Pedagogical Proposal for the Teaching of Natural Sciences through the Technological Mediation Course

Isabel C. Muñoz[1,*] and Karen P. Agudelo[2]

[1]Department of Educational Computing, Faculty of Education and Human Sciences, University of Córdoba, Montería, Colombia
[2]Department of Natural Sciences and Environmental Education, Faculty of Education and Human Sciences, University of Córdoba, Montería, Colombia
Email: icristina@correo.unicordoba.edu.co (I.C.M.); karenagudelo@correo.unicordoba.edu.co (K.P.A.)
*Corresponding author
Manuscript received July 23, 2025; revised August 11, 2025; accepted October 13, 2025; published April 13, 2026

***Abstract*—This study presents an innovative pedagogical proposal for teaching natural sciences through the Technological Mediation course in the undergraduate program at the University of Córdoba (Colombia). Using the Design Science Research Process, the project aimed to enhance students' digital and pedagogical skills by fostering the creation of narrative-based educational resources with Exelearning. The intervention, conducted with fifth-grade students at Colegio Juan XIII in Montería, led to improvements in pre-service teachers' technological competencies, instructional planning, and student engagement, as well as reading comprehension among primary students. The study highlights the effectiveness of Information and Communication Technologie (ICT) integration in fostering 21st-century skills and improving science education, emphasizing the value of digital storytelling and open-source tools in teacher training. However, the study's limitations include its implementation in a single institution and a relatively small sample size, which may affect the generalizability of the findings. Future research could address these limitations by including larger sample sizes and exploring the long-term impact of the intervention.**

***Keywords*—Information and Communication Technologie (ICT) integration, science education, digital narratives, technological mediation, design-based research, pedagogical innovation; teacher training**

I. Introduction

The integration of Information and Communication Technologies (ICTs) in education has been extensively discussed in academic literature [1–4]. Authors such as Bruner [1] and Gardner [3] have been foundational in the study of constructivist learning, highlighting how digital environments can enhance the understanding of scientific concepts. According to Gardner [3], the use of digital tools, such as digital narratives, can stimulate various forms of intelligence, allowing students to interact with content more flexibly and effectively.

In this regard, Prensky [5] has been a leading advocate for the idea of "digital natives", suggesting that the new generation has a different way of interacting with technology compared to "digital immigrants". This perspective is particularly relevant when considering the training of future teachers who must integrate ICTs into their pedagogical practices [2, 5, 6]. Cuban [7], on the other hand, has pointed out that despite the potential of ICTs, they are often underutilized in many educational contexts due to inadequate training and resistance to change in traditional pedagogical practices.

More recent studies, such as those by Haarala-Muhonen *et al.* [8] and Setiawan *et al.* [9], reinforce the need for more comprehensive training in the use of digital tools in education. These studies emphasize that teachers need not only to master technological tools but also to develop specific pedagogical skills that enable them to integrate these tools meaningfully into their teaching strategies. Moreover, Tamim *et al.* [10] conducted a comprehensive analysis of the effectiveness of ICTs in the classroom, concluding that their impact largely depends on the context in which they are implemented, something particularly true in Latin American settings, where socio-economic gaps may hinder access to quality technologies.

The use of digital narratives, such as those developed through platforms like eXeLearning, presents an innovative solution to address the limitations of traditional approaches to teaching natural sciences. Digital narratives have been widely supported by Jonassen *et al.* [11], who emphasize that active learning, powered by technological tools, can significantly improve conceptual understanding in complex subjects like science. In addition, Haarala-Muhonen *et al.* [8] highlight the effectiveness of these tools in fostering more personalized and participatory learning environments. The integration of digital storytelling as a teaching strategy allows students to engage with scientific concepts in a creative and dynamic way, thereby enhancing both learning outcomes and student motivation [9, 12]. Moreover, studies have shown that the use of digital tools for creating narratives can help bridge the gap between theoretical knowledge and practical application, providing a meaningful learning experience that enhances comprehension and fosters deeper connections with the subject matter [8, 9, 12]. This approach not only supports conceptual understanding in science but also promotes critical thinking, creativity, and collaboration among students, all of which are essential skills in 21st-century education.

II. Materials and Methods

The study was designed using the Design Science Research Process (DSRP) as proposed by Peffers *et al.* [13], which includes clear iterative cycles and feedback loops that allowed for ongoing refinement of the pedagogical proposal. Each iteration was based on the results from previous phases, ensuring the continuous improvement of the intervention. This systematic approach enabled the evolution of the educational tools and materials applied in the study. The DSRP consists of six sequential stages summarized in Fig. 1.

