computers

MDPI

Article

Potions & Dragons: Player-Informed Web-Based Gamification for Science Attitudinal Change in Initial Teacher Education

Gregorio Jiménez-Valverde [1,2,*], Noëlle Fabre-Mitjans [1] and Gerard Guimerà-Ballesta [1]

[1] EduCiTS Innovation and EMA Research Groups, Universitat de Barcelona, 08035 Barcelona, Spain; nfabre@ub.edu (N.F.-M.); gerard.guimera@ub.edu (G.G.-B.)
[2] Institut de Recerca en Educació (IREUB), Universitat de Barcelona, 08035 Barcelona, Spain
* Correspondence: gregojimenez@ub.edu

Abstract

This exploratory mixed-methods study examined whether a narrative-driven digital gamification platform, FantasyClass, grounded in the MDA (Mechanics–Dynamics–Aesthetics) framework and Bartle's player typology (used as a cohort-level design input), was associated with science attitudinal change in preservice primary teachers. The quantitative component employed a one-group pretest–posttest (pre-experimental) within-participant design using a validated 22-item attitudes questionnaire (N = 23), structured across three temporal dimensions: past (retrospective experiences), present (current perceptions), and future (teaching expectations). Significant improvements were observed across all attitudinal dimensions with large effect sizes, most notably in students' future expectations and confidence to teach science. Exploratory correlation analyses indicated that participants' perceived motivational value of narrative and immersion elements was moderately associated with Future-dimension attitudinal gains. Qualitative thematic analysis of open-ended responses (n = 15) revealed enhanced motivation, reduced science anxiety, more positive perceptions of physics and chemistry, and strong intentions to adopt game-based and gamified strategies in future teaching practice. Convergence across quantitative and qualitative strands suggests that structurally coherent, player-type-informed narrative gamification may be associated with attitudinal transformation and early professional identity development in STEM teacher education, while recognizing that the design does not permit causal attribution.

Keywords: gamification; Bartle player types; science attitudes; science education; tailored gamification; narrative gamification; FantasyClass; initial teacher education; attitudinal change; MDA framework

Academic Editors: Carlos Vaz de Carvalho, Hariklia Tsalapatas and Ricardo Baptista

Received: 22 December 2025
Revised: 21 January 2026
Accepted: 23 January 2026
Published: 1 February 2026

1. Introduction

Science education plays a critical role in shaping future teachers' professional identities, instructional practices, and their students' engagement with scientific inquiry [1,2]. Among preservice primary teachers, however, negative attitudes toward science—particularly physics and chemistry—remain a persistent and well-documented challenge [3–5]. These negative dispositions often stem from prior transmissive learning experiences, fragile self-efficacy, content-specific anxiety, and limited opportunities for meaningful scientific practice during their own schooling [6–8]. Left unaddressed, such attitudes risk perpetuating cycles of disengagement, as teachers who lack confidence or enthusiasm for science are

more likely to minimize instructional time, avoid inquiry-based pedagogies, and inadvertently communicate to their students that science is difficult, inaccessible, or irrelevant [1]. Conversely, teacher enthusiasm and positive attitudes can significantly enhance students' motivation, interest, and willingness to engage with scientific ideas [2].

Addressing the affective dimensions of science teacher education—including motivation, self-efficacy, and value beliefs—is therefore a high priority for research-informed preparation programs [8]. Understanding how attitudes can change clarifies why certain pedagogical designs may be effective for preservice teachers. Dual-process models (e.g., the Elaboration Likelihood Model, ELM) suggest that embedding content in meaningful, goal-directed tasks within a coherent context promotes central-route elaboration, while progression cues, immediate feedback, and aesthetic polish can operate as peripheral signals that sustain engagement when motivation or cognitive capacity fluctuate [9]. In parallel, mastery-laden experiences that contradict prior negative beliefs can induce cognitive dissonance, prompting attitudinal realignment [10]. Within the Theory of Planned Behavior (TPB), attitudes are antecedents of behavioral intentions [11], so even modest attitudinal gains are educationally meaningful if they increase trainees' willingness to adopt evidence-based, innovative practices. In this article, we treat attitude as a latent construct—"a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" [12] (p. 1)—and, consistent with classic work, as a factor that influences behavior but is not behavior per se [13].

