

Article

Reimagining Chemistry Education for Pre-Service Teachers Through TikTok, News Media, and Digital Portfolios

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Featured Application

Digital tools can support the transition from traditional, lecture-based instruction to more active, student-centered learning—addressing the growing need for adaptable, relevant, and participatory educational practices in the post-pandemic era.

Abstract

This study explores the integration of digital media tools—specifically TikTok, online press news analysis, and digital portfolios—into pre-service chemistry teacher education to enhance student engagement, foster conceptual understanding, and highlight the relevance of chemistry in society. The educational intervention involved 138 pre-service teachers who analysed digital news articles to reflect on the societal and environmental implications of chemistry, promoting media literacy and awareness of socioscientific issues. Additionally, they created short-form TikTok videos, using social media to communicate scientific concepts creatively and interactively. All participants compiled their work into digital portfolios, which served as both a reflective and integrative tool. A post-course Likert-scale questionnaire ($N = 77$) revealed high overall satisfaction with the methodology, with 94.8% valuing the news analysis activity and 59.7% finding TikTok particularly engaging. Despite some limitations regarding access to technical infrastructure, the findings indicate that incorporating Information and Communication Technology (ICT) in this manner supports motivation, meaningful learning, and the development of key teaching competencies. This case study contributes practical insights into ICT use in science education.

Keywords: chemistry education; chemical education; socioscientific issues; ICT in chemistry education; ICT in chemical education; pre-service teacher chemistry training; digital media; TikTok; digital portfolios



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1. Introduction

Chemistry plays a vital role not only within the natural sciences but also in advancing technological innovation, promoting public health, supporting environmental sustainability, and driving economic development [1]. Despite this significance, chemistry education continues to struggle with challenges related to student engagement, public perception, and its perceived relevance to real-world issues [2,3]. Many students view chemistry as difficult, disconnected, or even unappealing [4].

Research has consistently pointed to low enrolment rates and negative student attitudes, particularly in chemistry and physics, where learners frequently fail to see the relevance of scientific content to their everyday lives [5]. This disconnect is especially problematic in pre-service teacher education, where future educators' attitudes toward science profoundly shape their teaching practices and, ultimately, their students' perceptions [6,7].

Traditional lecture-based methods, still common in university contexts, tend to foster passive learning and disengagement. In contrast, student-centred pedagogies—emphasizing inquiry, collaboration, and authentic, real-world contexts—are more effective at cultivating meaningful understanding and sustained interest [8,9]. One positive, engaging classroom experience can have a lasting influence, even shaping students' career aspirations [10].

Moreover, the COVID-19 pandemic has underscored the need for flexible, technology-enhanced educational models that support discovery-based learning in rapidly evolving environments. In this context, approaches that explicitly connect chemistry to social issues and everyday life become essential [11,12]. Chemically literate students should not only understand scientific concepts but also be able to apply them responsibly, engage in public discourse, and contribute to innovation [13].

Nevertheless, many teachers still feel constrained by rigid curricula and time limitations, which can discourage the use of more interactive or context-based methods [14]. Selecting relevant, meaningful topics is therefore key to bridging content knowledge with student motivation and fostering a more socially connected, responsible form of science education [15].

1.1. Socioscientific Issues in Chemistry Education

Socioscientific issues (SSIs) are real, unresolved, and often controversial societal problems that require scientific understanding for informed discussion and decision-making. These issues are characterized by their complexity and their ethical, social, political, economic, and environmental dimensions [16,17]. Although not all controversial topics qualify as SSIs, the distinguishing feature of SSIs lies in their grounding in science—particularly in contexts such as sustainability, climate change, or emerging technologies [18].

In the field of chemistry education, SSIs offer a powerful pedagogical framework to address persistent challenges, including students' lack of motivation, low self-efficacy, and perception of chemistry as irrelevant or overly abstract [9]. Introducing SSIs into the classroom allows chemistry to be seen not just as foundational knowledge, but as a dynamic field intimately connected to societal concerns such as pollution, public health, or green technologies [19,20].

SSI-based instruction encourages dialogic and inquiry-based learning where students are engaged in argumentation, deliberation, and the consideration of multiple perspectives [11]. These processes support not only content mastery but also the development of critical thinking, ethical reasoning, and citizenship skills [21]. However, the effective integration of SSIs into chemistry education is not without obstacles. Teachers often report barriers such as limited content knowledge, a lack of training in addressing ethical or emotional aspects of science, and a shortage of time and resources [22].

Despite these challenges, a growing body of research highlights the benefits of using SSIs to foster engagement and scientific literacy [11–24]. When SSIs are presented through accessible media—such as news articles, videos, and digital platforms—they can help students relate chemistry to pressing societal issues and enhance their motivation to learn [25].

1.2. *The Role of TikTok and Digital Media in Chemistry Education*

The increasing integration of digital media in science education reflects broader cultural and technological shifts that have accelerated in the post-COVID-19 educational landscape. Social media platforms, audiovisual content, and journalistic texts now play a significant role in shaping how science is communicated, understood, and taught [26–28]. This is particularly relevant in the context of chemistry education, where abstract concepts often pose learning challenges. For chemistry students—and especially pre-service teachers preparing to become future educators—digital media offers both a means of deepening their understanding of scientific ideas and a toolset for developing engaging, context-rich teaching strategies.

Analysis of journalistic texts in science education, especially those addressing controversial SSIs, has been widely studied and promoted as a means of enhancing scientific literacy [29,30]. When news articles feature differing opinions among scientists, journalists, and the public, they offer a rich context for fostering critical thinking and developing students' argumentation skills—essential components of an informed citizenry [31]. Furthermore, teaching through SSIs aligns with calls to orient science education towards students' interests and everyday concerns without sacrificing conceptual rigour [32]. However, research also highlights the lack of teacher preparation in linking SSIs with foundational scientific concepts or handling the emotional aspects these topics often entail [33].

Complementing news analysis, TikTok [34] represents a novel and creative digital format through which students can express scientific knowledge. Similar to educational theatre or comics [35,36], TikTok's short, visual, and narrative-driven nature allows users to re-enact scientific ideas, personify abstract concepts, or simulate debates—effectively transforming the platform into a modern, interactive stage for science communication. This form of engagement supports a multi-sensory learning style [37].

Digital media also presents practical advantages for science teaching, addressing challenges of time, cost, and conceptual clarity in traditional instruction [38]. Moreover, for the digital-native generation of students—familiar with AI, mobile editing tools, and collaborative platforms—such methods feel intuitive and empowering [39].

Nonetheless, these approaches require thoughtful pedagogical scaffolding. Teachers must be equipped not only to curate appropriate media content—particularly news articles with embedded SSIs—but also to facilitate reflection, critique, and scientific reasoning within these formats. As Viehmann et al. [22] note, finding ways to integrate multiple disciplines remains a persistent challenge, particularly in compartmentalised curricula. Yet, as demonstrated in recent work, Information and Communication Technology (ICT)-supported activities such as TikTok production and digital news analysis offer promising avenues to overcome passive learning environments, making science education more active, reflective, and socially connected.

1.3. *Digital Portfolios in Higher Education*

The concept of the portfolio originates from the field of art, where it traditionally serves as a curated selection of an individual's best work and professional achievements [40]. In educational contexts, a portfolio is understood as a systematic and deliberate collection of student work that reflects their learning journey, progress, achievements, and conceptual understanding [41]. This collection not only documents learning but also serves as a space for critical reflection, offering valuable insight into student performance.

An effective educational portfolio includes student participation in content selection, explicit criteria for selection, and guidelines for evaluating its merit, alongside evidence of reflective practice [42]. Therefore, it is both a tool for structuring and documenting

learning and an instrument of formative assessment that supports ongoing evaluation and the showcasing of individual achievement [43].

Digital portfolios (also referred to as electronic portfolios or e-portfolios in the literature) are digital versions of traditional portfolios that can incorporate multimedia content such as text, images, audio, and video [44]. These tools provide new possibilities for presenting, organising, and assessing learning through hypertext, non-linear navigation, and multimodal communication [45]. The hypertextual nature of e-portfolios promotes learner autonomy by allowing students to define their own pathways and narrative structures [46].

Digital portfolios are increasingly recognised as powerful tools in higher education. They encourage engagement with authentic learning tasks, reflective thinking, and the integration of academic, professional, and digital competencies [47,48]. In particular, they are seen as valuable platforms for tracking long-term learning processes and enabling personalised feedback, contributing significantly to student autonomy and digital literacy [44]. Furthermore, they foster collaboration, communication, and critical thinking—key components of 21st-century learning [49].

In the context of teacher education, e-portfolios serve as an effective means of synthesising pedagogical theory with practice. They allow future educators to demonstrate reflective insight, communicate their evolving professional identities, and connect coursework with real-world applications [50]. This capacity to capture both the process and product of learning makes the digital portfolio an essential element in contemporary higher education pedagogies.