In the first stage, problem identification and motivation, a documentary review of existing research on digital tools in science education was conducted [5, 13–16]. These studies

revealed challenges related to the lack of engaging, technology-mediated instructional strategies. The motivation emerged from the need to enhance teaching practices through digital storytelling tools like eXeLearning.

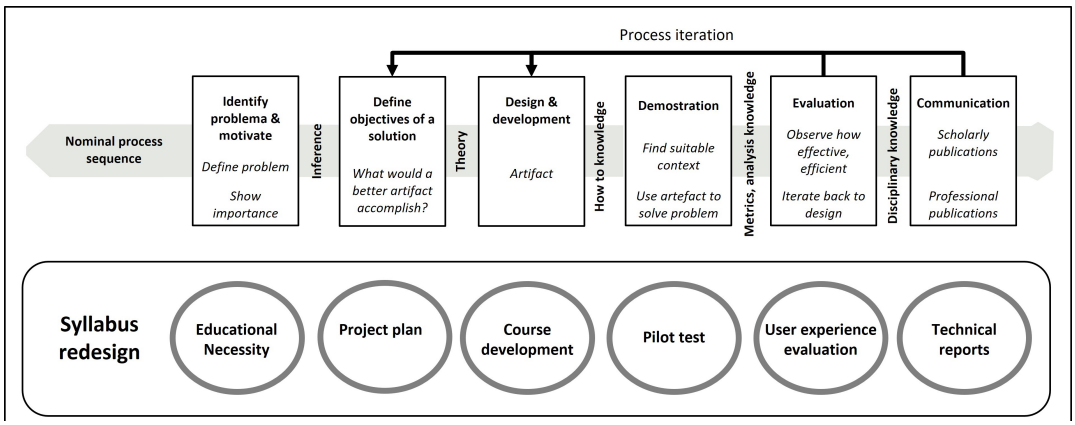

Fig. 1. Design science research process [13].

In the second stage, definition of the objectives for a solution, the project aimed to design a pedagogical proposal that would foster the development of digital narratives among pre-service teachers using eXeLearning. Specific goals included updating the course syllabus, fostering the creation of narrative texts with technological tools, and applying the proposal in real school settings.

During the third stage, design and development, a didactic sequence was constructed to guide the creation of digital narratives. This was co-developed with students in the teacher training program, ensuring curricular relevance and pedagogical alignment.

In the fourth stage, demonstration, the digital narratives were tested with fifth-grade students at Colegio Juan XIII in Montería, a public school serving a socioeconomically vulnerable community. The setting lacked modern technological infrastructure, which posed additional challenges for implementation. Despite these limitations, the pilot test allowed for the evaluation of the educational materials in real conditions (Figs. B1 and B2).

In the fifth stage, evaluation, the resources and student experiences were assessed through observation, comprehension tasks, and rubric-based scoring of the digital narratives (Table A1). Strengths and areas for improvement were identified based on classroom performance and participant feedback.

Finally, in the sixth stage, communication, results were disseminated through technical reports, a book publication, and the preparation of scientific articles. The findings were also shared in academic events, promoting dialogue and knowledge exchange within the educational research community.

The research was conducted within the undergraduate program in Natural Sciences and Environmental Education at the University of Córdoba (Colombia), specifically in the Technological Mediation course during the first semester of 2025. The participants were pre-service teachers enrolled in the course. The intervention was carried out with fifth-grade students from Colegio Juan XIII in the city of Montería, where the designed educational resources were implemented. The study involved four groups of students: biology, chemistry, physics, and an additional interdisciplinary group. Each group was tasked with creating digital resources based on their subject area, and the highest-rated content was selected for classroom use.

Furthermore, although no control or comparison group was included, we ensured internal validity by assessing the results across multiple cohorts of pre-service teachers. Future studies could benefit from including such groups to strengthen the findings.

In a first pilot phase, the virtualized narratives were implemented with fourth- and fifth-grade students at the Nueva Esperanza campus of Juan XXIII School in Montería. Pupils were divided into four groups—biology, chemistry, and physics narratives—and, from each thematic unit, the highest-rated text, based on the rubric assessment (Table B1), was selected for classroom use. In a subsequent semester, a refined version of the resources was applied by another cohort of pre-service teachers in three additional public schools in Córdoba: General Santander, Mega Colegio Los Araújos, and Normal Superior de Montería.

The core objective was to design a pedagogical strategy based on the creation of digital narratives, using Exelearning. Students received technical training and then developed their own science-based digital resources targeted at elementary education.

