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Developing Science Communication Competence in Initial Teacher Training

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Abstract

This study examines the development of scientific dissemination skills in initial teacher education through a sequential explanatory mixed-methods design (QUANTITATIVE→ QUALITATIVE). The purpose was to explore how the integration of Project-Based Learning (PBL) and Experiential Learning (EL) fosters the acquisition of cognitive, communicative, media–digital, and ethical–social competencies related to scientific communication. Seventy-nine students from Early Childhood Education (n = 36) and Primary Education (n = 43) degrees at the University of Valladolid participated during the 2024–2025 academic year. In the quantitative phase, a validated questionnaire was administered to assess four dimensions of competence, while the qualitative phase included systematic observations and focus groups. Data analysis combined descriptive and inferential statistics with thematic analysis and convergent integration. The results showed significant improvements in all dimensions, particularly in communicative and media–digital skills, with qualitative evidence explaining the mechanisms underlying this progress. The integration of findings revealed the transformation of students from passive recipients to active mediators of scientific knowledge. It is concluded that the combination of PBL and EL constitutes an effective pedagogical framework for promoting responsible scientific dissemination in higher education and reinforcing the social responsibility of teacher training.

Keywords: scientific dissemination; initial teacher training; Project-Based Learning; experiential learning; communication skills

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1. Introduction

Scientific dissemination is no longer the exclusive domain of specialists but has become a cross-cutting competence in higher education. It is particularly strategic in initial teacher training, where future educators must not only master disciplinary content but also communicate it effectively to diverse audiences—students, families, and educational communities (Fuentes-Cancell et al., 2026; Flores Mejía et al., 2024; O'Connor et al., 2021). In this way, communication serves as a bridge between science and everyday life, strengthening scientific literacy and critical thinking from the earliest stages of education (Kankam et al., 2024).

Communicating science involves translation, contextualization, and adaptation. It requires identifying reliable sources (Bucchi & Trench, 2014, 2021), synthesizing findings without distortion (Kappel & Holmen, 2019), and using accessible analogies or examples

(Jamison et al., 2022) that situate scientific content within relevant social issues (Bucchi & Trench, 2021).

In this study, we use the term scientific dissemination or science communication competence to refer to the capacity of future teachers to mediate scientific knowledge for non-specialist audiences in educational contexts. This competence involves identifying and critically selecting reliable sources, synthesising complex information without distorting evidence, and translating disciplinary concepts into accessible explanations linked to relevant social issues. It also includes organising messages into coherent narratives, using clear and engaging language, making informed decisions about the most appropriate media and formats—such as texts, videos, infographics, or podcasts—and applying visual and design principles to support understanding. Finally, science communication competence has an ethical and social component, which implies recognising the limits of available evidence, avoiding misleading or categorical claims, and promoting critical thinking in order to counter misinformation and reflect on the broader social implications of scientific knowledge (Stofer & Wolfe, 2018; L. S. Davis, 2014).

Mastering this skill demands adapting discourse for non-specialist audiences and employing clear, engaging language free from unnecessary technicality (Baram-Tsabari & Lewenstein, 2017; Dahlstrom, 2014). Communicative effectiveness is further enhanced through structured narratives and coherent oral presentations (Dahlstrom, 2014). In digital contexts, dissemination entails selecting appropriate formats—texts, videos, infographics, or podcasts (Al-Khresheh, 2024)—using visual and design principles strategically (Allgaier, 2019; Gioltzidou et al., 2024) and developing a critical understanding of the communicative logic of social media (Gioltzidou et al., 2024).

The ethical dimension of dissemination requires ensuring accuracy, recognizing the limits of evidence, and avoiding categorical or misleading statements (Besley et al., 2018; Tetteh et al., 2023). It should also promote critical thinking and counter misinformation (Ferrés & Piscitelli, 2012; Lopez-Gonzalez et al., 2023), addressing the broader social and cultural impacts of scientific knowledge (Besley et al., 2018; Besley et al., 2017).

In the context of teacher education, scientific dissemination fosters a deeper understanding of disciplinary content, reinforces professional identity, and positions future teachers as mediators between science and society. Consequently, it constitutes a complex professional competence—cognitive, communicative, digital, and ethical—that must be developed through authentic learning experiences supported by Project-Based Learning (PBL) and Experiential Learning (EL) methodologies.

1.1. Project-Based Learning and Experiential Learning in Higher Education

In higher education, the development of professional and cross-cutting competencies requires methodologies that transcend unidirectional knowledge transmission, integrating theory, practice, and critical reflection. Among these, PBL and EL stand out for their constructivist orientation and student-centered focus. Although they differ in emphasis, both approaches converge in situating learning within authentic contexts, linked to real-world problems and mediated by collaboration and reflective inquiry (Shivni et al., 2021).

PBL frames a problem or research question as the nucleus of the learning process, promoting autonomy, active inquiry, and teamwork (Kokotsaki et al., 2016). Its culmination in a verifiable product—such as a report, proposal, prototype, or presentation—serves as tangible evidence of learning and requires the integration of knowledge, skills, and attitudes around a shared goal (Ammar et al., 2024). It has become an effective strategy for developing communication, management, and collaboration skills, while connecting academic content with professional and social demands (Kong et al., 2024).

In turn, EL, grounded in Kolb's experiential cycle and its subsequent revisions, places lived experience at the core of learning (Morris, 2019). Knowledge emerges from contextualized experiences that demand active engagement and acceptance of uncertainty (Jamison et al., 2022). Its sequence—concrete experience, reflective observation, abstract conceptualization, and active experimentation—fosters deep learning by critically analyzing experience, recognizing the provisional nature of knowledge, and transferring insights to new contexts (Kavitha Devi & Thendral, 2023; Tembrevilla et al., 2023).

Both approaches emphasize the role of active learners capable of linking theory with practice and reflecting on their own learning process (Singha & Singha, 2024). While PBL structures learning around collaborative projects and concrete products, EL underscores situated experience, uncertainty, and critical reflection as drivers of transformative learning (Su, 2024). Together, they provide a comprehensive pedagogical framework for developing complex competencies—communication, problem solving, collaboration, and adaptability—beyond the mere acquisition of disciplinary knowledge.

1.2. Previous Studies on the Development of Scientific Dissemination Skills

Recent research in higher education has highlighted that students often display limited skills in communicating scientific content to non-specialist audiences (Ashcraft et al., 2020; Leon Duarte et al., 2025). Studies on science communication training and dissemination-oriented tasks report recurrent difficulties in identifying reliable sources, translating technical language into accessible explanations, structuring coherent narratives, and making a critical and pedagogically grounded use of digital and multimodal resources (R. Davis & D'Lima, 2020; Brownell et al., 2013; Burns et al., 2003). Although several programmes and courses have incorporated communication activities, these experiences are frequently peripheral, short-term, or focused on isolated products rather than on the systematic development of a broader competence in science communication (Reincke et al., 2020; Tillinghast et al., 2020).

In parallel, numerous studies have highlighted the potential of Project-Based Learning and Experiential Learning for developing scientific competencies in higher education. Both methodologies, grounded in constructivist principles, posit that knowledge is constructed more meaningfully when students actively engage in solving authentic problems, reflect on their experiences, and produce communicable results (Maulida et al., 2024). Empirical and theoretical research converges in showing that these approaches strengthen cognitive, procedural, communicative, and social competencies, dimensions closely related to the development of scientific dissemination skills.

PBL provides an organisational framework that immerses students in complex, collaborative projects. The creation of a tangible, socially relevant final product requires integrating knowledge, planning processes, distributing responsibilities, and effectively communicating results. In contrast, Experiential Learning emphasises situated experience and critical reflection as catalysts for deep learning. By confronting students with real contexts, uncertainty, and decision-making, it fosters conceptual understanding and the transfer of knowledge to new scenarios (Kokotsaki et al., 2016; Morris, 2019). The convergence of both approaches is particularly evident in science education, where PBL promotes scientific competence—encompassing conceptual, procedural, and epistemic dimensions—through realistic challenges that demand modelling, experimental design, argumentation, validation of evidence, and communication of findings to diverse audiences (Lavado-Anguera et al., 2024).

Empirical research in university contexts has also shown that working on collaborative projects enhances autonomy, creativity, leadership, and communication skills (Toledo Morales & Sánchez García, 2018), while bibliometric analyses link these methodologies to improvements in scientific literacy, critical thinking, and research competence (Misbah et al., 2024). Community-based experiences further support these findings: projects situated in real social contexts promote metacognitive awareness, the construction of a scientific identity (Avila-Bront, 2025), and the development of communication, problem-solving, and adaptability skills (Collins-Nelsen et al., 2021). When PBL and Experiential Learning are integrated into authentic projects, students not only learn disciplinary content but also develop the ability to translate and mobilise knowledge within educational and community environments.

Furthermore, Experiential Learning increases motivation and engagement through the sequence of doing, reflecting, thinking, and applying, which encourages cognitive, emotional, and behavioural involvement. Research in mathematics and STEM education confirms that these approaches foster creativity, participation, and academic performance, demonstrating that students learn more effectively in practical and communicative contexts (Maulida et al., 2024; Nguyen et al., 2025; Uyen et al., 2022).