1.1. Gamification

Educational gamification has emerged as a promising pedagogical strategy to foster affective and motivational change by operationalizing the persuasion and attitude-change mechanisms outlined above [14,15]. Gamification is understood as the systematic use of game design elements in non-game contexts to increase engagement, motivation, and behavioral outcomes [16,17]. From an ELM perspective, well-designed gamification can promote central-route processing by embedding content in meaningful, goal-directed tasks with coherent narratives and transparent feedback, while simultaneously leveraging peripheral-route cues such as aesthetic elements, progression signals, and social feedback to sustain engagement when cognitive load or motivation fluctuate [9]. Additionally, gamified learning environments can induce cognitive dissonance through positive mastery experiences that contradict prior negative beliefs, thereby motivating attitude realignment [10]. Because attitudes formed via central-route elaboration are more durable and resistant to counter-persuasion [9], and because attitudes predict behavioral intentions [11], gamification that meaningfully integrates content with game mechanics is more likely to produce lasting changes in both attitudes and future teaching practices. Across higher education and STEM settings, meta-analyses report positive average effects on motivation, engagement, and, in some cases, learning outcomes [18–20].

However, benefits are not automatic and are contingent on thoughtful, research-based design [15,21]. Design missteps—such as overreliance on superficial reward mechanisms like points, badges, and leaderboards without alignment to meaningful learning objectives—can undermine intrinsic interest, create over-justification effects, or even generate frustration and disengagement [22,23]. Thus, effective gamification in teacher education must be purpose-built, pedagogically grounded, and aligned with the affective and professional outcomes that matter for future classroom practice.

Within literature, it is useful to distinguish between structural gamification and content gamification [24,25]. Structural gamification overlays game elements (e.g., points, levels, leaderboards, progression systems, feedback mechanisms, and rewards) onto existing learning activities to scaffold engagement. Content gamification, by contrast, applies game

elements directly to the course content to make it more engaging by, for example, integrating a coherent narrative that gives meaning to tasks and links them through a unifying thematic arc. In science education, narrative can function as a cognitive–affective organizer that renders abstract concepts personally consequential, easier to remember, and more emotionally engaging, while increasing enjoyment and commitment to learning [26]. These two forms of gamification are complementary: structural mechanisms sustain momentum and provide actionable, real-time feedback, whereas narrative supplies purpose, continuity, and emotional resonance—together producing a richer motivational ecology than either approach alone [27].

1.2. Design Frameworks: MDA and Player Typology

Evidence increasingly suggests that "one-size-fits-all" gamification can yield uneven effects because the same game elements do not carry equivalent motivational value for all learners [28]. In higher-education and educational settings, tailored approaches that account for user differences tend to report more robust motivational benefits than uniform designs [29,30]. Accordingly, frameworks that clarify both how gameful experiences are constructed and for whom they are motivationally meaningful are especially useful when affective outcomes are central.

The Mechanics–Dynamics–Aesthetics (MDA) framework [31] offers a structured lens by distinguishing three interrelated layers. Mechanics are the rules and action possibilities of the system (e.g., progression rules, scoring functions, feedback loops, team formation). Dynamics describe the run-time patterns that emerge from mechanics and player input (e.g., time pressure, collaboration, exploration, competition). Aesthetics are the desirable experiential outcomes (e.g., sensation, challenge, discovery, fantasy, fellowship, expression, narrative, submission). Critically, designers work from mechanics toward target aesthetics, whereas players experience the system from aesthetics toward underlying mechanics [31]. This framework is particularly valuable in education because it provides a systematic method for aligning design decisions with intended learning and motivational outcomes [32]. Making explicit these mechanics–dynamics–aesthetics linkages help ensure that gamification strategies are coherent, purposeful, and aligned with educational objectives rather than superficial or disconnected from learning goals [32]. For example, mechanics such as progressive levels and exploration-based tasks can generate dynamics of iterative experimentation and discovery, producing aesthetics of challenge and curiosity; conversely, team-based tasks and social feedback can generate collaborative dynamics that produce fellowship aesthetics.

Building on this premise, even well-designed gamification is unlikely to be uniformly effective for all learners, as individual differences in preferences, motivations, and play styles moderate the impact of game elements on user experience and outcomes [33–35]. This recognition has given rise to the concept of tailored or personalized gamification, which adapts game elements to the characteristics of individual users or user groups [29,33]. Learner characteristics such as age and cultural background shape how students interact with gamified systems; player type has proven particularly influential in determining the motivational impact of gamification and thus represents a key design consideration for game-based educational interventions [33,36].