Informed consent was obtained from all pre-service teachers who participated in the pilot implementation of the digital narratives and provided feedback on their experiences. The pre-service teachers were fully informed about the study's objectives, procedures, and their right to withdraw from the study at any time without consequence. Since all participants were adults, no formal ethical approval number was required.

In terms of student data, the study only involved data from primary school students who were exposed to the educational materials created by the pre-service teachers. No identifiable student data was collected; all data were anonymized, and only aggregated, non-identifiable information was used in the analysis. These data were handled in compliance with the relevant institutional and educational guidelines to protect privacy and ensure that the students' rights were respected.

To evaluate the implementation, data were collected using the following instruments:

- Observation protocols to monitor classroom engagement and integration of the resources.
- Reflective journals kept by the pre-service teachers to document their experience and pedagogical insights.

- Feedback forms completed by the elementary students to assess clarity, interest, and effectiveness of the digital content.

Specific instruments were designed for this study, including comprehension tests, feedback forms, and rubrics. The tests evaluated students' understanding and inference skills. The forms gathered qualitative insights from both students and teachers on the effectiveness of the digital narratives. The rubrics assessed the scientific accuracy, structure, and creativity of the resources created by the pre-service teachers.

To ensure their validity and reliability, these instruments were reviewed by subject matter experts and underwent a pilot test with a small group of participants. The feedback from this phase was used to refine the instruments, improving their clarity and alignment with the study's objectives.

The evaluation focused on three key criteria:

1) Development of digital and teaching competencies among the university students;
2) Improvement in reading comprehension and engagement with science among the elementary school students;
3) Refinement of the Technological Mediation course curriculum to include collaborative and creative uses of educational technology.

Qualitative data were analyzed using a thematic coding approach based on grounded theory, and descriptive analysis was used to categorize student feedback and identify recurring patterns across classrooms.

A. Statistical Analysis

All analyses were conducted with a two-tailed significance level of $\alpha = 0.05$ and 95% confidence intervals (95% CI).

1) Reading comprehension (primary students). For each domain reported in Table 1, we tested whether the proportion of correct responses exceeded a predefined mastery criterion of 70% using exact one-sided binomial tests and reported Wilson 95% CIs.
2) Quality of digital narratives (pre-service teachers). We compared the distribution of rubric ratings between cohorts (Group 01 vs Group 02) using a chi-square test of independence (χ^2), with Cramér's V as effect size.
3) Course perception (pre-service teachers). For single-item "top-box" proportions (e.g., "very useful"), we ran exact one-sided binomial tests versus 50% and reported Wilson 95% CIs.

III. Result and Discussion

The implementation of the pedagogical proposal produced observable improvements in the development of key competencies among the participating pre-service teachers. Throughout the semester, students created digital educational resources based on science-related narrative texts, which were applied in fifth-grade classrooms at Colegio Juan XIII in Montería summarizes the principal areas of observed improvement.

A. Quantitative Evaluation of Student Outcomes

To assess the pedagogical impact of digital narratives, a structured comprehension assessment was conducted with fifth-grade students from Colegio Juan XIII. The evaluation addressed eight cognitive domains aligned with science literacy benchmarks. As shown in Table 1, students exhibited high achievement levels across all evaluated skills. Specifically, 90% of students correctly identified the main idea, 88% extracted relevant details, and 87% made appropriate inferences. Additionally, 85% demonstrated a solid understanding of character-environment relationships, 86% interpreted descriptive passages effectively, and 89% reported learning new scientific concepts. Notably, 83% displayed critical thinking regarding narrative construction, and 80% found the stories engaging or surprising. These results affirm that the narrative-based digital resources not only supported conceptual understanding in science but also significantly enhanced reading comprehension. The high percentage of students mastering inferential and interpretive skills underscores the effectiveness of this integrated approach.

Table 1. Reading comprehension achievement by domain among fifth-grade students ($n \approx 30$)

Comprehension Skill	Achievement (%)
Identifying the main idea	90%
Extracting key details	88%
Making inferences	87%
Understanding character–environment link	85%
Interpreting descriptions and features	86%
Acquiring new scientific Concepts	89%
Critical evaluation of narrative Elements	83%
Emotional engagement and surprise	80%

B. Qualitative Evaluation of Participants

Qualitative analysis of participants' reflection journals indicated consistent evidence of enhanced digital skills, more structured pedagogical planning, and increased creativity in instructional design. These improvements emerged through hands-on use of eXeLearning and collaborative work conducted within the Technological Mediation course. Table 2 summarizes the principal areas of observed improvement.