1.4. Effective ICT Integration into Pre-Service Teacher Education

Incorporating ICT meaningfully into pre-service teacher education is a key priority for 21st-century learning. Effective ICT integration is not merely about using digital tools, but about understanding how, why, and when to use them to enhance student learning. For pre-service science teachers, this requires an epistemologically integrated approach that links disciplinary content with pedagogical and technological knowledge.

The Technological Pedagogical Content Knowledge (TPACK) framework [51,52] has become a foundational model for guiding technology integration in education. Built upon Shulman's Pedagogical Content Knowledge (PCK) [53], TPACK emphasizes the dynamic interplay between three core components: content, pedagogy, and technology. Rather than treating these domains in isolation, TPACK highlights the need to understand their complex relationships, particularly in context-specific applications like science education [54,55].

In science education, this framework has evolved into what some scholars refer to as Technological Pedagogical and Science Content Knowledge (TPASK), underscoring the specificity of scientific disciplines and the need for contextualized instruction [54]. TPASK calls for a deeper understanding of how technology can support inquiry-based learning, the visualization of complex phenomena, and the development of scientific literacy through real-world problem-solving.

Accordingly, the effective preparation of future teachers must go beyond technical training in digital tools. Pre-service teachers should be equipped to make informed, pedagogically grounded decisions about the use of ICT—ranging from learning management systems to multimodal media [56]. Meaningful integration entails designing student-centred, inquiry-driven experiences where technology is not simply an “add-on” but a transformative element that enables active, reflective, and contextual learning [57,58].

Yet many ICT training initiatives remain overly focused on operational skills, often neglecting the pedagogical and disciplinary rationale behind technology use. This imbalance can result in superficial or disconnected uses of technology that fail to enhance learning [54]. To overcome this, teachers must understand not only how to use ICT, but also

how it can support strategies such as hypothesis testing, argumentation, and collaborative inquiry—particularly vital in science classrooms.

Science education is especially well positioned to benefit from ICT-enhanced pedagogies. It inherently supports problem-based learning, real-world application, and multimodal representations of abstract concepts. Technologies such as simulations, visualizations, and digital storytelling help bridge the gap between theoretical knowledge and practical understanding, making chemistry more accessible and relevant to learners [54,55].

Both TPACK/TPASK frameworks provide a reflective structure for pre-service teachers to develop competence in aligning technology with curricular goals, student needs, and disciplinary practices. This is crucial for preparing educators who can navigate evolving educational landscapes and select appropriate tools for meaningful integration.

Complementing the aforementioned models, the European Framework for the Digital Competence of Educators (DigCompEdu) [59] adds a broader, profession-wide perspective to what digital competence entails. DigCompEdu responds to the growing need for educators to act not only as users of digital tools, but also as digital role models for their students. It outlines six areas of competence: (1) professional engagement, (2) digital resources, (3) teaching and learning, (4) assessment, (5) empowering learners, and (6) facilitating learners' digital competence. These areas reflect the multifaceted nature of digital teaching and reinforce the idea that educators must be prepared to manage digital technologies for communication, personalization, and innovation in learning environments.

1.5. The Aim of This Work

This study aims to explore how digital media—specifically journalistic texts and short-form video content—can be leveraged to reimagine chemistry education in ways that align with post-pandemic educational priorities: pedagogical flexibility, contextual relevance, and active, student-driven learning. By embedding chemistry within meaningful, real-world contexts and offering creative platforms for expression, this approach seeks to foster scientific and media literacy while empowering future educators to teach chemistry in more engaging and socially connected ways.

To this end, a case study was conducted with pre-service primary teachers who participated in two ICT-supported activities: (1) the critical analysis of digital news related to chemistry, and (2) the creation of 60 s TikTok videos explaining Dalton's atomic postulates. These activities were designed not only to enhance student engagement and perceptions of chemistry but also to deepen their understanding of its societal and technological relevance.

Throughout the intervention, students compiled digital portfolios to document, organise, and reflect on their learning processes and artefacts, providing a comprehensive view of their development. This study examines how combining these digital media activities with portfolio-based reflection supports deeper learning and the professional preparation of future science educators.

In addition, taking into consideration the theoretical framework mentioned in Section 1.4, the ICT-supported activities developed in this study—namely the critical analysis of digital news texts, the production of short-form educational TikTok videos, and the use of digital portfolios—can be interpreted through the lens of the TPACK/TPASK frameworks [51,52]. Each activity fosters the integration of content, pedagogy, and technology in distinct but complementary ways. The journalistic text analysis supports content and pedagogical knowledge by contextualising chemistry within SSIs, encouraging students to critically engage with real-world implications of scientific topics. TikTok video creation targets the interplay between content and technology, requiring pre-service teachers to translate disciplinary concepts (e.g., Dalton's atomic theory) into engaging and accessible formats using digital media. Meanwhile, the digital portfolio serves as a metacognitive and

organisational tool, enabling students to reflect on and document their learning processes across tasks—thus strengthening their technological pedagogical knowledge. Together, these tools exemplify a dynamic, integrated approach to science teacher education that cultivates both disciplinary understanding and digital teaching competence in line with 21st-century educational challenges.

Accordingly, this study seeks to answer the following research questions:

- RQ1. How do pre-service teachers engage with and perceive the educational value of ICT-supported activities such as digital news analysis and TikTok video creation in chemistry education?
- RQ2. In what ways do digital portfolios support pre-service teachers' reflection in the context of these activities?

2. Materials and Methods

This study adopts a qualitative-dominant case study design to explore the integration of digital media tools within pre-service primary teacher education. Situated within an exploratory educational intervention, this design aims to investigate how ICT-supported activities—namely digital news analysis, TikTok video creation, and digital portfolios—contribute to student engagement, conceptual learning, and professional development.

The qualitative approach focuses on analysing learners' reflective portfolios and collaborative processes to capture their experiences and knowledge construction. Quantitative data, collected through a post-course questionnaire, complement this by providing a broader perspective on participant satisfaction and their perceived relevance of the activities. Together, these methods offer preliminary insights into the potential and challenges of embedding digital media in chemistry teacher preparation.

2.1. Characterisation of Sample

As part of the initial pre-service teacher training in Chemistry and Science Education at the Faculty of Education of the Complutense University of Madrid, a new educational initiative was developed. The didactic intervention was carried out with three official pre-service teacher groups, involving a total of 138 pre-service teachers enrolled in three officials' groups, identified in this paper as A, B, and C with 54, 37, and 47 future teachers, respectively.

2.2. Design of Activities

Every group of pre-service teachers conducted one activity devoted to digital news analysis and one more on the creation of TikToks.

2.2.1. Digital News Critical Analysis

To foster scientific and media literacy among pre-service teachers, the first ICT-supported activity centred on the critical analysis of a journalistic article related to chemistry. All three pre-service teacher groups (A, B, and C) participated in this task, which was designed to encourage reflection on the presence of chemistry in everyday life and to develop the cognitive skills necessary to evaluate science-related media.

Students were asked to apply a guided analysis framework to the article titled in English "Should new clothes be washed before wearing them?" [60]. This article, which discusses the presence of potentially harmful chemicals in new garments, provided an accessible entry point for exploring chemistry concepts within a socially relevant context.

The framework for analysis was adapted from the literature [61] and consisted of six dimensions, each associated with a set of guiding questions and targeted cognitive skills:

1. Claim, issue, or scientific model involved: Students identified the central claim or problem presented in the article and linked it to relevant scientific content, such as chemical residues in textiles and the concept of toxicity or exposure risk. This encouraged them to recognise scientific issues embedded in everyday scenarios.
2. Author's role: Learners considered who wrote the article and reflected on the possible intentions behind it. This step aimed to develop students' ability to infer authorial purpose and question the neutrality of science communication.
3. Underlying ideas or beliefs: Students discussed the values or beliefs that might have influenced the writing of the article, recognising that scientific reporting is not always free from ideological influence.
4. Testing the claim: The students were invited to formulate scientifically investigable questions that could test the article's main assertion. For example, they proposed hypothetical experiments to detect chemical substances in clothing and assess their potential health effects.
5. Evidence and data provided: This dimension asked students to identify and evaluate the information and evidence used in the article to support its claims. They compared these with their own scientific knowledge and judged the credibility of the data sources.
6. Conclusions and scientific validity: Finally, students reflected on whether the article's conclusions aligned with their understanding of current scientific consensus. They were encouraged to articulate agreements or disagreements with the conclusions, justify their positions with scientific reasoning, and consider the broader societal implications of the issue.

This activity served multiple educational goals. It allowed future teachers to critically engage with real-world texts, appreciate the socioscientific dimensions of chemistry, and practise key analytical and inferential skills. Moreover, it supported the development of pedagogical strategies for integrating media analysis into primary science teaching, reinforcing the idea that scientific literacy extends beyond the classroom and into students' lived experiences.

2.2.2. Creation of TikToks on Dalton's Atomic Postulates

Two groups of pre-service teachers (Groups A and B) were tasked with designing and producing TikTok videos to explain one of Dalton's atomic postulates. TikTok, a widely used video-based social media platform, offers an engaging format for the creation and dissemination of short, student-generated audiovisual content.