One of the most influential frameworks for understanding individual differences in game-based contexts is Bartle's player typology [37], which categorizes players into four types based on two dimensions: acting versus interacting, and world-oriented versus player-oriented. The resulting types are Achievers (acting on the world, motivated by mastery and goal completion), Explorers (interacting with the world, motivated by discovery and understanding), Socializers (interacting with other players, motivated by relation-

ships and communication), and Killers (acting on other players, motivated by competition and dominance) [37]. Research suggests that these types respond differentially to game elements: Achievers value progression systems and mastery cues; Explorers seek discovery-oriented mechanics and narrative depth; Socializers prioritize collaboration features; and Killers respond to challenge and rankings [33,37]. Bartle's four-type taxonomy offers a parsimonious framework that facilitates transparent alignment between learner profiles and gamification strategies. The typology has been employed in educational gamification contexts, where it supports the design of game elements aligned with learners' preferences and motivational profiles [33,38].

The integration of the MDA framework with player typology provides a powerful lens for designing and analyzing gamified science education interventions. The MDA framework clarifies how game elements function—what mechanics are deployed, what dynamics they produce, and what aesthetic experiences they afford—while player typology clarifies for whom these elements are most motivationally relevant. For example, a gamified science course designed with the aesthetic goal of discovery might employ mechanics such as exploration-based challenges, hidden content, and narrative mysteries (aligning with Explorer preferences), while also including mechanics such as team-based quests and social feedback (aligning with Socializer preferences) and progression systems with visible milestones (aligning with Achiever preferences). The resulting dynamics—such as collaborative exploration, shared discovery, and progressive mastery—would be experienced aesthetically as discovery, fellowship, and challenge, creating a rich and inclusive motivational environment that appeals to diverse player types.

Against this backdrop, the present study examines a university science course for preservice primary teachers that integrates structural gamification with a coherent narrative that recontextualizes all course activities. Specifically, the study contributes (i) an estimate of the magnitude of within-participant pre–post attitudinal change in an authentic teacher-education setting, (ii) an exploratory examination of whether attitudinal gains are statistically associated with participants' self-reported motivational relevance of theoretically aggregated game-element families, and (iii) an interpretation of these patterns through attitude-change theory (ELM and TPB).

1.3. Study Aims and Research Questions

This study investigates a structurally and narratively gamified intervention intended to improve preservice primary teachers' affective relationship with science by integrating structural game elements with a coherent narrative that recontextualizes physics and chemistry activities into meaningful, goal-directed experiences. The design is guided by the MDA framework to ensure coherence between implemented mechanics, emergent dynamics, and targeted experiential outcomes [31], and by Bartle's player typology to interpret how different learner profiles may relate to particular game mechanics [33,37]. Beyond estimating whether attitudes improve, the study addresses a more specific gap: clarifying how participants' perceived motivational relevance of game elements relates to the magnitude of attitudinal change, acknowledging that gamification effects may be contingent on individual differences rather than uniformly distributed [29]. Accordingly, the following research questions guided the investigation:

- RQ1. To what extent do preservice teachers' attitudes show positive within-participant change from pretest to posttest following participation in the course?
- RQ2. Which individual game elements do participants report as most motivating?
- RQ3. To what extent is the perceived motivational relevance of game-element categories statistically associated with the magnitude of attitudinal change?

2. Materials and Methods

A convergent mixed-methods design [39] was adopted, involving concurrent data collection, separate analyses, and integrated interpretation. Quantitatively, a one-group pre–post non-experimental design [40] was implemented using a validated 22-item attitudes questionnaire and a supplementary survey on perceived motivation toward game features. Accordingly, quantitative analyses estimate within-participant change and support associational interpretation rather than causal inference. Qualitatively, thematic analysis of participants' written responses provided triangulation. Integration occurred at the discussion stage, where patterns emerging from qualitative themes were examined alongside quantitative results. A detailed specification of the quantitative design, variables, and the operationalization of each research question is provided in Section 2.5.1.

2.1. Participants

The study included 23 fourth-year students (19 women and 4 men; M = 21.7 years, Mdn = 21) enrolled in the Primary Education bachelor's degree at the University of Barcelona (Spain). All participants took the course "Recreational and Everyday Science in the School" (RESC) during the 2022–2023 academic year. Participation was voluntary; of the 27 students registered for the course, complete paired data (pretest and posttest) were obtained for 23 participants. Informed consent was obtained from all of them.