Table 2. Descriptive summary of observed competency development in pre-service teachers

Competency Area	Evidence of Improvement
Digital Skills	Confident use of eXeLearning; familiarity with interactive design tools.
Pedagogical Planning	More coherent lesson sequencing; better integration of digital content.
Didactic Innovation	Creation of engaging, narrative-based educational resources.

C. Quantitative Evaluation of Student Outcomes

A structured comprehension assessment was administered to fifth-grade students ($N = 30$). Table 3 summarizes the per-domain performance with 95% CIs and binomial tests versus a 70% mastery benchmark. Students exceeded 70% in all domains; the excess was statistically significant for main idea, details, inferences, character–environment link, descriptions, and acquisition of new concepts ($p \leq 0.030$). For critical evaluation and emotional engagement, proportions were ≥80% but did not surpass the 70% benchmark with statistical significance under $\alpha = 0.05$.

Interpretation: performance was high across domains; most exceeded the 70% mastery criterion with statistical support; two domains were close (80–83%) but not significant at $\alpha = 0.05$ given the sample size.

Table 3. Reading comprehension by domain (N = 30): % correct, 95% CI, and binomial test vs 70% (one-sided)

Comprehension skill	n/N	% correct	95% CI	p (vs 70%)
Identifying main idea	27/30	90%	74.4–96.5%	0.009
Extracting key details	26/30	87%	70.3–94.7%	0.030
Making inferences	26/30	87%	70.3–94.7%	0.030
Character–environment link	26/30	87%	70.3–94.7%	0.030
Interpreting descriptions	26/30	87%	70.3–94.7%	0.030
Acquiring new concepts	27/30	90%	74.4–96.5%	0.009
Critical evaluation of narrative	25/30	83%	66.4–92.7%	0.077
Emotional engagement/surprise	24/30	80%	62.7–90.5%	0.160

D. Evaluation of Scientific Narratives

A key component of the project involved the evaluation of the scientific narratives created by the participants. A rubric assessed each narrative based on four core criteria: scientific accuracy, structure and coherence, pedagogical intention, and narrative creativity. Table 4 presents the criteria employed.

The intervention was implemented with two cohorts of pre-service teachers enrolled in the Technological Mediation course: Group 01 (first semester of 2024, n = 23) and Group 02 (second semester of 2024, n = 27). Each participant produced one digital scientific narrative, totaling 50 narrative texts assessed using the established rubric.

Based on the criteria described above, Table 4 summarizes the distribution of performance levels observed in each group, reflecting the outcomes of the rubric-based evaluation process.

Table 4. Rubric criteria used to assess the scientific digital narratives designed by pre-service teachers

Criterion	Description
Scientific Accuracy	Correct use of scientific content aligned with the school curriculum.
Structure and Coherence	Logical organization of the narrative and appropriate use of language.
Pedagogical Intention	Clear educational objectives and appropriate didactic strategies.
Narrative Creativity	Originality, relevance of the story, and effective integration of ICT tools.

E. Rubric-Based Assessment Results (with Statistical Test)

Fifty scientific narratives were rated using the rubric (Group 01: n = 23; Group 02: n = 27; as shown on Table 5). The distribution of performance levels did not differ significantly between cohorts (χ^2 = 1.361, df = 3, p = 0.715; Cramér's V = 0.17, small). "Good" ratings were similar: 15/23 = 65.2% (95% CI: 44.9–81.2%) in Group 01 and 18/27 = 66.7% (95% CI: 47.8–81.4%) in Group 02.

Table 5. Distribution of narrative text ratings by group

Performance Level	Group 01 (n = 23)	Group 02 (n = 27)
Excellent	1 (4%)	0 (0%)
Good	15 (65%)	18 (67%)
Satisfactory	4 (17%)	6 (22%)
Poor	3 (13%)	3 (11%)

Note: Ratings are based on the rubric presented in Table 3.

These results support consistency of narrative quality across cohorts under the established criteria.

However, the presence of "Satisfactory" and "Poor" outcomes points to the need for additional scaffolding and formative feedback during the design process. The use of rubric as both summative and formative assessment helped guide student revisions and reflective learning throughout the course.

F. Perception Survey Results

In parallel with the assessment of teacher-produced resources, the intervention produced preliminary positive effects among primary students who interacted with the digital narratives. Initial classroom observations confirmed that the narrative format captured students' attention and facilitated understanding of complex scientific concepts.

The evaluation phase included a perception survey administered to fourth- and fifth-grade students regarding their experiences with the narratives on topics in chemistry, physics, and biology. Exact binomial tests versus 50% indicated that "clarity" (85%), "engagement" (88%), and "usefulness of illustrations" (82%) were each significantly above 50% (all $p \leq 2.8\times10^{-6}$) (see Table 6).