This activity aimed to consolidate students' understanding of key chemistry concepts while fostering creativity, collaboration, and engagement. It was implemented following a structured pedagogical approach focused on Dalton's atomic theory, which had been introduced through collaborative work using coloured clips and schematic figures [62]. Students were guided to analyse visual prompts such as the following:

"We can observe two atoms of A and four atoms of B both before and after the arrow. The symbolic representation of this reaction is therefore: $2A + 4B \rightarrow 2AB_2$."

These tasks enabled students to visualise atomic-level processes, understand the conservation of matter, and critically evaluate chemical representations.

Once students had developed a solid grasp of Dalton's postulates, each group selected one postulate to illustrate and explain in a short video of up to 60 s, created using the TikTok app. To support their explanations, students were encouraged to incorporate the same coloured clips or atomic 3D models provided by the instructor. These videos were then shared within the classroom environment to facilitate peer learning and discussion, reinforcing conceptual understanding through a creative, collaborative format.

2.2.3. Creation of TikToks Based on Previous Science Learning Experiences at School

The third group of pre-service teachers (Group C) engaged in a collaborative TikTok activity with a different focus—this time on reflecting on their own science learning experiences from school. The aim was to encourage metacognitive reflection and foster an understanding of how personal educational trajectories influence future teaching approaches.

Working in small groups, students were asked to engage in a deep discussion around five reflective prompts:

1. The three most prominent characteristics they recall about how science was taught during their school years.
2. In their view, three features of what would constitute a desirable science education.
3. What strategies or activities they remember using to learn science.
4. How they used to demonstrate that they had learned science.
5. What learning means to them now, and how they currently recognise that they have learned something.

After discussing these questions, each group produced a TikTok video (maximum 60 s) summarising their reflections. The activity not only encouraged students to critically examine traditional approaches to science education, but also to envision and express more engaging, student-centred alternatives. By using a familiar digital platform in a reflective context, the task supported emotional engagement and peer connection while highlighting the evolving perceptions of science teaching and learning among future educators.

2.3. Survey Instrument and Assessment

2.3.1. Pre-Service Teacher Satisfaction Questionnaire

At the end of the course, a questionnaire created ad hoc was administered via a Google Form to assess pre-service teachers' perceptions of the learning experience. The instrument comprised 21 items, combining both closed-ended and open-ended questions. Closed-ended items used a 5-point Likert scale (1 = "Very unsatisfactory" to 5 = "Very satisfactory"). The full questionnaire, originally developed in Spanish, is included in Appendix A.

At the beginning of the form, pre-service teachers were presented with the following consent statement (translated from Spanish): "I consent to my responses being treated anonymously and used only in research aimed at improving student teaching and learning. Under no circumstances will the identity of any student be revealed." Participants were asked to indicate whether they consented to the use of their responses for research purposes. While all students were able to view and complete the questionnaire regardless of their choice, only the data from those who explicitly gave consent were included in the analysis. This approach ensured compliance with ethical standards concerning anonymity and voluntary participation.

As another issue to be considered, while the course included two main ICT-supported activities—critical analysis of digital news and the creation of TikTok videos—the questionnaire focused predominantly on the news-based activity. This emphasis reflects the growing importance of enhancing media literacy in science education, and the value of critically engaging with socioscientific issues in the media to foster scientific reasoning and civic awareness among future educators [16].

Accordingly, the survey explored participants' views on various aspects of the news activity, including its organisation, the adequacy of learning resources, methodological relevance, and its applicability to their future teaching practice. Although the TikTok activity was not the central focus of the questionnaire, one multiple-choice item asked pre-service teachers to indicate which of the two activities they found more appealing. This provided comparative insight into the motivational potential of both instructional approaches.

2.3.2. Assessment of Pre-Service Teachers' Activities

Each group of pre-service teachers was required to collaboratively design and maintain a digital portfolio of activities, documenting and reflecting on their learning process. The groups, consisting of three to seven members, were self-formed by the students themselves, typically based on their relationships.

Students were free to choose the digital platform most suitable for their needs, provided it allowed for submission to the course instructor for assessment. Prior agreement with the instructor regarding the chosen application or software was required to ensure consistency and accessibility. The general structure and required components of the digital portfolio can be found in Appendix B.1.

It is important to note that Groups A and B were enrolled in a subject specifically focused on chemistry within initial teacher education, including laboratory practice sessions. In contrast, Group C participated in a course on Science Education, where their primary task involved developing either a STEM-based educational project or a service learning project. As a result, the design of the activities to be included in the digital portfolio slightly differed. Nevertheless, a further common requirement across all three groups was the inclusion of a mandatory pedagogical reflection on the digital news activity. This reflection required pre-service teachers to critically assess elements such as pacing, time investment, resources used, emerging conceptual gaps, perceived difficulty, and skills developed during the activity. The full rubric is available in Appendix B.2 (Table A1).

Regardless of group, the digital portfolio accounted for 40% of the final grade in each respective course.

3. Results

A total of 138 pre-service teachers participated in the ICT-supported activities; however, only 77 completed the post-course questionnaire, yielding a response rate of approximately 56%. The following subsections present the results of both descriptive and inferential analyses of the Likert-scale-based items, including an assessment of the instrument's validity and reliability, summary statistics for all 18 items, and detailed response distributions across the three studied dimensions: course organisation, methodology and resources, and the digital news activity. Additionally, responses to the open-ended questions and the multiple-choice item comparing the digital news and TikTok activities are analysed. Finally, an overview of the general results drawn from the pre-service teachers' digital portfolios is provided.

3.1. The Validity and Reliability of the Questionnaire

To assess the internal consistency and construct validity of the Likert-scale part of the questionnaire, reliability analyses were conducted using Cronbach's alpha. The overall reliability of the 18 Likert-scale items was high ($\alpha = 0.922$), indicating strong internal consistency. As mentioned above, the questionnaire was structured into three thematic sections: (1) organisation of the course, (2) classroom, methodology, and resources, and (3) the impact and applicability of the activity involving digital news. Reliability within each section ranged from acceptable to excellent, with Cronbach's alpha values of 0.704 (after removal of item Q4 with a squared multiple correlation below 0.2), 0.829, and 0.921, respectively. The decision to exclude the aforementioned item was based on its low squared multiple correlation ($SMC < 0.2$), suggesting it did not align well with the construct measured. Despite its exclusion from the reliability analysis, descriptive statistics for this item are reported for transparency, see Table 1. These results support the validity and reliability of the instrument for evaluating students' perceptions of the course activities.

Table 1. Descriptive statistics (mean and standard deviation) of pre-service teachers' ratings of course organisation, the methodology, and the digital news activity.

Items	Group A (n = 28)		Group B (n = 28)		Group C (n = 21)		Total (N = 77)	
	M	SD	M	SD	M	SD	M	SD
Q1	4.46	0.64	4.36	0.73	4.48	0.81	4.43	0.72
Q2	4.21	0.74	4.61	0.57	4.52	0.81	4.44	0.72
Q3	4.61	0.79	4.82	0.39	4.52	0.98	4.66	0.74
Q4 *	3.25	1.17	3.89	1.10	4.52	0.75	3.83	1.15
Q5	4.39	0.79	4.32	0.82	4.24	1.18	4.32	0.91
Q6	4.32	0.90	4.61	0.57	4.48	1.03	4.47	0.84
Q7	4.18	0.90	3.21	1.29	4.33	1.24	3.87	1.24
Q8	4.50	0.79	4.25	0.80	4.52	0.93	4.42	0.83
Q9	4.54	0.69	4.57	0.57	4.67	0.91	4.58	0.71
Q10	4.25	0.84	4.32	0.72	4.33	0.80	4.30	0.78
Q11	4.50	0.64	4.50	0.58	4.52	0.75	4.51	0.64
Q12	4.54	0.58	4.57	0.69	4.67	0.80	4.58	0.68
Q13	4.46	0.64	4.71	0.46	4.52	0.98	4.57	0.70
Q14	4.18	0.86	4.36	0.68	4.33	1.06	4.29	0.86
Q15	4.04	0.92	4.18	0.77	4.48	0.81	4.21	0.85
Q16	4.25	0.89	4.25	0.65	4.29	0.85	4.26	0.78
Q17	4.25	0.93	4.37	0.63	4.38	0.80	4.33	0.79
Q18	4.43	0.74	4.32	0.61	4.50	0.76	4.41	0.70

* Note: Q4 was excluded from the internal consistency analysis due to a squared multiple correlation below 0.2. It is included here for completeness and transparency.

3.2. Descriptive and Inferential Analysis of the Likert-Scale Items

Descriptive statistics, including mean scores and standard deviations, were calculated to summarise pre-service teachers' responses to the 18 Likert-scale items (see Table 1).