Overall, evidence indicates that PBL and Experiential Learning not only reinforce conceptual understanding but also cultivate comprehensive scientific competencies, such as inquiry, argumentation, critical reflection, collaboration, and communication. These competencies are inseparable from scientific dissemination, as they enable students to make scientific knowledge understandable, relevant, and socially meaningful.

However, despite the growing body of work on active and experiential methodologies, there is still a lack of empirical studies that focus specifically on the development of science communication competence in initial teacher education. Most contributions either address scientific competence in general, examine isolated communication activities, or focus on STEM undergraduates, while research on pre-service teachers remains scarce. Furthermore, few studies combine Project-Based Learning and Experiential Learning in a coherent pedagogical framework, and even fewer adopt mixed-methods designs that capture both the quantitative evolution and the qualitative meanings of students' acquisition of science communication skills across cognitive, communicative, media–digital, and ethical–social dimensions. The present study seeks to contribute to this gap by examining how an integrated PBL and Experiential Learning proposal supports the development of science communication competence in two cohorts of pre-service teachers.

1.3. Research Objectives and Hypotheses

The overall purpose of this study was to analyse the development of science communication competence in initial teacher education through a teaching proposal grounded in Project-Based Learning and Kolb's Experiential Learning model. Previous research and our own diagnostic evidence indicate that many pre-service teachers reach advanced stages of their degree with limited skills in identifying reliable sources, translating scientific knowledge for non-specialist audiences, and using digital and multimodal resources in pedagogically meaningful ways. This situation reveals a gap between the central role that science communication is expected to play in contemporary teaching and the fragmented or insufficient preparation typically offered in university curricula. The present study addresses this gap by examining the impact of an integrated PBL and Experiential Learning intervention on the development of science communication competence across cognitive, communicative, media–digital, and ethical–social dimensions.

Based on this problem, the general objective was to determine whether the intervention produced significant improvements in the four dimensions of science communication competence.

1.3.1. Quantitative Hypotheses

H1. *Students will show a statistically significant improvement in the cognitive dimension of science communication competence between the pretest and posttest.*

H2. *Students will show a statistically significant improvement in the communicative dimension of science communication competence between the pretest and posttest.*

H3. *Students will show a statistically significant improvement in the media–digital dimension of science communication competence between the pretest and posttest.*

H4. *Students will show a statistically significant improvement in the ethical–social dimension of science communication competence between the pretest and posttest.*

1.3.2. Qualitative Research Questions

To complement and deepen the quantitative results, the study addressed the following qualitative research questions:

1. How do students describe their experience with the instructional intervention based on Project-Based Learning and Experiential Learning?
2. What aspects of the intervention do students perceive as relevant in shaping their learning processes related to science communication competence?
3. How do students explain the ways in which the intervention may have influenced their approaches to communicating, interpreting, and mediating scientific knowledge?

2. Materials and Methods

2.1. Participants

The study involved a convenience sample of 79 students from the University of Valladolid (Duques de Soria Campus, Spain), who participated voluntarily after receiving detailed information about the study's objectives and procedures. Participants were enrolled in the Bachelor's Degree in Early Childhood Education (n = 36; 26 women; aged 19–23) and the Bachelor's Degree in Primary Education (n = 43; 13 women; aged 20–23).

The selection of participants was intentional and context-based, corresponding to the educational and organizational characteristics of the courses in which the teaching intervention was implemented. Due to these contextual conditions, random assignment was not possible. All participants completed both the pretest and posttest assessments, and no dropouts occurred during the study.

The qualitative phase was conducted with the same group of participants, consistent with the logic of the sequential explanatory mixed-methods design (QUANT→QUAL), which aimed to explore in depth the perceptions and experiences of those who had taken part in the intervention.

2.2. Ethical Conditions

Participation was voluntary, and all students signed an informed consent form after receiving detailed information about the objectives, procedures, and guarantees of the study. The research was approved by the Ethics Committee of the University of Valladolid (reference: 2025-CEUVa-003-Z-1-D-4), complying with the ethical principles established in the Declaration of Helsinki and European data protection regulations.

2.3. Design

The study followed a sequential explanatory mixed-methods design (QUANT→QUAL) structured in two complementary phases. In the quantitative phase, the changes produced after the teaching intervention were identified and measured; in the qualitative phase, these results were explored in greater depth by analyzing participants' perceptions and experiences. This approach enabled the integration of numerical and narrative evidence to generate interpretive meta-inferences aimed at achieving a broader understanding of the phenomenon under study (Creswell & Plano Clark, 2018; Fetters et al., 2013).

The quantitative component employed a quasi-experimental design with intact, nonequivalent groups and pretest–posttest measurements, without random assignment of participants. Such a design is suitable for educational contexts where randomization is constrained by ethical or organizational factors, yet it allows the impact of a teaching intervention to be examined under real classroom conditions (Hernández Sampieri et al., 2018). The findings from this phase provided the empirical basis for the subsequent qualitative analysis, aimed at deepening the interpretation of the observed changes.

The subjects in which the intervention was implemented were taught in a face-to-face format, supplemented by supervised self-study sessions. Each degree program had a single theoretical class group; practical sessions were organized into one group in the Early Childhood Education degree and two parallel groups in the Primary Education degree. The intervention was carried out in two independent cohorts corresponding to different degree subjects to assess the consistency of impact across training contexts.

To mitigate threats to internal validity—such as maturation, history, or testing effects—the materials, teaching sequence, and assessment rubrics were standardized in both cohorts, and the same instructors implemented the intervention. This procedural consistency ensured comparability between programs and strengthened the reliability of the results.

The qualitative phase adopted an interpretive-descriptive approach, designed to explain and expand the quantitative findings by identifying the underlying learning processes. The same participants took part, in accordance with the principle of sequential connection (QUANT→QUAL). Three focus groups, each comprising 10–13 students, were organized to ensure balanced representation by degree program, gender, and level of engagement. Additionally, systematic pedagogical observations were conducted throughout the intervention.

Focus-group sessions were held after completion of the teaching experience, recorded, and fully transcribed. Their content was analyzed through thematic coding (Braun & Clarke, 2006) until conceptual saturation was achieved.

Finally, the quantitative and qualitative results were integrated through joint interpretation, relating patterns of change to participants' perceptions and experiences. This process led to the formulation of the following meta-inferential questions guiding the overall analysis:

4. How do students' perceptions explain and complement the quantitative improvements observed in scientific dissemination skills?
5. What pedagogical mechanisms associated with PBL and EL emerge from the integration of quantitative and qualitative results within each competency dimension?
6. What meta-inferences can be derived from combining both data sets regarding the impact of the teaching proposal on initial teacher education?

2.4. Instruments

Three complementary instruments were used to assess the dimensions of scientific communication competence, selected according to the objectives of each phase of the sequential explanatory mixed-methods design (QUANT→QUAL).

In the quantitative phase, an ad hoc questionnaire was administered, composed of 16 items distributed across four dimensions: cognitive, communicative, media–digital, and ethical–social (see Table 1). The items were developed based on a systematic review of recent literature on science communication and aligned with key frameworks of digital teaching competence, including DigCompEdu (Redecker, 2017) and the Spanish Reference Framework for Digital Teaching Competence (INTEF, 2022).

Table 1. Dimensions and indicators of scientific dissemination.

Dimensions	Indicators	ID
Cognitive dimension: Understanding and synthesis of knowledge	Identifies reliable primary and secondary scientific sources (Bucchi & Trench, 2014)	Id.1
	Summarizes complex information without distorting findings (Kappel & Holmen, 2019)	Id.2
	Explain disciplinary concepts using accessible analogies or examples (Huang & Xia, 2024; Kappel & Holmen, 2019)	Id.3
	Contextualizes content in social or everyday problems (Bucchi & Trench, 2014)	Id.4
Communicative dimension: Oral and written expression	Adapt scientific discourse to a non-specialist audience (Dahlstrom, 2014).	Id.5
	Use clear language, avoiding unnecessary technical terms (Baram-Tsabari & Lewenstein, 2017).	Id.6
	Organize messages into narratives with a beginning, middle, and end (Dahlstrom, 2014).	Id.7
	Demonstrate fluency, confidence, and clarity in oral presentations (Al-Khresheh, 2024).	Id.8
Media and digital dimension	Select the most appropriate medium (text, video, infographic, podcast) for the message and audience (Allgaier, 2019).	Id.9
	Use data visualization resources to simplify information (Liyanage & Andrade, 2012).	Id.10
	Apply graphic and narrative design principles in digital environments (Allgaier, 2019).	Id.11

Content validity was established through expert judgment involving 15 PhD specialists in Education, complemented by a pilot test with students sharing similar characteristics to the study sample. Construct validity was confirmed through exploratory factor analysis (EFA), and the instrument demonstrated satisfactory internal consistency ($\alpha = 0.80$; $\omega = 0.86$).

In the qualitative phase, two complementary instruments were employed. The first was a structured pedagogical observation guide, designed according to the criteria proposed by Ruiz-Olabuénaga (2012) to systematically record students' behaviors during practical activities. Content validity was ensured through review by three specialists in Education, and minor adjustments were incorporated prior to implementation.