Table 6. Perception survey results (top-box) with 95% CI and binomial test vs 50% (N = 50)

Item (top-box)	n/N	%	95% CI	p (vs 50%)
Course usefulness—"very useful"	42/50	85%	71.5–91.7%	5.8e−07
Info Management unit—"very relevant"	44/50	88%	76.2–94.4%	1.6e−08
Final evaluation—"very effective"	41/50	82%	69.2–90.2%	2.8e−06
Balance theory–practice—"fully agree"	31/50	62%	48.2–74.1%	0.059
Unit integration—"strongly agree"	26/50	53%	38.5–65.2%	0.444

Teachers observed increased student participation, greater interest in reading, and spontaneous connections between the scientific stories and students' daily lives. Quantitative comprehension checks and qualitative field notes collected during the pilot suggested significant gains in reading comprehension among fourth-grade learners, confirming the motivational effect of the narrative format. Follow-up surveys gathered overwhelmingly positive responses, highlighting clarity, engagement, and the usefulness of illustrations, while also offering suggestions for additional interactivity.

The evaluation phase included a perception survey administered to fourth- and fifth-grade students regarding their experiences with the narratives on topics in chemistry, physics, and biology. Although quantitative results are not reported here, responses indicated that students found the digital stories engaging and helpful for learning science content.

Teachers observed increased student participation, greater interest in reading, and spontaneous connections between the scientific stories and students' daily lives. Quantitative comprehension checks and qualitative field notes collected during the pilot suggested significant gains in reading comprehension among fourth-grade learners, confirming the

motivational effect of the narrative format. Follow-up surveys gathered overwhelmingly positive responses, highlighting clarity, engagement, and the usefulness of illustrations, while also offering suggestions for additional interactivity.

G. Evaluation of the Pedagogical Strategy

Evaluation of the pedagogical strategy by pre-service teachers also provided valuable insights, revealing strong consensus on its educational value and potential for improving student outcomes.

Pre-service teachers considered the use of eXeLearning and digital storytelling highly appropriate for the students' grade level and contextual needs. They noted its creativity, innovation, and ability to deliver science content in an engaging and dynamic manner. According to the feedback, the strategy effectively supported learning objectives and facilitated scientific concept acquisition. It also promoted active student engagement, increasing curiosity and classroom participation, while fostering essential 21st-century skills, including reading comprehension, critical thinking, collaboration, and creativity.

Several strengths were highlighted, such as motivation, effectiveness, and the integration of multimedia tools. However, respondents also identified challenges, including limited classroom time and the need for improved planning to adapt the strategy to diverse student needs. Recommendations for improvement included adding hands-on and experimental activities, using varied narrative styles, adapting content to diverse learning preferences, and improving class time management.

Overall, the evaluation confirmed that digital storytelling with tools such as eXeLearning supports meaningful science learning in both primary classrooms and teacher training programs. Additionally, this experience contributed to curricular refinement of the Technological Mediation course, which now includes new modules on narrative construction, collaborative content creation, and the use of open educational tools. This update reflects a shift toward more experiential, project-based training within the teacher education program. Furthermore, a quantitative perception survey was administered to evaluate the Technological Mediation course itself. As shown in Fig. 2, 85% of pre-service teachers rated the course as "very useful", highlighting its alignment with their training expectations and its potential for curricular innovation.

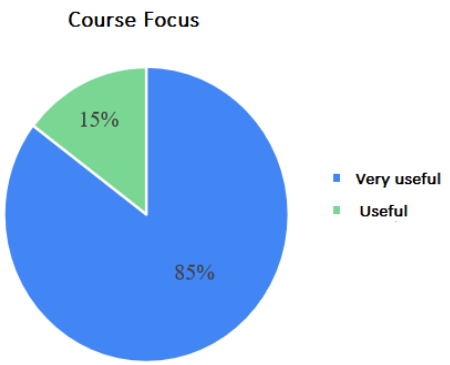

Fig. 2. Perception of course usefulness among students.

The Information Management module received high praise, with 88% of students considering it "very relevant" for enhancing their academic writing and theoretical grounding, as illustrated in Fig. 3.

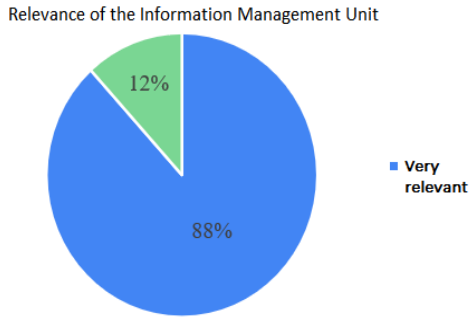

Fig. 3. Relevance of the information management unit.