Shapiro–Wilk tests indicated significant departures from normality for all Likert-scale items ($p < 0.05$) across all groups (A, B, and C), supporting the use of non-parametric tests for group comparisons. Accordingly, Kruskal–Wallis tests were employed (item Q4 was excluded from the internal consistency evaluation). Hence, this test identified statistically significant differences between groups for item Q7—related to the availability of technical resources ($H = 13.88, p = 0.001$). Post hoc Mann–Whitney U tests with Bonferroni correction ($\alpha = 0.0167$) revealed that Group B reported significantly lower satisfaction than both Group A ($p = 0.004, Z = -2.877$) and Group C ($p = 0.001, Z = -3.241$), while no significant difference was found between Groups A and C ($p = 0.218, Z = -1.231$). To further examine the statistically significant differences identified in the Kruskal–Wallis test for item Q7, post hoc Mann–Whitney U tests were conducted with Bonferroni correction (adjusted $\alpha = 0.0167$). Effect sizes were calculated using the formula $r = Z/(N)^{-1/2}$, where N is the combined sample size of the compared groups. The results revealed a small effect for the comparison between Groups C and A ($r = 0.176$), a medium effect for Groups A and B ($r = 0.381$), and a medium to large effect for Groups C and B ($r = 0.458$). These findings suggest that the lower satisfaction with technical resources reported by Group B, particularly concerning Wi-Fi availability, was not only statistically significant but also practically meaningful.

3.3. Percentage Distributions of the Likert-Scale Items

The percentage results of the Likert-scale responses are presented according to the three studied themes—course organisation, methodology and resources, and the activity involving digital news—in the following subsections.

3.3.1. Organisation of the Course

This subsection presents the percentage distribution of responses to the five items (Table 2) related to the organisation of the course (see Appendix A). These items focus on the clarity and adequacy of the course guide, the overall course structure, group sizes for collaborative activities, the duration of the course in relation to its objectives and content, and the suitability of the timetable for encouraging attendance.

Table 2. Percentages (%) of pre-service teachers' ratings on course organisation.

Items	Grade of Satisfaction	Group A (n = 28)	Group B (n = 28)	Group C (n = 21)	Total (N = 77)
Q1	Unsatisfactory ¹	0.0	3.6	4.8	2.6
	Neutral	7.1	3.6	4.8	5.2
	Satisfactory ²	92.9	92.9	90.5	92.2
Q2	Unsatisfactory ¹	0.0	0.0	4.8	1.3
	Neutral	17.9	3.6	4.8	9.1
	Satisfactory ²	82.1	96.4	90.5	89.6
Q3	Unsatisfactory ¹	3.6	0.0	4.8	2.6
	Neutral	7.1	0.0	4.8	3.9
	Satisfactory ²	89.3	100.0	90.5	93.5
Q4 *	Unsatisfactory ¹	28.6	14.3	0.0	15.6
	Neutral	25.0	21.4	14.3	20.8
	Satisfactory ²	46.4	64.3	85.7	63.6
Q5	Unsatisfactory ¹	3.6	0.0	14.3	5.2
	Neutral	7.1	21.4	0.0	10.4
	Satisfactory ²	89.3	78.6	85.7	84.4

* Note: Q4 was excluded from the internal consistency analysis due to a squared multiple correlation below 0.2. It is included here for completeness and transparency. ¹ Unsatisfactory or very unsatisfactory. ² Satisfactory or very satisfactory.

With the exception of item Q4—which was excluded from the validity analysis due to low item reliability—overall satisfaction levels across the remaining items in this dimension were notably high. The percentage of participants selecting “Satisfactory” or “Very satisfactory” (responses 4 and 5) ranged from 84.4% to 93.5%. Neutral responses (score 3) ranged from 3.9% to 10.4%, while dissatisfaction (responses 1 and 2, “Unsatisfactory” or “Very unsatisfactory”) remained low, between 1.3% and 5.2%. When broken down by group, the distribution of satisfaction levels was as follows:

Group A reported 82.1–92.9% satisfaction (responses 4 and 5), 7.1–17.9% neutral responses, and 0–3.6% dissatisfaction (responses 1 and 2).

Group B showed a satisfaction range of 78.6–100%, with neutral responses ranging from 0% to 21.4% and dissatisfaction between 0% and 3.6%.

Group C reported satisfaction levels between 85.7% and 90.5%, neutral responses from 0% to 4.8%, and higher levels of dissatisfaction compared to the other groups, ranging from 4.8% to 14.3%.

These group-specific findings are largely consistent with the overall results, confirming a generally high level of satisfaction with the organisational aspects of the course across the cohort.

3.3.2. Classroom, Methodology, and Resources

This subsection summarises the percentage results for the seven items (Table 3) concerning the physical and pedagogical learning environment. The evaluated aspects include the adequacy of the classroom and furniture, the availability of technical resources, the relevance and effectiveness of the teaching methodology, the balance between theoretical

and practical components, the perceived interest of the course content, the suitability of the proposed learning activities, and the quality of the documentation provided.

Table 3. Percentages (%) of pre-service teachers' ratings on classroom, methodology, and resources.

Items	Grade of Satisfaction	Group A (n = 28)	Group B (n = 28)	Group C (n = 21)	Total (N = 77)
Q6	Unsatisfactory ¹	7.1	0.0	4.8	3.9
	Neutral	7.1	3.6	9.5	6.5
	Satisfactory ²	85.7	96.4	85.7	89.6
Q7	Unsatisfactory ¹	3.6	32.1	9.5	15.6
	Neutral	21.4	21.4	4.8	16.9
	Satisfactory ²	75.0	46.4	85.7	67.5
Q8	Unsatisfactory ¹	3.6	3.6	4.8	3.9
	Neutral	7.1	10.7	0.0	6.5
	Satisfactory ²	89.3	85.7	95.2	89.6
Q9	Unsatisfactory ¹	3.6	0.0	4.8	2.6
	Neutral	0.0	3.6	0.0	1.3
	Satisfactory ²	96.4	96.4	95.2	96.1
Q10	Unsatisfactory ¹	3.6	0.0	4.8	2.6
	Neutral	14.3	14.3	4.8	11.7
	Satisfactory ²	82.1	85.7	90.5	85.7
Q11	Unsatisfactory ¹	0.0	0.0	4.8	1.3
	Neutral	7.1	3.6	0.0	3.9
	Satisfactory ²	92.9	96.4	95.2	94.8
Q12	Unsatisfactory ¹	0.0	0.0	4.8	1.3
	Neutral	3.6	10.7	4.8	6.5
	Satisfactory ²	96.4	89.3	90.5	92.2

¹ Unsatisfactory or very unsatisfactory. ² Satisfactory or very satisfactory.

For this case, the percentage of participants selecting “Satisfactory” or “Very satisfactory” (responses 4 and 5) ranged from 67.5% to 96.1%, with Q7—regarding the availability of technical resources (e.g., projector, Wi-Fi)—having a notably lower satisfaction rate of 67.5%. All other items in this dimension achieved satisfaction rates above 85%. Neutral responses (score 3) ranged from 1.3% to 16.9%, with question Q7 again recording the highest neutral percentage at 16.9%. Dissatisfaction (responses 1 and 2) was generally low, between 1.3% and 15.6%, with item Q7 reaching the upper limit at 15.6%. This lower satisfaction aligns with known issues in some classrooms, particularly for Group B, where the university Wi-Fi connection was reported to be unreliable. This result aligns with the statistical analysis described in Section 3.2. When examined by group, the following observations were made:

Group A reported satisfaction levels between 75.0% and 96.4%, neutral responses from 0% to 21.4%, and dissatisfaction ranging from 0% to 7.1%.

Group B showed a wider range of satisfaction from 46.4% to 96.4%, with neutral responses between 3.6% and 21.4%, and dissatisfaction ranging up to 32.1%. Regarding question 7, satisfaction stood at 46.4%, neutral responses at 21.4%, and dissatisfaction at 32.1%, highlighting significant concerns about technical resources for this group.

Group C demonstrated satisfaction rates from 85.7% to 95.2%, neutral responses between 0% and 9.5%, and dissatisfaction rates from 4.8% to 9.5%.

Overall, while satisfaction was generally high across this dimension, issues with technical resources (item Q7) notably impacted participant perceptions, especially in Group B, confirming the importance of addressing these infrastructure challenges to support effective course delivery.

3.3.3. Activity Involving Digital News

This subsection presents the percentage results (Table 4) related to the perceived impact and educational value of the digital news activity. The six items explored whether the activity contributed new knowledge or skills, its relevance to future teaching practice, its influence on the use of media—particularly digital newspapers—the extent to which it met students' expectations, their willingness to recommend it to others, and their overall evaluation of the experience.

Table 4. Percentages (%) of pre-service teachers' ratings on activity involving digital news.