The second instrument consisted of a semi-structured focus group protocol, designed to elicit participants' perceptions of the scientific dissemination process. The protocol was reviewed by experts, piloted with a non-sample group, and subsequently applied to the full participant cohort across three sessions involving 10 to 13 students each. Illustrative guiding questions included: "*How did project-based design and experiential learning contribute to developing your scientific dissemination skills?*" and "*How did you feel during the learning process?*"

All sessions were audio-recorded, transcribed verbatim, and independently coded by two researchers. Discrepancies were resolved by consensus, ensuring inter-rater reliability and analytical rigor.

It should be noted that the questionnaire assesses students' perceived competence rather than direct performance-based ability. This approach aligns with competence-assessment traditions in higher education, where self-perceived ability is considered an indicator of metacognitive awareness, confidence, and understanding of the processes involved in communicating scientific content. The qualitative phase, based on structured observations and focus groups, was included to complement this limitation by exploring how students enacted and articulated their communication strategies in authentic dissemination tasks.

2.5. Procedure

The research was conducted during the 2024–2025 academic year in two initial teacher training courses: Guidance and Tutoring for Students and Families (Early Childhood Education Degree, n = 36) and Methods of Innovation and Diagnosis in Education (Primary Education Degree, n = 43). Each course comprised 60 h of classroom instruction and 90 h of supervised independent work. The intervention lasted 15 weeks per cohort (September–January and February–June) and was structured into three successive phases: diagnostic, development, and evaluation.

To ensure that the intervention explicitly targeted the development of science communication competence, the PBL and Experiential Learning sequence was contextualised around the creation of scientific dissemination products for non-specialist audiences. Students selected a scientific topic, identified an intended audience, and analysed reliable scientific sources in order to translate technical information into accessible explanations. They planned and produced multimodal dissemination outputs such as videos, infographics, podcasts, or illustrated texts, applying principles of clarity, narrative coherence, audience adaptation, ethical communication, and responsible use of evidence. Iterative feedback sessions focused specifically on the effectiveness of students' communication strategies, while structured reflection cycles based on Kolb's model guided them to evaluate and refine how they mediated scientific knowledge. These actions ensured that the intervention was intentionally oriented toward strengthening science communication competence rather than functioning as a general PBL–EL experience.

In the initial phase, a diagnostic questionnaire assessing science communication competence was administered to establish a baseline across the cognitive, communicative, media–digital, and ethical–social dimensions (Figure 1).

The development phase, constituting the core of the intervention, was grounded in the principles of PBL and EL. Activities were designed to foster the progressive development of science communication competence through authentic experiences, collaboration, and critical reflection. In the Early Childhood Education course, students developed a Tutorial Action Plan focused on communication with families and students. In the Primary Education course, students prepared a literature review and an innovative educational proposal addressing a real educational challenge. Throughout the process, diverse strategies were integrated:

(a) The use of academic and digital resources (Scopus, Web of Science, UVaDoc, ResearchGate);
(b) The educational application of generative artificial intelligence (ChatGPT v3) to support content synthesis and reformulation;
(c) Multimodal production through infographics, summaries, and audiovisual capsules;
(d) Critical and ethical reflection on the products developed (Table 2).

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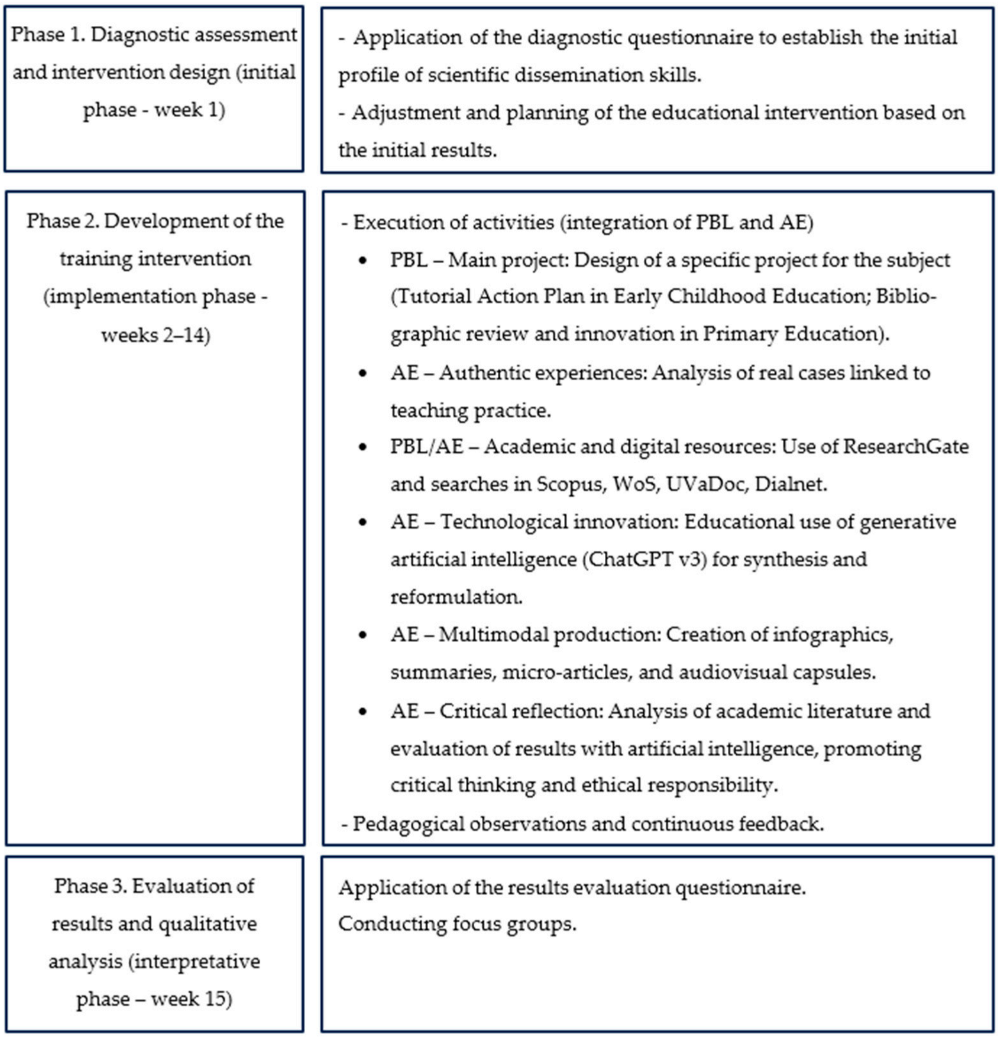

Figure 1. General procedure of the educational intervention.

Continuous structured pedagogical observations were conducted to record student performance and provide individualised feedback aimed at reinforcing strengths and addressing areas for improvement.

In the final phase, a post-intervention questionnaire was administered to assess the evolution of students' competencies. Subsequently, the qualitative phase was developed to deepen the interpretation of the quantitative findings. Three focus groups, each comprising 10–13 participants selected from the intervention cohort, were organised at the end of the teaching experience. Sessions were audio-recorded, fully transcribed, and analysed through thematic coding (Braun & Clarke, 2006) until conceptual saturation was achieved. The focus groups were not intended to assess performance directly, but to explore students' reflections on the strategies, criteria, and decisions they used while producing dissemination products, thereby providing insight into key metacognitive and strategic components of science communication competence.

Finally, the quantitative and qualitative results were jointly interpreted to integrate patterns of change with students' perceptions and experiences.

Continuous formative assessment was implemented throughout the intervention through structured pedagogical observations, which made it possible to monitor students' progress and adjust learning activities as needed. Individualized feedback was also provided to reinforce strengths—such as the accurate use of sources and the clarity of explanations—and to identify areas for improvement, particularly in the critical appraisal of information and the adaptation of scientific content for non-specialist audiences. This formative process supported the development of science communication competence by guiding students to make progressively more informed, coherent, and ethically responsible dissemination decisions.

Table 2. Innovative teaching strategies and their contribution to the development of scientific dissemination skills.

Teaching Strategies	Brief Description	Contribution to the Development of Scientific Communication Skills
PBL	Design and implementation of projects related to educational or social problems.	Promotes the integration of knowledge (cognitive dimension) and the communication of results in accessible formats (communicative dimension).
AE	Action-reflection cycle (Kolb) applied to scientific dissemination products.	Develops practical transferability and encourages critical reflection on scientific communication (ethical and social dimension).
ABP/AE—Academic and digital resources	Search for relevant information	Develops the capacity for analysis and synthesis (cognitive dimension) and the recognition of relevant bibliographic sources (ethical and social dimension)
AE—Scientific narratives and storytelling	Use of metaphors, analogies, and stories to explain complex concepts.	Improves clarity of presentation and adaptation of discourse to diverse audiences (communicative dimension).
AE—Debates	Simulation of public spaces for scientific communication.	Strengthens argumentation and dialogic interaction (communicative dimension).
AE—Critical and educational use of Generative Artificial Intelligence (e.g., ChatGPT)	Supports information synthesis, writing, and content reformulation.	Promotes critical digital literacy (media and digital dimension) and ethical evaluation of technology (ethical and social dimension).
AE—Authentic and peer assessment	Presentation of products in real contexts and peer assessment.	Develops self-regulation, critical awareness of one's own communication, and continuous improvement (all dimensions).
AE—Multimodal production	Creation of posters, infographics, podcasts, short videos, or micro- articles.	Enhances oral and written expression (communicative dimension) and the creative use of digital tools (media and digital dimension)

2.6. Data Analysis

Data analysis followed a mixed sequential integration approach, combining quantitative and qualitative procedures to enhance the credibility and interpretive validity of the findings through the convergence of evidence.