When asked about the integration of different course units, 53% strongly agreed that the combination was appropriate, while 47% agreed moderately, as reflected in Fig. 4. This indicates a well-balanced curriculum supporting both technical and reflective learning.

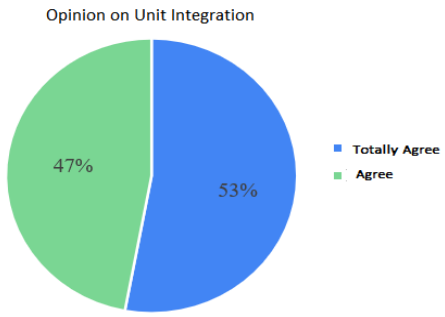

Fig. 4. Opinion on unit integration.

Regarding the evaluation component, Fig. 5 shows that 82% of students considered the final evaluation process "very effective" in guiding reflection and improving the digital resources. This finding aligns with formative assessment principles, which promote feedback and continuous improvement.

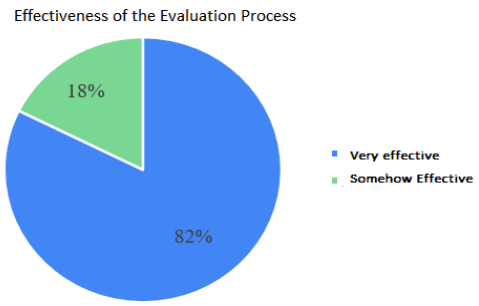

Fig. 5. Effectiveness of the evaluation process.

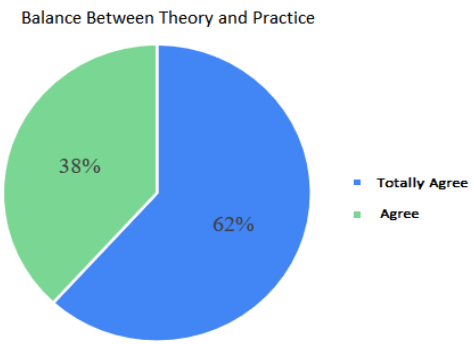

Fig. 6. Balance between theory and practice.

Finally, 62% of participants fully agreed that the course provided an appropriate balance between theory and practice, as illustrated in Fig. 6, confirming the course's value in offering comprehensive, experience-based training.

IV. Conclusion

The project successfully met its specific objectives, demonstrating that the construction of digital narratives with a scientific focus can significantly enhance reading comprehension among students. The integration of this pedagogical strategy into the Technological Mediation course not only facilitated the acquisition of scientific knowledge but also fostered the development of essential 21st-century skills.

More specifically, the use of digital narratives in the classroom promoted active and participatory learning, engaging students in the co-construction of knowledge. By connecting scientific concepts with relevant and engaging stories, this approach facilitated both comprehension and long-term retention, resulting in more meaningful learning experiences. Additionally, the use of tools such as eXeLearning and Artificial Intelligence (AI) in the creation of digital educational resources enabled pre-service teachers to develop both technological and pedagogical competencies. These skills are essential for designing and implementing innovative didactic proposals that respond to students' needs and the challenges of contemporary education.

The evaluation of the strategy through pilot tests and student feedback provided empirical evidence of its effectiveness. The results revealed improvements in reading comprehension, as well as increased motivation and interest in natural sciences. These outcomes support the scalability of the proposed approach and its applicability in teacher education programs seeking to innovate their curricular design.

This pedagogical experience generated several notable educational impacts. First, it set a precedent for future research in science education mediated by digital technologies, particularly in the use of design-based research, digital storytelling, and open-source tools such as eXeLearning and Google AI Studio. Second, the project resulted in a curricular refinement of the Technological Mediation course, equipping pre-service teachers with critical digital competencies. Third, the digital resources created were effective in enhancing elementary students' reading comprehension and engagement through interactive and contextualized science content. Lastly, the experience contributed to the development of communication, creativity, and adaptive language skills among the teacher candidates.

Despite these positive outcomes, the study had several limitations that should be acknowledged. First, the intervention was conducted in a single institution, which limits the generalizability of the findings to broader educational contexts. Second, the sample size was relatively small, and long-term learning effects were not measured beyond the duration of the project. Third, while the emotional and motivational impacts were observed, they were not systematically evaluated with validated instruments. However, statistical analyses of comprehension outcomes, including binomial tests with p-values and confidence intervals, support the validity of the findings. Additionally, external factors such as socioeconomic background or digital access were not controlled.