Items	Grade of Satisfaction	Group A (n = 28)	Group B (n = 28)	Group C (n = 21)	Total (N = 77)
Q13	Unsatisfactory ¹	0.0	0.0	4.8	1.3
	Neutral	7.1	0.0	4.8	3.9
	Satisfactory ²	92.9	100.0	90.5	94.8
Q14	Unsatisfactory ¹	3.6	0.0	9.5	3.9
	Neutral	17.9	10.7	0.0	10.4
	Satisfactory ²	78.6	89.3	90.5	85.7
Q15	Unsatisfactory ¹	3.6	0.0	4.8	2.6
	Neutral	28.6	21.4	4.8	19.5
	Satisfactory ²	67.9	78.6	90.5	77.9
Q16	Unsatisfactory ¹	3.6	0.0	4.8	2.6
	Neutral	17.9	10.7	9.5	13.0
	Satisfactory ²	78.6	89.3	85.7	84.4
Q17	Unsatisfactory ¹	3.6	0.0	4.8	2.6
	Neutral	21.4	7.1	4.8	11.7
	Satisfactory ²	75.0	89.3	90.5	84.4
Q18	Unsatisfactory ¹	0.0	0.0	4.8	1.3
	Neutral	14.3	7.1	0.0	7.8
	Satisfactory ²	85.7	92.9	90.5	89.6

¹ Unsatisfactory or very unsatisfactory. ² Satisfactory or very satisfactory.

For this dimension, the percentage of participants selecting “Satisfactory” or “Very satisfactory” (responses 4 and 5) ranged from 77.9% to 94.8%. Neutral responses (score 3) varied between 3.9% and 19.5%, while dissatisfaction (responses 1 and 2) remained low, ranging from 1.3% to 3.9%. Broken down by group, the following observations were made:

- Group A reported satisfaction levels ranging from 67.9% to 92.9%, with neutral responses between 7.1% and 28.6%, and dissatisfaction ranging from 0% to 3.6%.
- Group B showed satisfaction rates from 78.6% up to 100%, neutral responses between 0% and 21.4%, and no reported dissatisfaction (0%).
- Group C demonstrated satisfaction levels from 85.7% to 90.5%, neutral responses ranging from 0% to 9.5%, and dissatisfaction between 4.8% and 9.5%.

Overall, satisfaction with the impact and applicability of the digital news activity was high across all groups, although Group A exhibited a somewhat broader spread of neutral responses and Group C showed slightly higher levels of dissatisfaction compared to the others.

3.4. Personal Opinions (Open-Ended and Multiple-Choice Questions)

3.4.1. Preferences Between Activities: Multiple-Choice Question

To explore participants' preferences between the two main ICT-supported activities, a multiple-choice question asked “Which activity did you find most interesting?” (Q21, see Appendix A). The response options were as follows: (a) the activities with digital

newspaper articles, (b) the activity using TikTok, (c) both activities equally, and (d) neither the press nor the TikTok activity.

Overall (see Table 5), the majority of pre-service teachers (59.7%) selected the TikTok activity as the most interesting, followed by 29.9% who valued both activities equally. A smaller proportion preferred the digital news activity (7.8%), and only 2.6% reported that neither activity was particularly interesting. When disaggregated by group, the following observations were made:

- Group A showed a 57.1% preference for TikTok, 25% for both activities equally, 10.7% for digital news, and 7.1% for neither activity.
- Group B showed a stronger preference for TikTok (64.3%), 25% for both, and 10.7% for digital news, with no participants selecting “neither”.
- Group C, by contrast, revealed a different trend: 42.9% reported liking both activities equally, while 57.1% selected TikTok, and none chose digital news or neither.

Table 5. Percentages of pre-service teachers’ responses to multiple-choice question (Q21).

Options	Group A (<i>n</i> = 28)	Group B (<i>n</i> = 28)	Group C (<i>n</i> = 21)	Total (<i>N</i> = 77)
Digital news activity	10.7	10.7	0.0	7.8
TikTok activity	57.1	64.3	12.0	59.7
Both activities	7.0	25.0	42.9	29.9
None of them	7.1	0.0	0.0	2.6

A chi-square test of independence was conducted to examine potential differences among the three groups in their responses to the multiple-choice question (Q21). The results indicated no statistically significant association between group membership and activity preference, $\chi^2(6, N = 77) = 7.533, p = 0.274$.

These results suggest a clear overall preference for the TikTok-based activity, with some variation across groups and a notable proportion recognising value in both instructional approaches.

3.4.2. Open-Ended Responses (Q19 and Q20)

To complement the quantitative findings, participants’ responses to the two open-ended questions were thematically analysed. Selected verbatim comments have been translated from Spanish into English and are included below to illustrate key themes and provide deeper insight into the pre-service teachers’ perceptions. For context, the group (A, B, or C) of each participant is indicated alongside their respective quote. These comments were chosen to reflect common patterns, highlight particularly insightful views, and preserve the tone and intent of the original responses.

Regarding the first open question (Q19), which asked about the positive aspects of the activities with digital news articles (see Table 6), pre-service teachers across Groups A, B, and C highlighted several key strengths of the digital news-based activities: (1) students frequently noted the value of learning to assess the credibility of information, (2) many appreciated how the content linked science to real-life contexts, (3) several participants found the approach refreshing and engaging, (4) many noted the activities’ potential classroom use and relevance to future teaching, and (5) several participants reported learning things they did not previously know.

Table 6. Thematic categorisation of pre-service teachers' verbatim comments on digital news activities.

Category	Verbatim Comments (Translated)
Development of critical thinking and source evaluation	"It allowed us to learn to be more critical with what we read and to search for information to compare." (Group B). "Reflecting on the sources used in articles helps develop critical thinking about what we read in the press." (Group B). "The critical analysis of the press and applying science to everyday life." (Group A).
Connection to real-world and everyday issues	"Working with real news that makes learning more meaningful and helps us see its utility." (Group B). "Addressing real-world problems that affect people today, among students themselves." (Group A). "The news articles help connect science with reality and social issues." (Group C).
Engagement and motivation through innovative approaches	"It's a different way of working on the subject, which makes it more motivating." (Group B). "The curiosity the article sparked." (Group A). "We used applied digital tools, which made the learning more entertaining." (Group A).
Pedagogical relevance and applicability	"Very practical for daily life and useful for primary students." (Group B). "It's interesting to carry out a guided integration of technology with content." (Group C).
Acquisition of new knowledge and perspectives	"I learned something I didn't know before." (Group B). "It helped me to see the negative side of science, which I had always seen as positive." (Group C).

Regarding the second open question (Q20) (see Table 7), aspects for improvement in the digital news activities, although feedback was mostly positive, participants identified some areas needing refinement: (1) the most frequent concern was the lack of internet access in classrooms, particularly for Groups A and B, (2) some students suggested expanding the range of news topics, (3) a few respondents pointed to the need for more time or shorter texts, (4) one student felt that the activity could have benefited from deeper classroom discussion, and (5) one participant expressed discomfort with the subject matter.

Table 7. Thematic categorisation of pre-service teachers' verbatim comments on aspects for improvement in digital news activities.

Category	Verbatim Comments (Translated)
Technical limitations	"The Wi-Fi didn't work when we did the activity, which made it difficult." (Group B). "Sometimes the Wi-Fi wasn't working." (Group A). "The problem with the internet in some cases." (Group B).
Content variety and thematic focus	"Include more varied topics or news related to education as well as science." (Group C). "It would be better to cover more topics that affect future generations, like the climate crisis." (Group C).
Time allocation and activity structure	"Shorter news articles." (Group C). "The time spent on the activity." (Group A and C).
Need for more debate or discussion	"There should have been a short debate about what we thought of the article—whether it was exaggerated or realistic." (Group A).
Emotional response to content	"What I read made me feel uneasy." (Group A)

3.5. Analysis of Pre-Service Teachers' Digital Portfolios

A total of 30 subgroups ($N = 138$), each consisting of between three and seven students, participated in the development of digital portfolios as part of their respective subject modules—Chemistry (Groups A and B) and Science Education (Group C). As outlined in Section 2.3.2, all groups were required to include a description and reflection on an activity focused on the analysis of a digital news article, along with two additional activities of their choice. In this context, 19 groups voluntarily selected the TikTok-based task as one of the most significant elements to include in their portfolios.

The digital portfolios were created using a variety of platforms, reflecting both student preferences and technological familiarity: Google Sites [63] was the most frequently

used (11 groups), followed by Exelearning [64] (8 groups), PDF format documents [65] (7 groups), Canva [66] (4 groups), and Wixsite [67] (1 group). Beyond content, the portfolios themselves were a subject of reflection. Several subgroups commented on the autonomy and engagement promoted by the digital format, noting that it allowed them to “learn independently” and “move away from traditional learning” methods. Others highlighted the value of including diverse and interactive resources, recognising that portfolios of this nature “not only help in acquiring knowledge related to chemistry, but also introduce a transversal component” and “prepare students for real-life scenarios.”

This analysis explores both the format and substance of these portfolios, considering how students across the aforementioned activities pay attention to their reflective comments and conclusions.