In the quantitative phase, descriptive and inferential statistical analyses were conducted. The normality of the distributions was examined using the Shapiro–Wilk test, after which paired-sample t-tests were applied to compare pretest and posttest scores. The effect size was estimated using Pearson's r coefficient and interpreted according to the criteria established by Cohen et al. (2002).

In the qualitative phase, data were analyzed through thematic content analysis, following the procedures proposed by Braun and Clarke (2006) and Strauss and Corbin (1995) for open and axial coding. Coding was conducted in two stages, based on the transcripts of focus groups and pedagogical observations, and organized into categories aligned with the theoretical model of scientific dissemination competencies. Two researchers independently performed the coding and resolved discrepancies through consensus, ensuring inter-coder reliability. The development of a codebook further ensured the transparency and traceability of the analytical process.

The results were integrated through a sequential connection strategy (QUAN→QUAL), whereby the quantitative findings guided the subsequent qualitative interpretation, enabling a dialogue between data sets. This articulation facilitated corroboration and interpretive convergence, allowing the results to be contrasted and expanded from complementary methodological perspectives. Moreover, the consistency of effects across the two participating cohorts—Early Childhood Education and Primary Education—was analyzed, and the findings were interpreted in light of the conceptual frameworks of Project-Based Learning (PBL) and Kolb's (1984) Experiential Learning Cycle.

This procedure—consistent with current recommendations in mixed-methods research (Creswell & Plano Clark, 2018; Hernández Sampieri et al., 2018; Fetters et al., 2013)—strengthened the internal validity and interpretive credibility of the study, providing a deeper and contextualized understanding of the impact of the teaching proposal on the development of scientific dissemination skills in initial teacher education.

3. Results

3.1. Quantitative Phase

Shapiro–Wilk tests of normality were applied to the differences between the initial and final assessments, revealing significant deviations from normality in some cases ($p < 0.05$). However, since the t-test for related samples is considered robust to minor violations of normality in moderate sample sizes (n = 36 and n = 43), it was retained as the primary analytical procedure. To strengthen the robustness of the findings, the analysis was complemented by the nonparametric Wilcoxon signed-rank test (see Table 3).

Table 3. Comparison of initial and final assessment results in scientific dissemination skills (Group 1 and Group 2).

Group	Dimension	Initial M (SD)	Final M (SD)	t (gl)	*p*	95% CI Δ	r
Group 1 (n = 36)	Cognitive	1.65 (0.74)	3.35 (0.66)	11.65 (35)	0.000	[1.41, 2.00]	0.89
	Communicative	1.29 (0.37)	3.61 (0.82)	13.19 (35)	0.000	[1.96, 2.68]	0.91
	Media–digital	1.36 (0.41)	3.54 (0.96)	13.02 (35)	0.000	[1.84, 2.52]	0.91
	Social ethics	1.53 (0.49)	3.51 (0.84)	11.78 (35)	0.000	[1.63, 2.31]	0.89
Group 2 (n = 43)	Cognitive	1.28 (0.56)	3.48 (0.59)	19.09 (42)	0.000	[1.97, 2.43]	0.95
	Communicative	1.10 (0.25)	3.76 (0.56)	28.01 (42)	0.000	[2.47, 2.85]	0.97
	Media–digital	1.19 (0.37)	3.73 (0.64)	23.19 (42)	0.000	[2.31, 2.76]	0.96
	Social ethics	1.43 (0.43)	3.63 (0.65)	16.95 (42)	0.000	[1.94, 2.47]	0.93

Note. M = mean; SD = standard deviation; t (gl) = t-statistic with degrees of freedom; *p* = significance value; 95% CI Δ = 95% confidence interval of the difference in means; r = effect size.

The results revealed a consistent pattern of improvement across all dimensions of scientific communication competence. In both cohorts, the differences between the initial and final measurements were statistically significant ($p < 0.001$), with very large effect sizes (Group 1: r = 0.89–0.91; Group 2: r = 0.93–0.97). Group 2 obtained slightly higher final means (3.73–3.76) compared to Group 1 (3.35–3.61), showing particularly strong effects in the communicative (r = 0.97) and media–digital (r = 0.96) dimensions.

Inferential analyses confirmed statistically significant gains in the four evaluated dimensions ($p < 0.001$), providing evidence of a substantial and consistent enhancement of scientific dissemination skills following the intervention. The effect sizes obtained indicate a large practical impact in both groups, especially within the communicative and media–digital domains.

As shown in Figure 2, the initial scores reflected low levels in all dimensions (M = 1.1–1.6 out of 5), particularly in the cognitive and communicative dimensions. This homogeneity suggests that, regardless of degree program or subject area, participants began with notable deficiencies in scientific communication skills. Within these dimensions, the indicators with the lowest initial performance corresponded to the identification of reliable sources (ID1) and the adaptation of discourse for non-specialized audiences (ID5).

Figure 2. Standard deviation of each group (initial vs. result).

After the intervention, scores increased to medium-to-high levels (M = 3.3–3.8), representing an average improvement of at least two points compared with the initial values.

In the cognitive dimension, both groups demonstrated significant progress in conceptual understanding and knowledge mediation. The indicator ID3 (explaining concepts using analogies) showed the greatest gains (r = 0.93 in G1; r = 0.98 in G2). In contrast, ID1 (identifying reliable sources) exhibited a more moderate increase (from 1.7 to 2.7 in G1; from 1.3 to 2.9 in G2).

The communicative dimension yielded the largest effect sizes, particularly in Group 2 (r = 0.97). Indicators ID5 (adapting discourse to non-specialized audiences) and ID8 (clarity in oral presentations) stood out, both showing remarkable improvements ($r \geq 0.92$).

The media–digital dimension also displayed very large improvements in both cohorts (r = 0.91 in G1; r = 0.96 in G2). The most strengthened indicators were ID9 (selection of appropriate media) and ID10 (use of data visualization).

Within the ethical and social dimension, which began with relatively higher pretest scores ($M \approx 1.5$), substantial progress was observed. Indicators ID13 (accuracy of information conveyed) and ID14 (recognizing the limits of evidence) showed high effect sizes ($r \approx$ 0.92–0.96). Conversely, ID15 (promoting critical thinking) and ID16 (considering social, cultural, and political impacts) presented slightly lower yet still large effects ($r \approx 0.81$ in G1; r = 0.84–0.86 in G2).

Overall, the data analysis across both samples confirmed low initial levels in all dimensions (M = 1.1–1.6), followed by significant post-intervention increases to medium-high levels (M = 3.3–3.8). The overall effect sizes were very large (Group 1: r = 0.89–0.91; Group 2: r = 0.93–0.97). These findings demonstrate a substantial and sustained improvement in scientific communication competence as a result of the teaching intervention, with large effects across all evaluated dimensions.

3.2. Qualitative Phase

The focus groups conducted in Early Childhood Education (Group 1, three subgroups) and Primary Education (Group 2, four subgroups) provided explanatory nuances that deepened and broadened the interpretation of the quantitative results, revealing how students experienced the teaching approach based on Problem-Based Learning (PBL) and Kolb's Experiential Learning (AE) cycle.

Participants consistently described the intervention as a departure from traditional methodologies. During the initial weeks, this novelty generated uncertainty and tension, which gradually transformed into motivation and pride in their achievements. One student from subgroup 2 of Group 1 reflected: "*At first it was stressful—we didn't know if we could produce a quality product—but in the end, we felt proud because what we wanted to communicate was understood*."

Similarly, a participant from Group 2 noted: "*It was a different way of learning, more practical and motivating than the usual classes*."

These perceptions help explain the quantitative increases in motivation and perceived usefulness of the proposal, establishing a direct link between the learning experience and the improvement of communicative competence.

The testimonies revealed advances across the four evaluated dimensions:

- Cognitive dimension. Students emphasized the use of analogies as a key strategy for understanding and communicating complex concepts. A member of Group 1 stated, "*Using analogies was the most useful; it helped us think differently*," while Group 2 added, "*Analogies helped me reflect on how we learn ourselves*." These insights support the quantitative improvement in ID3 and underscore the connection between metacognitive reflection and experiential learning.
- Communicative dimension. Participants highlighted the importance of speaking clearly and adapting discourse to different audiences. In Group 1, a student recalled, "*When we presented to families, we realized we had to use fewer technical terms*." In Group 2, another noted, "*The project helped us lose our fear of public speaking; now we feel more confident explaining complicated topics*." These accounts complement the quantitative gains in ID5 and ID8, clarifying why this dimension recorded the largest effect sizes—situated practice promoted self-assessment and communicative improvement.
- Media–digital dimension. Students recognized the usefulness of technological resources in enhancing message clarity. One participant commented, "*We had never used digital tools so much; it was a discovery to learn how to choose what best conveyed the message*." Group 2 added, "*A good graphic or clear image is worth more than a long explanation*." These testimonies align with the improvements in ID9 and ID10, demonstrating how digital literacy strengthened communicative effectiveness.
- Ethical and social dimensions. Students developed an awareness of the responsibility inherent in communicating scientific information accurately. A Group 1 student reflected, "*We realized how important it is to convey information well so as not to confuse families.*" A participant from Group 2 added, "*We saw that communicating science also has social consequences; speaking inaccurately can lead to misinformation*." These reflections support the quantitative progress in ID13 and ID14, while also highlighting persistent challenges in ID1 (source literacy) and ID16 (consideration of social impacts), which were less developed in the questionnaires.

