly central dimension of digital competence not captured by the instrument used here.

5. Conclusions

The three specific objectives of this study have been addressed. The sociodemographic and digital trajectory profile of the sample has been characterized, revealing a predominantly young and female cohort with early and near-universal technological exposure, though with markedly heterogeneous ICT integration across university courses. Pre-service teachers' perceptions about ICT use and methodological change have been examined at the item level, showing broad consensus on the need for pedagogical renewal alongside notable ambivalence about whether such change has actually occurred in practice. Finally, the relative weight of the technological and methodological repertoires has been formally tested using proportionally comparable indicators, and the psychometric properties of both instruments have been evaluated in detail, yielding a set of findings that are more nuanced, and in several respects more modest, than initially hypothesized.

With respect to the hypotheses, the null hypothesis H_{01} was rejected in favor of H_1 : teaching specialization is significantly associated with age profile ($\chi^2(1) = 67.46, p < 0.001, \phi = V = 0.478$), a difference attributable to the structural entry requirements of each training pathway rather than to attitudinal or competence factors. The null hypothesis H_{02} was rejected ($\rho = 0.155, p = 0.008$); however, the result did not support the direction anticipated by H_2 , since daily ICT exposure showed a weak but statistically significant positive association with tool familiarity, rather than the expected dissociation between the two. The negligible effect size ($r^2 \approx 0.024$) indicates that this association is substantively trivial, offering qualified support for the broader argument that mere exposure does not generate meaningful digital competence. Regarding RQ_1 , primary and secondary pre-service teachers differed on a single perception item, concerning the persistence of the

lecture format despite ICT adoption ($p_{\text{Holm}} = 0.031$), with no differences on the remaining perception items or on future methodological orientation, suggesting a largely, though not entirely, homogeneous predisposition across training pathways. The null hypothesis H_{03} was not rejected: no reliable asymmetry was found between the proportional breadth of the technological repertoire and that of the methodological repertoire (Wilcoxon $Z = 1.32$, $p = 0.186$, $r = 0.08$), indicating that, once expressed on a comparable scale, pre-service teachers' familiarity with tools and with methodologies is essentially balanced.

Beyond hypothesis testing, two exploratory analyses qualify this picture further. Cluster analysis identified two digital profiles that did not differ in tool familiarity but differed in how digital experience was acquired, through curricular integration or self-initiated training, suggesting these pathways may function as partial substitutes rather than complements. Regression analysis showed that specific ICT training actions and tool familiarity, but not daily exposure or curricular integration alone, modestly predicted future methodological orientation ($R^2 = 0.055$), reinforcing the distinction between passive exposure and pedagogically meaningful engagement that runs through this study's findings.

Taken together, these findings do not support the narrative of a large, structural gap between technological exposure and pedagogical competence among pre-service teachers in this sample. They instead point to a more specific and more actionable pattern: it is not the breadth of what pre-service teachers know that appears to matter for their methodological orientation, but the nature of how that knowledge is acquired, through deliberate training rather than passive exposure or reported curricular coverage. The most direct implication is not to expand the technological content of initial teacher education curricula, but to ensure that ICT integration in university coursework is accompanied by sustained, supervised practice with active methodologies and by consistent pedagogical modeling on the part of teacher educators themselves. As a single-institution case study, these conclusions should be understood as a plausible account of one specific training context rather than as a generalizable characterization of initial teacher education, and their extension to other settings remains an empirical question for future research.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/educsci16081177/s1>, Doc S1: Data collection instrument (questionnaire); Doc S2: Informed consent form; Doc S3: Ethics committee approval.

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Abbreviations

The following abbreviations are used in this manuscript:

ICT	Information and Communication Technologies
M	Arithmetic mean
Md	Median
SD	Standard deviation
CI	Confidence interval
r	Effect size/Pearson correlation coefficient
ρ	Spearman's rank correlation coefficient
α	Cronbach's alpha coefficient
ω	McDonald's omega
Z	Standardised test statistic (Wilcoxon/Mann–Whitney)
U	Mann–Whitney U statistic
φ	Phi coefficient
χ^2	Pearson's chi-square statistic
r^{ITc}	Corrected item-total correlation
P25/P50/P75	25th, 50th, and 75th percentiles
TPACK	Technological Pedagogical Content Knowledge
DigCompEdu	Digital Competence Framework for Educators
DigComp	Digital Competence Framework for Citizens
ESO	Educación Secundaria Obligatoria (Lower Secondary Education)
VET	Vocational Education and Training
SPSS	Statistical Package for the Social Sciences
OECD	Organisation for Economic Co-operation and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization

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