2.2. Setting and Course Context

The intervention was implemented in RESC, a 6-ECTS, fourth-year optional course delivered over one semester (15 weeks) via face-to-face instruction. Building upon foundational physics and chemistry didactics completed in year two, RESC focuses on practical, everyday applications of these disciplines through activities such as analyzing recreational demonstrations, designing hands-on inquiry activities with everyday materials, and developing science lesson plans that connect out-of-school experiences to formal learning.

A typical class session followed a stable structure. It opened with a brief narrative prompt and a short activation cue to situate the session within the ongoing storyline, followed by an instructor-led introduction to the day's scientific focus. Students then engaged in hands-on, group-based labs and problem-solving activities, supported by formative guidance and feedback. Sessions typically concluded with a short whole-class debrief connecting observations to target concepts and a brief closure designed to reinforce continuity and anticipation for subsequent sessions.

2.3. Procedure

The selection and implementation of specific game elements was informed by two complementary frameworks: (1) the MDA model to systematize the relationship between game components and intended player experiences, and (2) Bartle's player typology to align the configuration of those elements with cohort-level motivational profiles. Player-type alignment was conceptualized as design- and context-dependent, not as a fixed attribute of the feature itself [41]. Accordingly, "alignment" refers to cohort-informed selection and configuration of mechanics; it did not involve differential treatment, and all participants experienced the same course design. Because player-type information was not used at the participant level for analysis, the typology is reported here as a design input rather than as an analytic grouping. These frameworks guided the implementation via FantasyClass (https://fantasyclass.app/, accessed on 10 December 2025), a web-based platform designed for implementing structural gamification in educational settings (Figure 1). FantasyClass

functions as a modular system that overlays a fantasy-themed, game-like layer onto the existing course curriculum. The platform provides instructors with flexible feature activation controls, allowing selective implementation based on pedagogical objectives and learner characteristics. The instructor had implemented FantasyClass once previously in a different university course; thus, this intervention represented the second overall implementation of the platform and the first within this specific subject, and it was participants' first exposure to FantasyClass-based gamification.

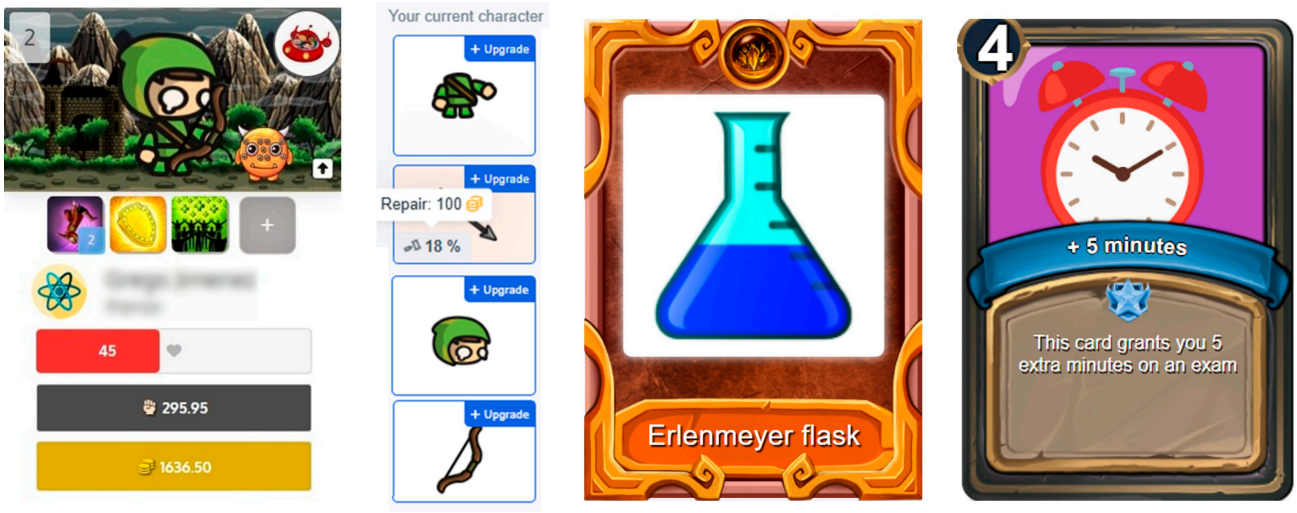

Figure 1. Examples of four FantasyClass features. From left to right: a student's avatar (showing their health and experience points, gold coins, pet, level, and skills), the upgrading/repairing equipment at the virtual shop, a collectible item (from the laboratory equipment collection), and a card. Both collectibles and cards can be obtained at random from the virtual shop or granted as rewards for leveling up or completing tasks. The use of these screenshots has been authorized by the creator of FantasyClass.