3.5.1. Groups A and B (Chemistry Subject)

The responses from Groups A ($n = 54$, 12 subgroups) and B ($n = 37$, 8 subgroups) reveal a high level of engagement with the digital news and TikTok-based activities, highlighting their pedagogical value and relevance to both scientific understanding and everyday life.

Regarding the digital news task, participants from Group A viewed the activity as intellectually stimulating and socially meaningful. One group noted that “the issue raised by this article seemed of great interest to us, and raising such questions with our students, which go beyond mere reading, is fundamental when working in the classroom.” Another valued the multifaceted learning opportunity it presented: “through this activity, reading comprehension, cooperative work and writing, among many other aspects, are addressed.” Students appreciated the connection between scientific literacy and informed decision-making, stating that “we can infer the importance that science and its advances have in everyday life, and how important it is to have the necessary information to be able to act accordingly.”

Group A also praised the interdisciplinary potential of the task, with one group asserting that “activities of this kind are not only necessary for acquiring knowledge related to the subject of chemistry, but also add a transversal component.”

Meanwhile, Group B echoed similar sentiments, focusing on the benefits of contextualising chemistry within relatable frameworks. One group emphasised that “issues like these are very beneficial when teaching chemistry in the classroom, as it starts from a familiar context and a simple concept for students.” Importantly, future teachers acknowledged the task’s role in fostering critical thinking: “as future teachers, we must try to make our students critical and discerning people. . . Activities like this one are a good way to learn to be that.”

Turning to the TikTok activity, students in both groups appreciated the creative and collaborative nature of the task. Group A acknowledged initial challenges—“the content of the activity was a bit complex, after all we had to first understand what each postulate meant in order to carry it out”—but noted that the opportunity to share their videos with peers and their instructor was highly motivating.

Many valued the way TikTok aligned with students’ digital habits, remarking that “working on chemistry content through audiovisual activities such as TikTok is a way to better reach students, through a platform they use daily and are familiar with, while also having fun learning.” One group further explained that “thanks to using TikTok, we worked on cooperation, renewed the way students can work, adapted to digitalisation, and developed innovation and creativity by seeking different ways to represent a message originally.” These experiences were echoed by Group B, who highlighted TikTok’s potential for fostering “positive emotions, which are key to promoting learning—in this case, of chemistry.” Students also showed an awareness of the pedagogical implications of such

digital tools, noting that “using TikTok can help develop students’ creativity and innovation, contributing to more dynamic didactic interventions.” While some pointed out technical constraints—“in our case, the 30-s limit complicated things a bit. . . however, we realised that by synthesising the key points, we had even more time than needed”—the overall response was highly positive. The activity was described as “very interesting and enriching,” and one group even suggested creating a school-wide TikTok account to foster peer learning across classes.

In both tasks, the responses from Groups A and B highlight not only the effectiveness of integrating real-world contexts and digital tools in science education, but also the critical and reflective capacities these activities can cultivate in pre-service teachers. They demonstrate a growing recognition of the value of innovative pedagogical strategies that promote active learning, encourage collaboration, and integrate digital tools.

3.5.2. Group C (Science Education Subject)

The analysis of Group C’s digital portfolios ($n = 47$, 10 subgroups) reveals rich engagement with scientific literacy through innovative, reflective, and contextually grounded activities. The digital news task, a mandatory component, was particularly effective in fostering critical thinking and connecting science to everyday life.

Several students acknowledged their initial unawareness of complex topics such as the environmental and health impacts of clothing manufacturing, stating that “we realised how little we actually knew about the process of making a garment and everything it entails before it reaches us,” and noting how the activity allowed them to “connect our own experiences with the scientific explanations offered in the article.” This activity was consistently praised for its ability to contextualise science, with one group remarking that it “connects Natural Sciences with real life in a direct way—something any student would wish for in their science education.”

Beyond content acquisition, the activity also encouraged cognitive and metacognitive reflection. Students highlighted the development of synthesis and critical communication skills, as well as empathy through perspective-taking, explaining that “reflecting on the author’s perspective develops empathy, and analysing their arguments helps improve critical communication.” One group explicitly described the experience as “a metacognitive exercise that allowed us to recognise what we learned, what we struggled with, and why we didn’t achieve some cognitive skills.”

The TikTok activity, chosen by five of the ten subgroups as one of their most meaningful tasks, further exemplified how digital media can be leveraged for educational purposes. Students were generally enthusiastic about the platform’s potential, noting that “social media can be useful for learning” and that its use “fosters interaction and creates a sense of community.” However, participants also demonstrated critical awareness, cautioning that “not all information online is true, so [students] must be critical and reflective.” The activity promoted creativity and engagement, as one student observed that “Some chose dances, others songs or theatre. . . This app is a great educational tool. It encourages creativity, curiosity, and fun learning.” Importantly, the exercise was not perceived as merely entertaining; it prompted introspection, with students reflecting on their own experiences with science learning and acknowledging the role of affect in learning, stating that “We didn’t just learn content—we understood why it matters.” The TikTok activity was also seen as a way of bridging generational and cultural gaps with future students, as one group commented that “Making this kind of video brought us closer to our future students. It was a challenge, since we had never used TikTok for class before.” The associative nature of memory was highlighted as a pedagogical benefit, with participants noting how “we linked all the content from theory and practice and built a meaningful learning process.”

Finally, the global reflections across the digital portfolios painted a coherent picture of an innovative and empowering learning environment. Activities were described as “interconnected” and “dynamic,” fostering student autonomy and collaboration. Participants felt that they were not simply recipients of knowledge, but active agents in the learning process: “Each task was unique and required cooperative work. We were the ones adjusting the learning to our reality.” Many referred to the experience as transformative, pointing to the “significant learning that we haven’t forgotten” and a growing sense of professional identity as future educators. The integration of digital tools was not seen as superficial or trend-driven but as deeply pedagogical, contributing to inclusive, reflective, and meaningful science education.

4. Discussion

The results presented in the previous section offer substantial insight into pre-service teachers’ perceptions of integrating digital tools—specifically digital news articles and TikTok—into science education. These findings address the first research question (RQ1) by highlighting how participants engaged with and perceived the educational value of these activities. Overall, students expressed positive and nuanced views, recognising not only the technological appeal of these tools but also their pedagogical potential to foster critical thinking, creativity, and motivation.

At the same time, the analysis of digital portfolios provides a deeper understanding of the second research question (RQ2), illustrating how such portfolios supported reflective practice in the context of these ICT-supported activities. Across groups, portfolios served not only as a platform for documenting learning but also as a space for metacognitive reflection, professional identity development, and collaborative meaning-making. The combination of these tools and reflective spaces points toward a broader shift in how digital technologies can shape both instructional approaches and teacher learning in science education. The following subsections discuss in more detail the potential of using digital news to foster engagement with SSIs, participants’ perceptions of the digital news activity compared to the TikTok-based task, and the role of digital portfolios in supporting meaningful reflection.

4.1. Digital News and Socioscientific Issues

The results of this study demonstrate that the use of digital news articles in science education was well received by pre-service teachers, particularly for its ability to connect scientific content with real-world and socially relevant issues. This aligns with growing recognition in the literature that addressing complex, real-world problems is a key strategy for fostering scientific literacy [22]. Many participants explicitly valued the opportunity to engage with content that was relevant to their lives and the broader social context. For instance, comments such as “The news articles help connect science with reality and social issues” (Group C) and “Addressing real-world problems that affect people today” (Group A) reflect the positive reception of socioscientific content.

SSIs are not the only path to promoting scientific literacy, but they offer a powerful framework for stimulating intellectual and social development in students [16]. By involving learners in the critical evaluation of media, data, and conflicting viewpoints, SSI-based approaches help build students’ capacity for informal reasoning, argumentation, and evidence-based decision-making—competencies that are essential for citizenship in a scientifically complex world [68]. As some participants noted, the activity encouraged them to become more critical and discerning consumers of information: “It allowed us to learn to be more critical with what we read and to search for information to compare” (Group B).

From a pedagogical perspective, the integration of digital news also supports contextualized learning, which is especially important in disciplines like chemistry that are often perceived as abstract and disconnected from everyday life [69].

Despite these benefits, the shift toward teaching with SSIs remains challenging for educators. Research highlights that teachers often resist new pedagogical approaches, particularly those that require a repositioning of their role—from knowledge transmitters to facilitators of student-led inquiry [22]. The interdisciplinary and controversial nature of many SSI topics also demands that teachers draw on broad competencies, including pedagogical content knowledge, life experiences, and familiarity with societal contexts [20]. One participant's reflection—"It's interesting to carry out a guided integration of technology with content" (Group C)—suggests a growing openness to such practices, especially when appropriate support and structure are provided.

Importantly, this pedagogical model encourages not only cognitive but also social-emotional development. Students involved in SSI-based learning tend to develop empathy, a stronger sense of responsibility, and a heightened awareness of their roles as citizens [70]. These outcomes are further enhanced through collaboration, as students learn to navigate diverse perspectives and communicate effectively [71]. The digital news activity in this study often involved group work and discussion, which several participants cited as positive aspects of the experience.