The emerging patterns revealed both convergences and tensions with the statistical findings. While the questionnaires documented generalized improvement, the qualitative evidence clarified the processes underlying these changes:

- Motivation stemmed from overcoming initial uncertainty.
- Communicative clarity emerged from authentic interaction with real audiences.
- The ethical dimension deepened through awareness of the risks of misinformation.

Thus, the focus groups not only validated the quantitative results but also explained, nuanced, and expanded them, highlighting both strengths (ID3, ID5, ID8, ID13) and areas for improvement (ID1, ID16).

The thematic analysis (Braun & Clarke, 2006) made it possible to trace these perceptions, coding them into categories aligned with the dimensions and indicators of scientific communication competence. This analytic process enabled the articulation of qualitative experiences with the quantitative outcomes, yielding richer interpretive insights into the observed changes.

Across both cohorts, students expressed positive emotions—pride, confidence, and creativity—which acted as catalysts for experiential learning, reinforcing the pedagogical logic of PBL and Kolb's AE cycle.

Table 4 summarizes this WHAT→WHY integration, presenting for each dimension the relationships among the questionnaire results, students' perceptions, the degree of integration (strong, moderate, or complementary convergence), and the theoretical anchoring in PBL and Kolb's Experiential Learning framework. The themes presented in Table 4 represent students' perceptions of their learning processes, specifically how they understood, justified, and reflected on the strategies they employed to communicate scientific knowledge throughout the intervention.

Table 4. Thematic analysis of focus groups.

Initial Code	Core Theme	Emerging Theme	Dimension/Indicators	Interpretative Synthesis
Difficulty in distinguishing the validity of information	Basic scientific literacy	Cognitive and reflective strengthening	Cognitive—ID1	The need to discern the reliability of sources and
Use of teaching resources for comprehension	Conceptual mediation strategies	Cognitive and reflective strengthening	Cognitive—ID3, ID4	Analogies facilitate deep understanding and communication of complex concepts.
Adaptation of discourse	Clarity and communicative confidence	Communicative consolidation	Communicative—ID5, ID6, ID7	Effective communication strategies and adaptation to diverse audiences are consolidated.
Overcoming stage fright	Development of oral confidence	Communication consolidation	Communication—ID8	Practice in real contexts strengthen self-confidence and fluency in presentation.
Exploration and selection of media	Applied digital competence	Media–digital literacy	Media–digital—ID9, ID10, ID11	Reflective use of digital tools increase communication effectiveness.
Responsibility in messaging	Ethics of dissemination	Ethical and social awareness	Social ethics—ID13, ID14	Ethical awareness regarding the rigorous trans- mission of information is promoted.
Social and cultural implications	Reflection on social effects	Ethical and social awareness	Social ethics—ID15, ID16	Sensitivity to social and the cultural impact of scientific dissemination is developed.
Positive experience of achievement	Affective-motivational transformation	Emotions as catalysts for learning	Crosscutting (all dimensions)	Positive emotions reinforce motivation and experiential learning.

The focus groups provided an integrated qualitative explanation of the quantitative results, illustrating how the teaching proposal not only fostered the acquisition of technical skills in scientific dissemination but also cultivated an awareness of the social responsibility inherent in communicating with rigor, clarity, and an educational purpose.

This integration of QUANTITATIVE→QUALITATIVE evidence demonstrates that the learning outcomes identified in the questionnaires were underpinned by collaborative dynamics, critical reflection, and experiential learning processes. Together, these findings reinforce the interpretive validity of the study and highlight its pedagogical relevance for initial teacher education in contemporary contexts of scientific literacy.

3.3. Integration of the Results Obtained

The integration of quantitative and qualitative findings was conducted through a sequential process (QUANTITATIVE→QUALITATIVE), grounded in the complementary integration of methods, data, and theory. This approach followed the guidelines for mixed-methods research in education (Creswell & Plano Clark, 2018; Fetters et al., 2013; Hernández Sampieri et al., 2018; Tashakkori & Teddlie, 2010).

Table 5, presented as a joint display, summarizes in parallel the correspondence between the statistical results, students' perceptions, and their theoretical interpretation, providing a visual synthesis of the convergence and complementarity between both strands of evidence.

Table 5. Triangulation of methods, data, and theory.

Dimension	Quantitative	Qualitative	Integration	Theoretical Anchoring
Cognitive (ID1–ID4)	Significant improvement (M pre = 1.3–1.7 → M post = 2.7–3.5; $p < 0.001$; r = 0.89–0.95). Most progress: ID3 (analogies). Moderate improvement: ID1 (reliable sources).	"*The exercise of using analogies was the most useful; it helped us think differently*" (G1, Sub3). "*Using analogies helped me reflect on how we learn*" (G2, Sub4). Difficulties persist: "*We had a hard time finding reliable sources*" (G1, Sub1).	Strong convergence in ID3; moderate convergence in ID1.	PBL requires explaining to others (cognitive mediation). AE: concrete experience + reflection → conceptualization.
Communicative (ID5–ID8)	More intense growth (M pre = 1.1–1.3 → M post = 3.5–3.8; $p < 0.001$; r = 0.91–0.97). ID5 (discourse adaptation) and ID8 (oral clarity) stood out.	"*We had to speak more clearly and use fewer technical terms*" (G1, Sub1). "*The project helped us overcome our fear of public speaking*" (G2, Sub1). "*Organizing our ideas forced us to speak with more confidence*" (G1, Sub2).	Very strong convergence.	PBL: public product and real audiences. AE: rehearsal–feedback–rehearsal → communicative confidence.
Media and digital (ID9–ID12)	Very large advances (M pre = 1.2–1.4 → M post = 3.5–3.7; $p < 0.001$; r = 0.91–0.96). ID9 (media selection) and ID10 (data visualization) stood out.	"*We had never used digital tools so much before; we learned to choose what best conveyed the message*" (G1, Sub2). "*A good graphic is worth more than a long ex- planation*" (G2, Sub2). "*Digital was a challenge, but we learned to choose the most appropriate format*" (G2, Sub4).	Strong convergence.	PBL: requires multimodal production. AE: active experimentation with resources→ reflection and adjustment.
Ethical and social (ID13–ID16)	Significant improvement (M pre ≈ 1.5 → M post ≈ 3.6; $p < 0.001$; r = 0.84–0.96). Greatest progress: ID13 (informative fidelity) and ID14 (limits of evidence). Moderate progress: ID15–ID16.	"*We realized how important it is to convey information well so as not to con- fuse families*" (G1, Sub3). "*Science communication has social consequences; you can't communicate without rigor*" (G2, Sub3). "We still find it difficult to assess the social impacts of communication" (G2, Sub3)	Strong convergence in ID13–14; moderate convergence in ID15–16.	ABP: outreach with community impact. EA: critical reflection on ethical implications.

The first integrative question explored how students' perceptions explain and complement the quantitative improvements observed in scientific communication skills. A strong convergence was identified between the two strands in the cognitive, communicative, and media–digital dimensions.

In the cognitive dimension, the improvement in the ability to explain concepts using analogies (ID3) coincided with testimonies emphasizing their usefulness in promoting understanding—"*Using analogies was the most useful; it helped us think differently.*" This correspondence leads to Meta-inference 1: the systematic use of analogies functions as a pedagogical mechanism that facilitates the transition from concrete experience to abstract conceptualization, consistent with Kolb's Experiential Learning Cycle.

The communicative dimension recorded the most pronounced effects (r up to 0.97 in Group 2), supported by qualitative reports of reduced stage fright and greater clarity in oral expression. This alignment supports Meta-inference 2: practice in front of authentic audiences enhances communicative competence in initial teacher training by fostering self-efficacy and reflective awareness.

In the media–digital dimension, improvements in media selection (ID9) and data visualization (ID10) were linked to reflections on communicative efficiency—"*A good graphic is worth more than a long explanation.*" This relationship underpins Meta-inference 3: digital literacy transcends technical mastery, fostering critical decision-making regarding the most effective media for scientific dissemination.

The second integrative question examined the pedagogical mechanisms associated with PBL and AE. The findings indicate that PBL acted as a catalyst for situated learning by engaging students in authentic, problem-centered tasks, while AE accounted for the progression from initial uncertainty to critical reflection and active experimentation. This integration suggests that progress extends beyond statistical improvement, reflecting deep learning processes mediated by practice, collaboration, and reflection.

The third integrative question addressed the implications for teacher education. In the ethical and social dimension, significant gains were found in information fidelity (ID13–ID14) and in awareness of the responsibility to communicate accurately, although persistent limitations remained in information literacy (ID1) and in the consideration of social impacts (ID16). From this emerges Meta-inference 4: the ethical development of scientific dissemination requires pedagogical scaffolding that strengthens critical reading, media literacy, and communicative responsibility.