Architecturally, FantasyClass comprises three integrated subsystems: (1) progression and assessment (experience points, levels, grade-contribution mechanics), (2) economic simulation (virtual currency, marketplace, collectibles), and (3) social-narrative framework (team structures, storylines, character systems). Beyond feature configuration, the platform automates reward distribution, provides real-time student dashboards, and generates instructor analytics for monitoring engagement and performance.

Prior to the intervention, participants completed the Bartle Test of Gamer Psychology [42] to identify their dominant player-type profile. Results revealed a cohort composition of 39% Explorers, 36% Socializers, 18% Killers, and 7% Achievers. These proportions were used to inform cohort-level design emphasis rather than to support subgroup analyses. In alignment with the MDA framework's emphasis on coherence between mechanics, dynamics, and intended aesthetic outcomes, FantasyClass features were strategically selected and configured to connect game mechanics with specific dynamics that would produce the desired aesthetic experiences for each player type, with greater emphasis on the dominant profiles in this cohort, while still incorporating elements designed to engage less prevalent profiles. Table 1 presents the complete mapping of thirteen implemented FantasyClass features to Bartle player types, categorized according to Tondello et al.'s taxonomy of gameful design elements [35], with empirical support drawn from systematic literature reviews [33] and targeted empirical studies [38,41].

Table 1. Mapping of FantasyClass Features to Bartle Player Types and Gameful Design Elements.

FantasyClass Feature	Description	Game Element	Game Category	Explorers	Socializers	Killers	Achievers
Narrative	Medieval storyline with 4 kingdoms and an antagonist; integrated into all course activities	Narrative or story	Immersion	X	X		
Groups	Stable teams of 4 with differentiated roles (coordinator, secretary, supervisor, spokesperson)	Guilds or teams	Socialization		X	x	x
Events	Daily narrative-linked events activated at the beginning of each class session; the system selects one event at random from an instructor-curated, preloaded list and presents it as an episodic development in the storyline	Mystery box	Immersion	X	x		
Fortune Wheel	Fortune wheel awarding random amounts of gold to students	Rewards or prizes	Incentive				X
Uplevelling	Experience points-based leveling system with predefined thresholds; students advance through levels as experience points accumulate; in this implementation, the final level contributed to the course grade	Levels of progression	Progression	x		x	X
Collections	Thematic card sets (polymers, lab equipment, etc.) that students complete for XP/gold rewards; collectibles can be traded between students	Collection	Incentive	X	x		x
Cards	Reward cards with rarity hierarchy (Common, Rare, Epic, Legendary) providing various benefits	Lotteries or games of chance	Risk/Reward	X		x	x
Skills	Special abilities (active single-use or passive persistent) with probabilistic effects; obtained randomly	Lotteries or games of chance	Risk/Reward	x		X	
Pets	Virtual companions offering passive attribute bonuses; require gold-based feeding maintenance	Power-ups or boosters	Assistance	x			x
Upgrade equipment	Avatar enhancements (armor, weapons, shields) providing percentage-based attribute bonuses	Power-ups or boosters	Assistance	x		X	x
Chests	Purchasable containers from virtual shop with random rewards	Lotteries or games of chance	Risk/Reward	x			X
Wordlet	Word puzzle challenge related to lesson concepts; students receive progressive feedback	Challenge	Risk/Reward				X
Battles	Cooperative entire-class vs. monster challenges; randomly selected students answer on behalf of all	Boss battle	Risk/Reward		X	x	x

Note: Game elements and categories according to [35]. X = primary alignment; x = secondary alignment.