Finally, the findings reinforce the need for chemistry education—and science education more broadly—to prepare students to engage critically with science in society. In fact, science teaching should contribute to forming well-informed citizens who are capable of analysing complex problems, making reasoned decisions, and assuming social responsibility [17]. The use of real-world news articles as a pedagogical tool thus represents a valuable step toward this goal.

4.2. TikTok as Didactic Tool in Chemistry Education

The second activity, which involved the creation of educational TikToks, elicited largely positive responses from pre-service teachers. While some participants found the task challenging—particularly due to time constraints and a lack of experience with video editing—many highlighted the engaging and creative nature of the activity, as reflected in the results of the multiple-choice question. Notably, preferences for the TikTok activity varied by group, depending on the nature of the video content created.

In addition to the activity on digital news, Groups A and B developed TikToks on Dalton's atomic postulates, thus engaging directly with core chemical content. Group A showed a 57.1% preference for the TikTok activity, 25% selected both activities—TikTok and digital news—equally, 10.7% preferred digital news, and 7.1% chose neither. Group B demonstrated even stronger enthusiasm for TikTok, with 64.3% favouring it, 25% choosing both, and 10.7% preferring digital news, while no participant rejected both activities. In contrast, Group C, whose TikToks focused on personal reflections about previous science learning experiences rather than disciplinary content, exhibited a slightly different trend: 42.9% liked both activities equally and 57.1% selected TikTok as their preference, with no participants selecting digital news or "neither."

These results suggest that even when the TikTok activity does not involve direct engagement with chemistry content, the platform's format and creative possibilities can still resonate positively with learners. However, the stronger preference for TikTok in Groups A and B may reflect the added pedagogical value and satisfaction derived from successfully simplifying and communicating abstract scientific content through digital media.

TikTok, as a social media application grounded in brief, visually engaging content, represents a powerful didactic tool aligned with the principles of microlearning and nanolearn-

ing. Microlearning involves small, focused learning activities typically lasting between 30 s and 5 min [72], while TikTok's format—usually 15 s to 3 min—makes it ideal for nanolearning [73]. These formats reduce cognitive load, promote knowledge retention, and adapt well to the preferences of today's learners who favour fast, on-demand access to content [74].

Moreover, engaging with TikTok in an educational context has the potential to bridge the gap between abstract scientific concepts and students' lived experiences. Thus, chemistry—often perceived as abstract and difficult—can be rendered more relatable and meaningful through digital storytelling [75]. Pre-service teachers in this study reported that transforming complex topics into concise, accessible videos required them to rethink their understanding of chemical concepts and find innovative ways to communicate them. Likewise, student-created videos offer a powerful mode of learning, as students actively engage in simplifying and translating content into a language their peers understand [75].

In addition to enhancing comprehension, TikTok as a learning medium promotes key 21st-century skills, including creativity, communication, collaboration, and critical thinking [76]. The development of a short, coherent educational video necessitates decision-making, idea exchange, and problem-solving—skills crucial to both scientific reasoning and pedagogical practice.

The motivational aspects of TikTok were also evident in participant responses. The use of music, humour, and audiovisual tools created an enjoyable learning environment, aligning with prior research indicating that social media can enhance engagement and motivation [77].

However, the implementation of TikTok as an educational tool is not without its challenges. Some participants expressed initial discomfort or insecurity, reflecting broader concerns regarding privacy, institutional policies, and the public nature of social media platforms [78]. Educators must take care to ensure that the use of TikTok aligns with ethical guidelines and protects students' personal information. As alternatives, videos could be shared through platforms like YouTube [79] using “unlisted” settings or within institutional learning management systems (LMSs), such as Moodle [80], both of which provide more secure and access-controlled environments. However, a key reason for choosing TikTok in this context was its alignment with students' everyday digital practices. As a platform they already use regularly and feel comfortable navigating, TikTok offers a more engaging and authentic space for creative expression, making it particularly appealing for educational tasks aimed at connecting science content with students' lived experiences. At the same time, many students may be unfamiliar with the platform's educational potential, suggesting a need for guided integration and scaffolding when introducing such activities [78].

Despite these concerns, the potential of TikTok to support innovative science education remains significant. As learners increasingly consume and create media through platforms like TikTok, incorporating these tools into the classroom can make scientific content more accessible and engaging, ultimately helping to develop a new generation of educators who are fluent in both pedagogy and digital communication. As echoed in participant reflections, this activity allowed them to “translate” scientific content into engaging narratives, making chemistry—and science more broadly—feel relevant, dynamic, and accessible to diverse audiences.

4.3. The Role of Digital Portfolios in Supporting Reflection

The analysis of digital portfolios across all three groups (A, B, and C) underscores their strong potential as tools for promoting reflective practice among pre-service teachers [45]. In alignment with RQ2, the findings reveal that digital portfolios served not only as a

medium for documenting and showcasing work but, more importantly, as a space for structured, metacognitive reflection on both the content and pedagogical value of the activities undertaken [81].

Across the portfolios, students engaged in personal and professional reflection, identifying challenges, successes, and meaningful learning outcomes [44]. This was particularly evident in their discussions of the digital news analysis task, which was consistently described as intellectually stimulating and socially relevant. Pre-service teachers articulated how the task helped bridge science content with real-life contexts, encouraging critical thinking, decision-making, and empathy. Their reflective comments went beyond mere description, often including evaluative insights into how the task could be adapted for their own future classrooms. This demonstrates an early capacity for professional reflexivity, a critical skill in teacher development [82].

Furthermore, several groups commented directly on the process of portfolio creation itself as reflective and empowering. The diversity of platforms used (e.g., Google Sites, Canva, PDF, Exelearning) allowed students to exercise autonomy and agency, tailoring the format and content to their own preferences. This freedom contributed to a sense of ownership over their learning and a greater appreciation for non-traditional, student-centred approaches. For many, the portfolio was not merely a repository of tasks but a space for synthesising experience, articulating educational values, and projecting their future teaching identity.

The metacognitive depth evident in some responses—especially those that identified personal learning struggles, emotional engagement, or shifts in perspective—suggests that digital portfolios can effectively scaffold reflection at both the cognitive and affective levels. In several instances, students used the portfolios to connect theory to practice, thereby reinforcing the link between educational knowledge and classroom application.

Taken together, these findings suggest that digital portfolios functioned as catalysts for reflective learning, supporting both individual growth and collaborative understanding. By encouraging students to critically engage with their experiences, assess the impact of their activities, and imagine their future teaching roles [83], the portfolios contributed meaningfully to the development of reflective, digitally competent science educators.

4.4. Limitations, Practical Implications, and Future Work

One key issue identified by participants was unequal access to reliable internet connectivity, though this problem manifested differently across the two activities. The digital news activity required the use of laptops or tablets, which depended more heavily on stable Wi-Fi connections. Participants reported that connectivity problems hindered their ability to access resources, navigate digital news platforms, or complete the activity efficiently. In contrast, the TikTok-based activity was less affected by these issues, as students primarily used their smartphones, which often rely on mobile data. This suggests that smartphone-based microlearning tasks may offer a more accessible and flexible alternative, especially in settings with uneven digital infrastructure.

To address such disparities in future implementations, educators should continue to prioritize mobile-friendly formats and explore offline or pre-downloadable resources—especially for activities involving digital news—to ensure that all students can participate equitably regardless of their connectivity conditions. Moreover, as part of future research, it would be valuable to investigate the impact of these learning activities on academic performance through experimental designs that incorporate control groups. Such studies could provide robust evidence regarding the effectiveness of social media-based microlearning in enhancing conceptual understanding and long-term knowledge retention.

Regarding the survey, a methodological limitation also arose in the evaluation instrument. The item assessing “the duration of the course in relation to its objectives and content” yielded a low squared multiple correlation ($SMC = 0.169$), indicating a weak relationship with the overall satisfaction construct. Its removal modestly improved the internal consistency of the scale (α increased from 0.68 to 0.70). We attribute this to the multidimensional phrasing of the item, which may have led to participant confusion. For future iterations, we recommend splitting this into two distinct statements—“The course duration was adequate” and “The objectives and content were well-balanced”—to improve both conceptual clarity and psychometric robustness.

Finally, while the integration of digital media—particularly TikTok—into science teacher education proved effective in enhancing engagement, several limitations emerged that warrant consideration for future implementations. For instance, privacy and data security emerged as critical considerations in the use of TikTok as an educational tool. Public TikTok accounts allow for wide dissemination and audience reach but pose risks related to unauthorized content sharing and personal exposure [76]. Conversely, private accounts limit those risks but restrict collaboration, which is a key pedagogical affordance of the platform. This duality underlines the need for institutional guidelines and digital literacy training to help pre-service teachers navigate privacy settings, content permissions, and ethical content creation within educational environments. It is also essential that activities involving social media align with institutional policies on data protection and student privacy.