Taken together, Table 5 and the derived meta-inferences demonstrate a substantive integration of results, where quantitative and qualitative approaches not only complement each other but also generate explanatory knowledge about the pedagogical mechanisms underpinning the development of scientific dissemination skills. The study is thus consolidated as a sequential explanatory mixed-methods design (QUANTITATIVE→QUALITATIVE) that provides both empirical evidence of effectiveness and a deep interpretive understanding of the training processes involved, thereby strengthening validity, internal consistency, and transferability to other educational contexts.

The integration of results corroborated the consistency of findings, broadened their interpretive scope, and reinforced the credibility and contextual relevance of the knowledge generated.

4. Discussion

The diagnostic phase results revealed low initial levels across all dimensions of scientific communication competence (M = 1.1–1.6). From a pedagogical perspective, this finding indicates that students, even at advanced stages of their university studies, showed notable limitations in identifying reliable sources (ID1), adapting discourse for non-specialized audiences (ID5), and considering the social implications of knowledge (ID16). Interpreted through Kolb's Experiential Learning Model, participants appeared to remain in a phase of fragmented concrete experience, not yet having reached the stages of reflective observation and abstract conceptualization necessary for the reorganization of knowledge and the development of critical understanding.

These initial shortcomings were corroborated in the qualitative phase, where the focus groups revealed convergent perceptions: "*At first, we had a hard time finding reliable sources*" (G1, Sub1) and "*I didn't think I could explain a scientific concept*" (G1, Sub3). Such testimonies underscore the value of Problem-Based Learning (PBL) as a framework for promoting authentic, socially meaningful learning capable of compensating for the weaknesses detected in the initial diagnosis.

Following the implementation of the teaching proposal, data from the development phase reflected consistent and statistically significant progress in the four competency dimensions (M = 3.3–3.8; $r \geq$ 0.89–0.97). When interpreted alongside the qualitative results, this evidence demonstrates the internalization of new ways of understanding, communicating, and applying scientific knowledge.

In the cognitive dimension, a marked strengthening was observed in the ability to explain concepts through analogies (ID3)—a strategy explicitly valued by participants: "*The exercise of using analogies was the most useful; it helped us think differently*" (G1, Sub3); "*Using analogies helped me reflect on how we learn ourselves*" (G2, Sub4).

In the communicative dimension, the indicators of discourse adaptation (ID5) and clarity in oral presentations (ID8) showed remarkable progress, closely linked to processes of self-efficacy and confidence: "*We had to speak more clearly and use fewer technical terms*" (G1, Sub1); "*The project helped me overcome my fear of public speaking*" (G2, Sub1).

The media–digital dimension also exhibited significant improvement, particularly in media selection (ID9) and data visualization (ID10). These quantitative findings were complemented by student reflections on the communicative power of digital resources: "*We had never used digital tools so much before; we learned to choose what best conveyed the message*" (G1, Sub2); "*A good graph is worth more than a long explanation*" (G2, Sub2).

Finally, the ethical and social dimension revealed substantial progress in the accuracy of information conveyed (ID13) and in the recognition of the limits of evidence (ID14). The focus group discussions reflected a heightened awareness of the social responsibility inherent in rigorous dissemination: "*We realized that disseminating science also has social consequences; you can't communicate without rigor*" (G2, Sub3). Nevertheless, the integration of both methodological strands revealed that identifying reliable sources (ID1) and considering social impacts (ID16) remain areas of lesser development, suggesting the need for sustained pedagogical support aimed at consolidating critical and slow-maturing skills.

4.1. Interpretation and Pedagogical Integration of the Results

The integration of results confirms the internal coherence of the didactic design and its methodological soundness within a sequential mixed-methods approach. In this sense, PBL functioned as a structural bridge between theory and practice, connecting learning with real-world problems and authentic audiences, while Kolb's AE cycle provided the explanatory framework for the transformative process observed among students.

The progression identified—from initial uncertainty to the critical appropriation of scientific dissemination—can be interpreted as a transition through the phases of Kolb's experiential cycle: concrete experience (development of authentic products), reflective observation (analysis of one's own difficulties), abstract conceptualization (identification of effective communication strategies), and active experimentation (refinement and improvement of the developed products). This trajectory indicates that learning extended beyond the acquisition of technical skills, encompassing a cognitive and attitudinal reconstruction oriented toward communicating knowledge with clarity, rigor, and social purpose.

Students' reported emotions of pride, confidence, and motivation—for instance, "*When we saw the final result, we felt proud because what we wanted to communicate was understood*" (G1, Sub2)—reinforce the interpretation that concrete experience and active experimentation evolved into reflection and critical conceptualization, consistent with the logic of Kolb's model. Thus, positive emotions acted as affective mediators of experiential learning, fostering cognitive engagement and meaningful knowledge retention.

The consistency between quantitative and qualitative findings across two cohorts—Early Childhood Education and Primary Education—strengthens the internal validity and transferability of the proposed model. The evidence demonstrates that the teaching approach not only led to measurable improvements in scientific communication competencies but also generated a transformative shift in how future teachers approach, interpret, and disseminate scientific knowledge. Overall, participants evolved from being recipients of information to becoming active mediators of knowledge, capable of interpreting, adapting, and communicating science from a critical, ethical, and socially responsible perspective.

4.2. Integration of Findings with the Literature on Active and Experiential Methodologies

The findings of this study are clearly aligned with the international literature that underscores the transformative potential of active methodologies in higher education. Numerous studies have shown that AE and PBL foster deep understanding, affective engagement, and the development of cross-cutting competencies in complex educational contexts.

In particular, Kolano and Sanczyk (2022) demonstrate that narrative and digital learning experiences generate sustainable attitudinal change, a phenomenon consistent with the trust, responsibility, and self-regulation expressed by participants in this study. Similarly, the works of Bennett et al. (2016) and Tinkler et al. (2019) reveal that critical service-learning and community engagement projects strengthen social awareness, professional identity, and civic commitment—dimensions also evidenced here in the ethical–social advances (ID13–ID14) and in students' reflection on the social impact of scientific communication (ID16).

Likewise, Zocher and Hougham (2020) confirm that linking academic content to real-world problems promotes critical reflection and the contextualization of knowledge, findings that resonate with the improvements observed in conceptual mediation (ID4) and in the understanding of dissemination as a situated social practice. From this perspective, the present study not only corroborates existing research but also extends it by showing how the systematic integration of PBL and AE operates synergistically to generate meaningful learning in initial teacher education.

Furthermore, recent studies focused on PBL (e.g., Castillo-Salvatierra et al., 2025) support the idea that designing and developing authentic projects enhances communication and media–digital skills, a pattern replicated in this study's indicators ID5, ID8, ID9, and ID10. Likewise, Beissembayeva et al. (2025) emphasize that critical thinking, digital literacy, and scientific communication constitute essential pillars of contemporary teacher education—core components that this proposal addresses in an integrated and coherent manner.

Finally, Guaya et al. (2025) show that incorporating social networks and digital environments into educational projects enhances students' ability to select, produce, and disseminate scientific information responsibly, a tendency mirrored in the significant advances in media and digital literacy observed in this research.

Taken together, the convergence between empirical results and theoretical evidence reinforces the external validity of the proposed model. The integration of PBL and AE not only enhances academic performance and self-perceived competence but also transforms the relationship that future teachers establish with scientific knowledge, fostering an ethical, communicative, and technologically critical understanding of science dissemination in contemporary society.

4.3. Educational Implications of the Study

The findings of this study have significant implications for higher education, particularly in the field of initial teacher education. First, the results confirm that active methodologies such as PBL and Kolb's Experiential Learning constitute effective pedagogical frameworks for the development of transversal competencies, specifically those related to scientific communication and dissemination. The progression from low initial levels to medium-high performance across the four dimensions of competence demonstrates that universities can go beyond the transmission of disciplinary knowledge to also foster the communicative, digital, and ethical skills required for responsible teaching practice.

Second, the implemented teaching approach illustrates how PBL fosters situated and meaningful learning by engaging future teachers in authentic problem-solving tasks and the creation of products for real audiences (families, students, and the wider educational community). This type of experience transforms traditional university instruction into a participatory learning environment, where knowledge is applied, communicated, and evaluated in context. Such dynamics enhance motivation, engagement, and commitment—key conditions for persistence and high-quality learning in teacher preparation.

Third, Kolb's experiential model offers a structural framework for understanding the training process experienced by the participants: concrete experience (creation of dissemination products), reflective observation (analysis of difficulties and learning), abstract conceptualization (formulation of communication and ethical strategies), and active experimentation (adjustment and improvement of outputs and presentations). Embedding this cycle in university curriculum design strengthens autonomy, self-regulation, and transferability of learning, ensuring that teacher education is both deep and transformative.

Finally, the educational experience described provides higher education institutions with a replicable and adaptable pedagogical model for diverse curricular contexts. In an era marked by information overload and digital misinformation, the ability to communicate science with rigor, clarity, and social awareness emerges as an essential professional competence for contemporary educators. Integrating PBL and AE into university teaching not only optimizes knowledge construction and transfer but also promotes a critical, ethical, and socially engaged education, preparing future teachers to act as cultural mediators between science and society.