Explorers constituted the largest segment of the cohort (39%). The Narrative and Events—as detailed in Table 1—served as core elements specifically aligned with Explor-

ers' documented preferences for discovery, experimentation, and immersive experiences. Consistent with Kocadere & Çağlar [41], we treat these alignments as design intentions rather than exclusivities, because the same game element can afford different motivational mechanics depending on its configuration and classroom enactment (Table 1 therefore distinguishes primary and secondary alignments). The Narrative mechanic, in particular, generated dynamics of immersion and curiosity through the instructor's active storytelling role (presenting character-led video messages) and systematic adaptation of all classroom activities to the medieval storyline. Students were introduced to the overarching narrative on the first day through an introductory video in which the narrator—a fictional medieval character—recruited them into the quest and outlined their mission (https://www.youtube.com/watch?v=6HQZV1RFsQ0, accessed on 10 December 2025). Throughout the semester, the instructor continued this narrative engagement, transforming course activities into coherent, emotionally meaningful contexts that produced the aesthetic experiences of fantasy and discovery (Figure 2). The Events mechanic complemented this narrative foundation by introducing teacher-curated, preloaded random events within FantasyClass that were activated at the beginning of each class session. Rather than operating as a stand-alone reward mechanism, these events were narratively framed as episodic developments within the storyline (e.g., unexpected encounters, shifting conditions, or situational constraints), thereby creating moment-to-moment variability and anticipation while reinforcing the aesthetic of discovery through surprise and uncertainty.

Figure 2. Screenshot from one of the daily narrative videos in which the narrator presents the challenge of the day. The map situates the action within a specific location on the Realms reinforcing narrative continuity and spatial coherence throughout the semester.

Beyond these core mechanics, additional features supported sustained Explorer engagement. Collections and Cards generated discovery dynamics through rarity, variability, and completion-driven curiosity. Pets and avatar-related enhancements (including Equipment Upgrades) supported experimentation dynamics through personalization and tactical exploration of system affordances, allowing students to test different configurations and observe their effects across the semester.

Socializers, representing the second-largest segment (36%), were addressed primarily through two core mechanics: stable Group configurations and the Narrative framework. The Group mechanic generated dynamics of interdependence and shared responsibility, while the Narrative mechanic provided shared thematic context and communal mission—together producing the aesthetic of fellowship and collective identity. Although cooperation predominated both within and across groups, the Group mechanic also enabled occasional,

instructor-bounded inter-group comparisons (e.g., short competitive moments tied to specific activities), introducing secondary competitive dynamics without shifting the overall cooperative classroom climate. The Battles mechanic complemented these core features through dynamics that created intense shared emotional experiences (cooperative entire-class-versus-monster challenges that fostered collective tension, mutual support, and communal victory celebration), thereby reinforcing the fellowship aesthetic across the wider learning community [33,41]. The Collections mechanic further reinforced Socializer engagement through card trading functionality, which extended collaborative opportunities beyond fixed group assignments and fostered peer-to-peer interaction.

Killers, constituting a minority profile within the cohort (18%), presented unique design challenges given the educational context's emphasis on cooperative learning. Mechanics traditionally associated with Killers—such as direct player-versus-player combat—were deliberately constrained to maintain pedagogically appropriate collaboration. Nevertheless, as shown in Table 1, Skills and Equipment Upgrades offered partial alignment with Killer motivations while remaining educationally sound, generating competitive dynamics within cooperative constraints. The Skills mechanic enabled bounded competitive interactions consistent with Killers' preferences for influence and dominance within a rule-governed system; Equipment Upgrades simultaneously functioned as visible status markers that supported prowess-signaling dynamics [38]. The Battles mechanic, while primarily cooperative, retained competitive undertones by randomly selecting individuals to demonstrate knowledge as class representatives, thereby generating moments of high-visibility intellectual dominance in a pedagogically acceptable format.

Although Achievers represented the smallest segment (7%), their motivational profile aligned particularly well with pedagogically essential platform functions. The Levels mechanic—the core progression system—quantified achievement through experience points and clear advancement sequences, generating mastery dynamics and accomplishment aesthetics. Importantly, as students accumulated experience points, they advanced through a structured sequence of levels, with their final level contributing to their overall course grade, thus directly linking gamified progress to academic evaluation. The Fortune Wheel complemented this progression architecture as an incentive mechanism by awarding random amounts of gold, reinforcing engagement through intermittent rewards that could be reinvested in other platform features. Additional Achiever-oriented mechanics (Wordlet, Collections, Treasure Chests, and, to some extent, Battles) were configured to generate task-completion, goal-accumulation, and measurable achievement dynamic.

2.4. Instrument

To assess changes in attitudes toward physics and chemistry among preservice primary teachers, the study employed a 22-item validated questionnaire specifically developed for this population [43]. Participants indicated their level of agreement to each statement using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire incorporates three temporal dimensions reflecting distinct facets of learners' relationships with science: (a) a past dimension (items 1–8), examining retrospective learning experiences with physics and chemistry; (b) a present dimension (items 9–16), assessing current perceptions as both active society members and university students; and (c) a future dimension (items 17–22), eliciting professional expectations regarding their anticipated role as primary education teachers. At least one reverse-coded item appeared in each dimension to mitigate response acquiescence bias.