While the present study centred on chemistry, future research should examine how micro- and nanolearning strategies can be effectively adapted and applied across other Applied Science disciplines, particularly those that pose distinct conceptual challenges and require diverse representational approaches.

5. Conclusions

The findings of this study indicate a broadly positive impact of integrating ICT-based methodologies in science and chemistry education for pre-service teachers. The convergence of quantitative survey results and qualitative reflections from the pre-service teachers’ digital portfolios demonstrates not only high levels of satisfaction but also the pedagogical value of blending traditional and digital strategies.

Across the 30 student subgroups, digital portfolios served as a medium for both documentation and metacognitive reflection, facilitating deeper engagement with content and methods. The mandatory activity centred on digital news analysis was especially well received. In the survey, 94.8% of respondents reported acquiring new knowledge and/or skills through this activity, and 85.7% recognised its relevance to their future teaching practice. These quantitative findings were mirrored in students’ written reflections, where they emphasised the development of scientific literacy, awareness of societal issues, and critical thinking. Several groups highlighted that the activity encouraged them to relate chemistry to real-life contexts and to approach scientific content through interdisciplinary and ethical lenses. This alignment confirms the utility of media-based analysis as a powerful tool for science education.

The TikTok-based task, although optional, was selected by 19 subgroups and generated diverse and enthusiastic responses. According to the questionnaire, 59.7% of students found this activity more engaging than the digital news analysis. Students described it as motivating, creative, and aligned with their everyday digital habits. Portfolio entries praised the way audiovisual creation enhanced group cooperation, promoted conceptual clarity, and made scientific content more accessible. Moreover, the activity was perceived to foster innovation and adaptability—traits that are increasingly essential in modern teaching.

These outcomes highlight the pedagogical potential of integrating familiar digital tools such as social media in structured educational tasks, especially when supported by scaffolding and reflection.

The choice of digital platforms for portfolio creation also illustrated student autonomy and digital competence. Students often commented on the versatility and engaging nature of the digital format itself, noting that it enabled them to ‘learn independently’ and to move ‘beyond traditional instruction’. Such sentiments reinforce the role of digital portfolios not only as assessment artefacts but also as active learning environments.

Nonetheless, this study also exposed infrastructural limitations. Only 67.5% of students expressed satisfaction with the availability of technical resources, particularly Wi-Fi access. This issue was more pronounced in certain groups and was reflected in both survey data and portfolio reflections. Addressing these barriers is critical for the sustainable implementation of digitally enriched pedagogies.

In summary, the combined evidence underscores that digital portfolios—when grounded in relevant, student-centred tasks—can enhance disciplinary learning, support reflective practice, and bridge the gap between digital fluency and pedagogical content knowledge. While further improvements are needed, particularly in technical infrastructure, the model explored in this study holds considerable promise for initial teacher education in science-related fields.

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Abbreviations

The following abbreviations are used in this manuscript:

ICT Information and Communication Technology
SSI socioscientific issue

Appendix A. Satisfaction Questionnaire

To evaluate the experience and satisfaction of pre-service teachers participating in the activities, a questionnaire was administered at the end of the course. The original instrument, written in Spanish, was translated into English for reporting purposes. The questionnaire included a total of 21 items, combining Likert-scale and open-ended questions. A 5-point Likert scale was used (1 = “Very Unsatisfactory”, 5 = “Very Satisfactory”).

Questionnaire for Pre-Service Teachers

About course organisation (5-point Likert scale)

1. The information provided in the course guide
2. Overall organisation of the course
3. The number of students in the working groups for activities
4. The duration of the course in relation to its objectives and content
5. The course schedule in terms of supporting student attendance

About the classroom, methodology, and resources (5-point Likert scale)

6. Suitability of the classroom and furniture for carrying out activities
7. Availability of technical resources (e.g., projector, Wi-Fi) for course development
8. The teaching methodology proposed for learning
9. Balance between theory and practice
10. The interest level of the course content
11. Appropriateness of the learning activities
12. Quality of the supporting documentation provided

The usefulness, applicability, and impact of the news activity (5-point Likert scale)

13. The activity provided new knowledge and/or skills
14. What was learned is applicable to my future role as a teacher
15. The activity positively influenced my use of media, particularly digital newspapers
16. The activity met my expectations
17. I would recommend this type of activity to other students
18. Overall evaluation of the activity

Personal opinions (open-ended and multiple-choice questions)

19. Identify the most positive aspects of the digital news activity
20. Identify aspects of the digital news activity that should be improved
21. Which activity did you find most interesting?
 - (a) The activities with digital newspaper articles
 - (b) The activity using TikTok
 - (c) Both activities equally
 - (d) Neither the press nor the TikTok activity

Appendix B

Appendix B.1. The Structure of the Digital Portfolios

The general structure and required components of the digital portfolio were as follows:

1. Cover Page.
2. Introduction: This section was intended to capture student expectations for the subject, its perceived relevance to their future role as educators, and its relationship with other content areas in their degree programme. Where applicable, references were to follow APA guidelines.
3. Description of activities: For each selected activity (both assigned and elective), students were asked to evaluate the pacing, time investment, resources used, emerging conceptual gaps, perceived difficulty, and skills involved. Both qualitative and quantitative reflections on the activity were to be included.
 - Instructor-assigned activity: A compulsory task set by the instructor, to be documented in all portfolios. For the three groups, the mandatory activity was the activity involving digital news.

- Student-selected activities: Groups A and B were to choose two additional activities that they deemed particularly meaningful to their learning process. Group C, due to the distinct nature of their course, selected only one additional activity. These were to differ from the instructor-assigned task and be chosen through group consensus.
 - Activities related to STEM or service learning (SL) projects (Group C only): This section required a detailed account of the initiation, development, and conclusion phases of the respective project. For SL, students also reported the date, partnering institution, and a summary of the service learning activities undertaken. If permitted, photographs taken during the activity could be included. In both STEM and SL projects, students were required to produce a short video (maximum 5 min) involving all group members, summarising the project and its outcomes. The portfolio included only the video’s link, hosted on a cloud-based service.
4. Critical personal reflection: This component served two core purposes, (1) to allow students to interpret and discuss the outcomes of their activities in depth, and (2) to provide a space for speculative thinking, including questions such as “What if. . .?” or “Why not. . .?”. Students were encouraged to self-evaluate, highlight both strengths and areas for improvement, critique their own results and those of other groups, and propose enhancements to the activity design, methodologies, or instructional materials. Additionally, they were asked to reflect critically on the pedagogical value of the activities and how they might contribute to the development of key teaching competencies within initial teacher training.
 5. Diary and record of incidents and anecdotes: Here, students documented noteworthy events—both positive and negative—that significantly influenced their learning experience throughout the course.
 6. References: A list of all bibliographic sources used, formatted in accordance with the APA style.

Appendix B.2. The Assessment Rubrics of the Digital Portfolios

Table A1. Rubric for pre-service teachers’ digital portfolios.

Criteria	Insufficient	Satisfactory	Good	Excellent
Didactic quality of the activity descriptions	The description of the activities is underdeveloped and lacks pedagogical reflection.	The activity descriptions are somewhat underdeveloped and show little pedagogical reflection.	The activity descriptions are well developed and demonstrate a moderate level of pedagogical reflection.	The activity descriptions are very well developed and demonstrate a strong level of pedagogical reflection.
Quality of written expression in the portfolio	Contains very serious issues with appropriateness, coherence, and cohesion, and does not comply with language norms (lexicon, grammar, and spelling).	Contains serious issues with appropriateness, coherence, and/or cohesion, and/or does not fully comply with language norms (lexicon, grammar, and spelling).	Contains minor issues with appropriateness, coherence, or cohesion, but generally complies with language norms (lexicon, grammar, and spelling).	Appropriate, coherent, cohesive, and fully compliant with language norms (lexicon, grammar, and spelling).

Table A1. Cont.

Criteria	Insufficient	Satisfactory	Good	Excellent
Organisation, design, and visual presentation of the portfolio	Difficult to read and not visually appealing. Lacks variety in creative features.	Easy to read but not visually appealing. Has limited variety in creative features.	Easy to read and visually appealing. Aesthetically pleasing with a good variety of creative features.	Very easy to read and visually appealing. Aesthetically very pleasing with a wide variety of creative features.
Critical reflection and final conclusions of the portfolio	Shows no meaningful connection between knowledge, attitude, disposition, and competency acquisition. There is no reflection on the transfer to personal and professional contexts.	Shows minimal connection between knowledge, attitude, disposition, and competency acquisition. Reflection on transfer to personal and professional contexts is weak.	Shows a general connection between knowledge, dispositions, and indicators of appropriate competency acquisition, as well as some reflection on transfer to personal and professional contexts.	Shows a clear and precise connection between knowledge, dispositions, and indicators of appropriate competency acquisition, and reflects effectively on the transfer to personal and professional contexts.
Bibliographic references	No bibliographic references are included in the reports.	Only class notes are used as bibliographic references.	Includes at least one bibliographic reference beyond class notes.	Includes more than two bibliographic references beyond class notes.

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