4.4. Limitations of the Study

Despite its methodological coherence and internal consistency, this study presents certain limitations that should be considered when interpreting and transferring the findings.

First, although the sequential explanatory mixed design (QUANTITATIVE→QUAL ITATIVE) enabled the progressive integration of quantitative and qualitative results, it did not include random assignment of participants or the use of control groups, given the natural and contextualized nature of the educational settings involved. This circumstance prevents the establishment of strict causal relationships between the teaching proposal and the observed changes; however, it does allow for educational and theoretical inferences based on the consistency of the patterns detected across both cohorts.

Second, while the sample size was adequate for the statistical and interpretive analyses ($n = 36$ and $n = 43$), it limits the generalizability of the findings to other university contexts or teacher education programs. Nevertheless, the diversity of the degrees included and the consistency of the effects observed in two distinct training contexts reinforce the transferability of the model and suggest its potential applicability in comparable educational environments.

Third, qualitative data were collected through focus groups conducted after the intervention. Although these provided rich and complementary insights, they did not allow for a longitudinal assessment of the evolution of participants' perceptions throughout the process. Additionally, a degree of social desirability bias may have influenced responses,

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as students could have expressed more favorable opinions due to the academic nature of the project.

Finally, although all four dimensions of scientific communication competence showed significant improvement, the more complex indicators, particularly the identification of reliable sources (ID1) and the consideration of social impacts (ID16), remained at incipient levels. This finding suggests that such competencies require longer development periods, along with conceptual scaffolding and reflective support, to reach full consolidation.

Overall, these limitations do not undermine the validity of the study but rather delineate its interpretive scope and indicate directions for future research aimed at strengthening methodological integration, expanding sample diversity, and deepening longitudinal understanding of competency development in teacher education.

4.5. Areas for Future Work

Based on the results obtained, several lines of future research have been identified to consolidate and expand knowledge on scientific communication and dissemination training within the university setting.

First, it is proposed to replicate and extend this study to other degree programs and institutional contexts, incorporating larger samples and longitudinal designs that enable the observation of the evolution of scientific dissemination skills over time. This approach would facilitate a deeper understanding of how learning derived from PBL and AE becomes consolidated, as well as the sustainability of its effects on teaching practice in the medium and long term.

Second, further research should focus on the indicators that showed more moderate progress, particularly literacy in reliable sources (ID1) and the consideration of social impacts (ID16). Future studies could incorporate specific instructional strategies for critical thinking and media literacy, combined with the reflective use of emerging technologies, to reinforce these more complex and slow-developing components of competence.

Third, it is recommended to adapt and apply the proposed teaching model to continuing professional development for in-service teachers, in order to examine its relevance at different stages of professional growth. Such research would allow for an evaluation of the model's potential to promote scientific updating, effective communication, and social responsibility among educators in real classroom contexts.

Moreover, future work should integrate technological tools for digital performance analysis and objective metrics of media production, allowing for richer methodological triangulation and more robust empirical evidence regarding the quality, creativity, and impact of the dissemination products created by students.

In summary, these research directions contribute to advancing a teacher education model that organically integrates scientific, communicative, digital, and ethical competencies, thereby consolidating university social responsibility as the articulating axis of higher education in the 21st century.

5. Conclusions

This study provides empirical and theoretical evidence supporting the integration of PBL and Kolb's Experiential Learning as effective strategies for developing scientific dissemination skills in initial teacher education. Using a sequential explanatory mixed-methods approach (QUANTITATIVE→QUALITATIVE), the results reveal a significant and consistent alignment between quantitative and qualitative data, demonstrating not only measurable improvements in performance but also transformations in how students understand, communicate, and apply scientific knowledge.

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The findings indicate that future teachers can become active mediators between science and society when their training experiences promote reflection, situated practice, and ethical responsibility. The articulation of quantitative and qualitative phases enabled an understanding of how the observed progress is grounded in authentic learning processes, where engagement with real problems, experimentation with media resources, and collaborative work act as catalysts for competency development.

From a methodological perspective, the study highlights the value of mixed method designs in educational research, not merely as a combination of techniques but as an epistemological approach that facilitates the construction of comprehensive and contextually grounded knowledge about teacher training processes. By integrating data, perceptions, and theoretical foundations, this research achieves a deep understanding of the pedagogical impact of the implemented model, thereby strengthening the credibility, internal validity, and transferability of the results.

Finally, the study confirms that the development of scientific communication and dissemination skills constitutes a cornerstone of university social responsibility, as it equips teachers to communicate with rigor, clarity, and critical awareness in increasingly complex educational and social contexts. The proposed approach—replicable and adaptable to other disciplinary and institutional settings—contributes to the promotion of a more ethical, inclusive, and socially engaged higher education, committed to fostering scientific literacy and citizenship in the 21st century.

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Abbreviations

The following abbreviations are used in this manuscript:

PBL	Project-based learning
EL	Experiential Learning

References

Al-Khresheh, M. H. (2024). The role of presentation-based activities in enhancing speaking proficiency among Saudi EFL students: A quasi-experimental study. *Acta Psychologica*, *243*, 104159. [CrossRef]

Allgaier, J. (2019). Science and environmental communication on YouTube: Strategically distorted communications in online videos on climate change and climate engineering. *Frontiers in Communication*, *4*, 36. [CrossRef]

Ammar, M., Al-Thani, N. J., & Ahmad, Z. (2024). Role of pedagogical approaches in fostering innovation among K-12 students in STEM education. *Social Sciences & Humanities Open*, *9*, 100839. [CrossRef]

Ashcraft, L. E., Quinn, D. A., & Brownson, R. C. (2020). Strategies for effective dissemination of research to United States policymakers: A systematic review. *Implementation Science*, *15*, 89. [CrossRef] [PubMed]

Avila-Bront, L. G. (2025). Shifting Perspectives: A Community-Based Learning Science Outreach Course That Engages Undergraduate Metacognition through Midsemester Redesign. *Journal of Chemical Education*, *102*(4), 1436–1444. [CrossRef]

Baram-Tsabari, A., & Lewenstein, B. V. (2017). Science communication training: What are we trying to teach? *International Journal of Science Education Part B*, *7*(3), 285–300. [CrossRef]

Beissembayeva, S., Oshakbayeva, Z., Yerkibayeva, G., Babayeva, K., & Chakanova, S. (2025). Formation of key skills of the XXI century in the educational practice of a teacher. *International Journal of Evaluation and Research in Education*, *14*(4), 3125. [CrossRef]

Bennett, D., Sunderland, N., Bartleet, B.-L., & Power, A. (2016). Implementing and sustaining higher education service-learning initiatives. *Journal of Experiential Education*, *39*(2), 145–163. [CrossRef]

Besley, J. C., Dudo, A., & Yuan, S. (2017). Scientists' views about communication objectives. *Public Understanding of Science*, *27*(6), 708–730. [CrossRef] [PubMed]

Besley, J. C., Dudo, A., Yuan, S., & Lawrence, F. (2018). Understanding scientists' willingness to engage. *Science Communication*, *40*(5), 559–590. [CrossRef]

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. [CrossRef]

Brownell, S. E., Price, J. V., & Steinman, L. (2013). Science communication to the general public: Why we need to teach undergraduate and graduate students this skill as part of their formal scientific training. *Journal of Undergraduate Neuroscience Education*, *12*(1), E6–E10. [PubMed]

Bucchi, M., & Trench, B. (2014). *Routledge handbook of public communication of science and technology*. Routledge.

Bucchi, M., & Trench, B. (Eds.). (2021). *Routledge handbook of public communication of science and technology* (3rd ed.). Routledge.

Burns, T. W., O'Connor, D. J., & Stocklmayer, S. M. (2003). Science communication: A contemporary definition. *Public Understanding of Science*, *12*(2), 183–202. [CrossRef]

Castillo-Salvatierra, L., Cárdenas-Cobo, J., de la Fuente-Burdiles, C., & Vidal-Silva, C. (2025). Programming competencies in university students through game development. *Frontiers in Education*, *10*. [CrossRef]

Cohen, L., Manion, L., & Morrison, K. (2002). *Research methods in education* (5th ed.). RoutledgeFalmer. [CrossRef]

Collins-Nelsen, R., Koziarz, F., Levinson, B., Allard, E., Verkoeyen, S., & Raha, S. (2021). Social context and transferable skill development in experiential learning. *Innovations in Education and Teaching International*, *59*(4), 421–430. [CrossRef]

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications.