In light of these limitations, future research could pursue several directions. Longitudinal studies may help assess the sustained impact of digital narrative-based resources on science comprehension and language development. Comparative research across multiple educational settings could evaluate the adaptability of the model to different curricula, age groups, and cultural contexts. The integration of adaptive learning technologies, gamification, or immersive tools like augmented reality may further enhance the learning experience and deserve exploration. Moreover, future studies could focus on the development of validated instruments to measure affective, motivational, and collaborative outcomes. Expanding the participatory design process to include families, interdisciplinary teams, and policy stakeholders may also increase the scalability and sustainability of such educational innovations.

Appendix

A. Appendix A

1) Virtualization of narrative texts using eXeLearning

After refining the narrative texts, pre-service teachers used eXeLearning to convert them into interactive digital educational resources. This process ensured accessibility and enhanced engagement through multimedia and structured design. The quality of the resulting resources was assessed using the criteria presented in Table A1:

Table A1. Evaluation format for educational resources created in eXeLearning

Section	Criterion	Rating Options
General Information	The resource has a clear title.	Yes / No / Comments
	The resource objectives are clearly defined.	Yes / No / Comments
	The content is appropriate for the target educational level (e.g., Grade 5).	Yes / No / Comments
Introduction	The beginning captures students' interest.	Excellent / Good / Fair / Poor / Comments
	Topics are clearly introduced.	
Planning	The instructional planning is structured and organized.	Excellent / Good / Fair / Poor / Comments
	Objectives and goals of the resource are clearly defined.	
Content	Content is precise and accurate.	Excellent / Good / Fair / Poor / Comments
	Content is contextualized and relevant.	
	Content is appropriate for the educational level.	
Activities	Activities are engaging and interactive.	Excellent / Good / Fair / Poor / Comments
	Activities align with the defined objectives.	
	Activities are suitable for the students' level.	
Assessment	Evaluation methods are clear and fair.	Excellent / Good / Fair / Poor / Comments
	Assessments align with content and objectives.	
	Feedback is constructive and useful.	

Bibliography	Bibliographic references are complete and up-to-date.	Yes / No / Comments
	Sources are relevant and credible.	
Credits	All authors and contributors are properly credited.	Yes / No / Comments
Overall Evaluation	The resource is usable and stable.	Excellent / Good / Fair / Poor / Comments
	Visual and design aspects are attractive and educational.	
	The resource is accessible and easy to navigate.	
General Comments		Free text field for observations

B. Appendix B

Table B1. Rubric for evaluating scientific narrative texts

Criterion	Excellent (5)	Good (4)	Fair (3.5)	Poor (2.5)
Integration of Scientific Knowledge	The student integrates scientific knowledge exceptionally well, demonstrating deep understanding of the topic.	Scientific knowledge is well integrated, though some areas could be more thoroughly explained.	Basic integration is present, but important details are missing or there are minor inaccuracies.	Integration is minimal or inaccurate, indicating a superficial understanding of the topic.
Creativity and Narrative	The story is original and engaging, making the scientific topic accessible and compelling.	The narrative is interesting and includes creative elements, but could be more imaginative.	The story is basic, with limited creativity. It meets the goal but lacks engagement.	The narrative lacks creativity and fails to make the scientific topic interesting.
Structure (Beginning, Middle, End)	The text has a clear, coherent structure with a strong beginning, well-developed body, and coherent conclusion.	General structure is adequate, though some parts could be better developed or connected.	The structure is basic, with minimal fluency or cohesion in parts.	The structure is confusing or incoherent, making the narrative difficult to follow.
Questions and References	Questions are relevant and promote critical thinking; references are complete and pertinent.	Questions are adequate; references are appropriate but could be more detailed or varied.	Basic questions and minimal referencing; lacks depth.	Questions are irrelevant or poorly formulated; referencing is insufficient or inappropriate.

Fig. B1. Screenshot of the introductory page of the digital resource created using eXeLearning.

The interface is shown in Spanish because the resource was designed by Spanish-speaking pre-service teachers for Colombian primary students, ensuring contextual relevance and accessibility.

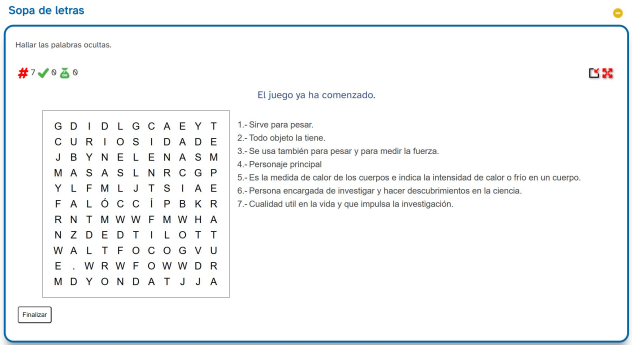

Fig. B2. Example of an interactive learning activity developed using eXeLearning.