The questionnaire was administered digitally at two timepoints: pretest (course beginning) and posttest (course end). In the posttest, items in the past dimension were contextually reframed to reference the RESC course experience specifically, enabling a

within-participant comparison between prior physics/chemistry learning experiences and the RESC experience. For example, the pretest item "In physics and chemistry class, I could express my own ideas" was adapted for posttest administration to read "In RESC, I could express my own ideas".

Given the multidimensional structure of the instrument, internal consistency was evaluated separately within each temporal dimension [44]. As shown in Table 2, Cronbach's α coefficients ranged from 0.573 to 0.818 at pretest and from 0.660 to 0.786 at posttest, indicating questionable to good internal consistency. McDonald's ω coefficients, computed on items with non-zero posttest variance, ranged from 0.736 to 0.888. Although some Cronbach's α coefficients fell below the conventional threshold in social sciences [45], McDonald's ω provides a more robust reliability estimate under non-normality and restricted variance; in this context (including ceiling effects at post-test), ω values supported an overall interpretation of adequate internal consistency.

Table 2. Reliability Coefficients for Attitude Dimensions at Pretest and Posttest.

Reliability Coefficients	Past		Present		Future	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Cronbach's α	0.784	0.573	0.818	0.660	0.595	0.677
McDonald's ω_t	0.847	0.753	0.888	0.786	0.736	0.836

Note: Several posttest items exhibited zero variance (items 10, 17, 20), which constrained the computation of internal consistency estimates for those items. McDonald's ω_t was therefore computed on the subset of items with non-zero posttest variance within each dimension.

Beyond attitudinal assessment, the posttest incorporated two supplementary measures. First, students rated their perceived motivational relevance for 13 specific FantasyClass features and gamification elements using an ad hoc questionnaire developed for this study, in which participants rated each feature on a 5-point Likert scale (1 = not motivating at all, 5 = very motivating). The questionnaire has not been validated in prior research; responses should therefore be interpreted as descriptive self-reports of subjective motivational experience rather than psychometrically validated constructs or objective evaluations of gamification quality. Because the aim is to capture perceived motivational relevance, participants are appropriate informants for their own experience, irrespective of formal expertise in gamification. To characterize shared versus heterogeneous preferences, we summarize these ratings using distributional indices (median, IQR, and high-endorsement and maximum-endorsement frequencies, operationalized as the proportions of ratings ≥ 4 (% ≥ 4) and ratings = 5 (% = 5)), and we treat the results as descriptive indicators of consensus and variability across participants.

For subsequent analyses, these features were aggregated a priori into six theoretical game-element categories (based on [35]); given the sample size, this categorization was not examined via factor-analytic validation and is therefore treated as a theory-driven analytic grouping. The six categories were: Assistance (equipment upgrades, pets), Immersion (narrative/ambient features), Incentive (collectibles, fortune wheel), Progression (leveling up), Risk/Reward (chance- and payoff-contingent mechanics), and Socialization (working in groups) (see Table 1 for complete feature-to-category mapping). Multi-item categories were evaluated for internal consistency using Cronbach's α: Assistance (k = 2, α = 0.922), Immersion (k = 2, α = 0.663), Incentive (k = 2, α = 0.749), and Risk/Reward (k = 5, α = 0.792). Progression and Socialization were single-indicator categories (k = 1) and therefore do not admit α estimates. Consistent with recent methodological guidance [44,46], alpha values are interpreted contextually rather than against universal thresholds; Immersion's lower

value likely reflects the small number of items and conceptual breadth of combining distinct mechanics (Narrative and Events).

Second, an open-ended question invited participants to reflect on whether and how their perspectives on science teaching had changed following the gamified course experience.