Dahlstrom, M. F. (2014). Using narratives and storytelling to communicate science with nonexpert audiences. *Proceedings of the National Academy of Sciences*, *111*(Suppl. S4), 13614–13620. [CrossRef]

Davis, L. S. (2014). Outreach activities by universities as a channel for science communication. In L. Tan Wee Hin, & R. Subramaniam (Eds.), *Communicating science to the public* (pp. 161–181). Springer. [CrossRef]

Davis, R., & D'Lima, D. (2020). Building capacity in dissemination and implementation science: A systematic review of the academic literature on teaching and training initiatives. *Implementation Science*, *15*(1), 97. [CrossRef]

Ferrés, J., & Piscitelli, A. (2012). Media literacy: Articulated proposal of dimensions and indicators. *Comunicar*, *19*(38), 75–82. [CrossRef]

Fetters, M. D., Curry, L. A., & Creswell, J. W. (2013). Achieving integration in mixed methods designs—Principles and practices. *Health Services Research*, *48*(6), 2134–2156. [CrossRef]

Flores Mejía, J. G., Gatica, B. V., & Vargas, M. G. B. (2024). Divulgación científica en Educación Primaria: Aplicación e innovación más allá del aula. *Revista Eureka Sobre Enseñanza y Divulgación de las Ciencias*, *21*(3). [CrossRef]

Fuentes-Cancell, D. R., Estrada-Molina, O., & Gutiérrez-Ortega, M. (2026). Teachers and science communication on social media: Development and initial validation of assessment instruments [Docentes y divulgación científica en redes sociales: Desarrollo y validación inicial de instrumentos de evaluación]. *RIED-Revista Iberoamericana de Educación a Distancia*, *29*(1), 133–159. [CrossRef]

Gioltzidou, G., Mitka, D., Gioltzidou, F., Chrysafis, T., Mylona, I., & Amanatidis, D. (2024). Adapting traditional media to the social media culture: A case study of Greece. *Journalism and Media*, *5*(2), 485–499. [CrossRef]

Guaya, D. E., Jaramillo-Fierro, X. V., Meneses, M. A., & Valarezo, E. (2025). Innovative chemical engineering education: Social media-enhanced project-based learning approaches. *Emerging Science Journal*, *8*, 358–378. [CrossRef]

Hernández Sampieri, R., Fernández Collado, C., & Baptista Lucio, M. P. (2018). *Research methodology: Quantitative, qualitative, and mixed methods* (7th ed.). McGraw-Hill.

Huang, Q., & Xia, S. (2024). Preparing learners for digitally mediated academic communication: Digital multimodal practice in students' knowledge dissemination videos. *Journal of English for Academic Purposes*, *71*, 101429. [CrossRef]

INTEF. (2022). *Reference framework for digital competence in teaching*. Ministry of Education and Professional Training.

Jamison, C. S. E., Fuher, J., Wang, A., & Huang-Saad, A. (2022). Experiential learning implementation in undergraduate engineering education: A systematic search and review. *European Journal of Engineering Education*, *47*(6), 1356–1379. [CrossRef]

Kankam, P. K., Acheampong, L. D., & Dei, D. J. (2024). Dissemination of scientific information through open access by research scientists in a developing country. *Heliyon*, *10*(7), e28605. [CrossRef]

Kappel, K., & Holmen, S. J. (2019). Why science communication, and does it work? A taxonomy of science communication aims and a survey of the empirical evidence. *Frontiers in Communication*, *4*, 55. [CrossRef]

Kavitha Devi, M., & Thendral, M. S. (2023). Using Kolb's Experiential Learning Theory to Improve Student Learning in Theory Course. *Journal of Engineering Education/Journal of Engineering Education Transformations/Journal of Engineering Education Transformation*, *37*(1), 70–81. [CrossRef]

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277. [CrossRef]

Kolano, L., & Sanczyk, A. (2022). Transforming preservice teacher perceptions of immigrant communities through digital storytelling. *Journal of Experiential Education*, *45*(1), 32–50. [CrossRef]

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice Hall.

Kong, S., Cheung, M. W., & Tsang, O. (2024). Developing an artificial intelligence literacy framework: Evaluation of a literacy course for senior secondary students using a project-based learning approach. *Computers and Education Artificial Intelligence*, *6*, 100214. [CrossRef]

Lavado-Anguera, S., Velasco-Quintana, P.-J., & Terrón-López, M.-J. (2024). Project-based learning (PBL) as an experiential pedagogical methodology in engineering education: A review of the literature. *Education Sciences*, *14*(6), 617. [CrossRef]

Leon Duarte, G. A., Contreras-Cázarez, C. R., & Meneses Jurado, E. C. (2025). Validación de un instrumento para evaluar la difusión, divulgación y uso de productos comunicativos científicos para la enseñanza-aprendizaje en educación superior [Validation of an instrument to evaluate the dissemination, outreach, and use of scientific communication products for teaching and learning in higher education]. *Norteamérica, Revista Académica del CISAN-UNAM*, *20*(1), 179–205. [CrossRef]

Liyanage, S., & Andrade, A. D. (2012). The changing role of research and education in New Zealand universities. *Science, Technology & Society*, *17*(2), 201–232. [CrossRef]

Lopez-Gonzalez, H., Sosa, L., Sánchez, L., & Faure-Carvallo, A. (2023). Media and information literacy and critical thinking. *Revista Latina de Comunicación Social*, *81*, 399–422. [CrossRef]

Maulida, A. S., Wahyudin, W., Turmudi, T., & Nurlaelah, E. (2024). The effect of experiential learning and directed instructions assisted by augmented reality on students' self-regulated learning. *Infinity Journal*, *13*(2), 553–568. [CrossRef]

Misbah, M., Hakam, A., Qamariah, N., Umar, F., Harto, M., & Muhammad, N. (2024). Project Based Learning (PjBL) Model in Science Learning: A Bibliometric Analysis. *E3S Web of Conferences*, *482*, 04031. [CrossRef]

Morris, T. H. (2019). Experiential learning—A systematic review and revision of Kolb's model. *Interactive Learning Environments*, *28*(8), 1064–1077. [CrossRef]

Nguyen, V., Tran, D. N., Tran, V. D., Trung, D., & Duong, T. H. (2025). Integrating local educational content into experiential activities for students of ethnic boarding schools in Vietnam. *Multidisciplinary Science Journal*, *7*(11), 2025501. [CrossRef]

O'Connor, S., McGilloway, S., Hickey, G., & Barwick, M. (2021). Disseminating early years research: An illustrative case study. *Journal of Children's Services*, *16*(1), 56–73. [CrossRef]

Redecker, C. (2017). *European framework for the digital competence of educators: DigCompEdu* (Y. Punie, Ed.). Publications Office of the European Union.

Reincke, C. M., Bredenoord, A. L., & Van Mil, M. H. (2020). From deficit to dialogue in science communication. *EMBO Reports*, *21*(9), e51278. [CrossRef]

Ruiz-Olabuénaga, J. (2012). *Qualitative research methodology* (5th ed.). University of Deusto.

Shivni, R., Cline, C., Newport, M., Yuan, S., & Bergan-Roller, H. E. (2021). Establishing a baseline of science communication skills in an undergraduate environmental science course. *International Journal of STEM Education*, *8*(1), 47. [CrossRef] [PubMed]

Singha, R., & Singha, S. (2024). Application of experiential, inquiry-based, problem-based, and project-based learning in sustainable education. In *Practice, progress, and proficiency in sustainability* (pp. 109–128). IGI Global Scientific Publishing. [CrossRef]

Stofer, K. A., & Wolfe, T. M. (2018). Investigating exemplary public engagement with science: Case study of extension faculty reveals preliminary professional development recommendations. *International Journal of Science Education Part B*, *8*(2), 150–163. [CrossRef]

Strauss, A., & Corbin, J. (1995). Grounded theory methodology: An overview. In N. K. Denzin, & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 273–285). Sage.

Su, K. (2024). The Challenge and Opportunities of STEM Learning Efficacy for Living Technology Through a Transdisciplinary Problem-Based Learning Activity. *Journal of Science Education and Technology*, *33*(4), 429–443. [CrossRef]

Tashakkori, A., & Teddlie, C. (2010). *Handbook of mixed methods in social & behavioral research* (2nd ed.). SAGE Publications.

Tembrevilla, G., Phillion, A., & Zeadin, M. (2023). Experiential learning in engineering education: A systematic literature review. *Journal of Engineering Education*, *113*(1), 195–218. [CrossRef]

Tetteh, E. K., Geng, E. H., & Huffman, M. D. (2023). Developing ethical standards for dissemination and implementation research: A roadmap for consensus and guidance. *Implementation Science Communications*, *4*(1), 132. [CrossRef] [PubMed]

Tillinghast, R. C., Appel, D. C., Winsor, C., & Mansouri, M. (2020, August 1). *STEM outreach: A literature review and definition*. The 9th IEEE Integrated STEM Education Conference (ISEC), Princeton, NJ, USA. [CrossRef]

Tinkler, A., Tinkler, B., Reyes, C., & Elkin, S. (2019). Critical service-learning: Learning through experience to advance teacher education. *Journal of Experiential Education*, *42*(1), 65–78. [CrossRef]

Toledo Morales, P., & Sánchez García, J. M. (2018). Aprendizaje basado en Proyectos: Una experiencia universitaria. *Profesorado Revista de Currículum y Formación del Profesorado*, *22*(2), 471–491. [CrossRef]

Uyen, B. P., Tong, D. H., & Lien, N. B. (2022). The Effectiveness of Experiential Learning in Teaching Arithmetic and Geometry in Sixth Grade. *Frontiers in Education*, *7*. [CrossRef]

Zocher, J. L., & Hougham, R. J. (2020). Implementing ecopedagogy as an experiential approach to decolonizing science education. *Journal of Experiential Education*, *43*(3), 232–247. [CrossRef]

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