This screenshot is in Spanish as the materials were designed for native Spanish-speaking primary students in Colombia.

The word search challenges students to associate scientific concepts (e.g., mass, scientist, dynamometer) with definitions, fostering vocabulary development and comprehension through play.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Isabel Cristina Muñoz designed and coordinated the overall research project, supervised the implementation of the pedagogical intervention, and led the development of the article. Karen Patricia Agudelo contributed to the design and application of the data collection instruments, conducted classroom observations, and participated in the qualitative data analysis. Both authors reviewed the literature, collaborated in interpreting the results, and revised the manuscript critically for important intellectual content. All authors read and approved the final version of the manuscript.

References

[1] J. Bruner, *Acts of Meaning*, Cambridge, MA, USA: Harvard Univ. Press, 1990.

[2] A. Sánchez-Caballé and J. González-Martínez, "Transmedia learning: Fact or fiction? A systematic review," *Culture and Education: Culture and Education*, vol. 35, no. 1, pp. 1–32, 2023. doi: 10.1080/11356405.2022.2121131 (in Spanish)

[3] H. Gardner, *Frames of Mind: The Theory of Multiple Intelligences*, New York, NY, USA: Basic Books, 1983.

[4] H. Gardner, *Five Minds for the Future*, Boston, MA, USA: Harvard Business School Press, 2008.

[5] M. Prensky, "Digital natives, digital immigrants," *On the Horizon*, vol. 9, no. 5, pp. 1–6, 2001. doi: 10.1108/10748120110424816

[6] M. R. Prensky, *Teaching Digital Natives: Partnering for Real Learning*, Thousand Oaks, CA, USA: Corwin, 2010.

[7]L. Cuban, *Oversold and underused: Computers in the classroom*, Cambridge, MA, USA: Harvard Univ. Press, 2001.

[8] A. Haarala-Muhonen *et al.*, "The impact of pedagogical and ICT training in teachers' approaches to online teaching and use of digital tools," *Front. Educ.*, vol. 8, 1223665, 2023. doi: 10.3389/feduc.2023.1223665

[9] D. Setiawan *et al.*, "Impact of digital storytelling for developing oral communication skills, digital literacy, and learning motivation among pre-service elementary teachers," *Int. J. Educ. Qual. Quant. Res.*, vol. 2, no. 2, pp. 34–42, 2023. doi: 10.58418/ijeqqr.v2i2.118

[10] R. M. Tamim, R. M. Bernard, E. Borokhovski, P. C. Abrami, and R. F. Schmid, "What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation

study," *Review of Educational Research*, vol. 81, no. 1, pp. 4–28, 2011. doi: 10.3102/0034654310393361

[11] D. H. Jonassen, J. Howland, J. Moore, and R. M. Marra, *Meaningful Learning with Technology*, Upper Saddle River, NJ: Merrill/Prentice Hall, 2003.

[12] H. Wang, "Multimodal digital storytelling as literacy learning and moral cultivation practices for university EFL students," *Arab World Engl. J.*, vol. 16, no. 1, pp. 366–383, 2025. doi: 10.24093/awej/vol16no1.23

[13] K. Peffers *et al.*, "A design science research methodology for information systems research," *J. Manage. Inf. Syst.*, vol. 24, no. 3, pp. 45–78, 2007. doi: 10.2753/MIS0742-1222240302

[14] J. Adell and L. Castañeda, "Personal Learning Environments (PLEs): A new ecology of learning," *RED: Rev. Educ. Distancia*, no. 39, 2010. (in Spanish)

[15] R. R. Alonso, K. A. Carvajal, and N. R. Acevedo, "Role of artificial intelligence in the personalization of distance education: A systematic review," *Rev. Iberoam. Educ. Distancia*, vol. 28, no. 1, pp. 9–32, 2025, doi: 10.5944/ried.28.1.41538

[16] M. J. Koehler, P. Mishra, and W. Cain, "What are Technological and Pedagogical Content Knowledge (TPACK)?" *Virtualidad, Educ. Cienc.*, vol. 6, no. 10, pp. 9–23, 2015. doi: 10.60020/1853-6530.v6.n10.11552 (in Spanish)

Copyright © 2026 by the authors. This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (CC BY 4.0).