2.5. Data Analysis

2.5.1. Quantitative Design and Variables

The quantitative component followed a one-group pretest–posttest (pre-experimental) within-participant design [40]. Time (pretest vs. posttest) served as the within-participant factor. Primary dependent variables were participant-level composite scores for the three temporal attitude dimensions derived from the validated instrument (Past, Present, Future; see Section 2.4), computed after reverse-coding where required. Item-level attitude analyses were treated as a secondary, finer-grained complement to the dimension-level composites. RQ1 is operationalized as pre–post change on the three attitude dimensions using nonparametric within-participant tests, complemented by item-level pre–post analyses within each dimension. RQ2 is operationalized descriptively as participants' self-reported perceived motivational relevance ratings for each implemented FantasyClass feature and as aggregated summaries at the level of six theory-driven game-element categories (as defined in Section 2.4). RQ3 is operationalized as exploratory associations between attitudinal change indices (post–pre change scores for Past, Present, and Future) and participants' composite motivation ratings for the six game-element categories (Spearman correlations). Given the pre-experimental one-group design and the absence of preregistered hypotheses, inferential results are interpreted as estimates of within-participant change and exploratory association, not as causal effects attributable to gamification.

2.5.2. Quantitative Analysis

Quantitative analyses were conducted in IBM SPSS Statistics v27. Item-level distributions were screened with the Shapiro–Wilk test; given non-normality ($p < 0.05$), item descriptives are reported as median and interquartile range (IQR). For individual Likert-type items, medians are reported as integers on the 5-point scale, whereas IQRs may include half units due to quartile computation. Reverse-worded items were recoded so that higher scores consistently indicated more positive attitudes. Dimension composite scores were computed at the participant level as the mean of the constituent items after reverse-scoring where required, following standard practice for summated Likert scales treated as approximately interval when aggregating multiple items. To respect sample-level distributional departures, we summarize the distribution of these participant-level composites with median and IQR across participants and base inferential tests on nonparametric statistics. Consistent with classic and contemporary perspectives on attitude measurement, we interpret change primarily at the group level and emphasize dimension-level indices rather than relying solely on a single global score [47].

Pre–post changes were evaluated using Wilcoxon signed-rank tests (two-tailed, continuity-corrected) at two levels of granularity. First, to assess global attitudinal shifts, we computed composite scores for each temporal dimension (Past, Present, Future) by averaging constituent items at the participant level. Wilcoxon signed-rank tests were conducted for each of the three dimension-level comparisons (Past, Present, Future), with p-values adjusted using the Holm step-down family-wise error procedure ($\alpha = 0.05$) across these three tests. For each dimension, we report the Wilcoxon W statistic, Holm-adjusted p-value, matched rank-biserial effect size (r_rb) with 95% bootstrap confidence intervals, and the Hodges–Lehmann median paired difference (HL Δ) with 95% bootstrap confidence intervals.

Second, to localize where changes were most pronounced within each temporal dimension, we conducted item-level Wilcoxon signed-rank tests for all 22 questionnaire items. Within each dimension separately, *p*-values were adjusted using the Holm step-down procedure (Past: 8 tests; Present: 8 tests; Future: 6 tests). Item-level results report the Wilcoxon W statistic, dimension-specific Holm-adjusted *p*-value, and matched rank-biserial effect size (r_rb).

Associations between attitudinal change and perceived motivation for gamification design elements were examined using Spearman rank-order correlations (ρ). Specifically, we correlated post–pre change scores for each temporal attitude dimension (Δ Past, Δ Present, Δ Future) with participants' composite motivation ratings for the six game-element categories, computed as the mean of the feature ratings within each category, and interpreted as self-reported perceived motivational relevance. All correlations were computed on complete cases with N = 23 participants (list-wise). We report two-tailed *p*-values and 95% bias-corrected and accelerated (BCa) bootstrap confidence intervals (B = 5000 resamples), resampling at the participant level, and we adjusted *p*-values using the Holm step-down family-wise error procedure ($\alpha = 0.05$) within this correlation family.

2.5.3. Qualitative Analysis

For the qualitative analysis, we conducted a thematic analysis [48] using ATLAS.ti v.23. This approach allowed for the identification of recurring themes that emerged from participants' reflections, ensuring that the analysis remained grounded in their lived experiences. The open-ended prompt was optional; consequently, qualitative responses were available for 15 of the 23 participants (N = 15). The emergent themes were triangulated with the quantitative findings to strengthen the validity of the results and provide a richer understanding of the participants' experiences and perceived changes within the gamified course context.

2.6. Relationship to Prior Publications and Data Provenance

This manuscript reports an original dataset collected in RESC during the 2022–2023 academic year and examines pre–post attitudinal change toward physics and chemistry. Our group has reported related FantasyClass-based implementations in subsequent RESC cohorts [49,50]; however, those studies involve different participants and academic years and address different focal constructs (e.g., intrinsic motivation or needs satisfaction/presence rather than attitudinal change), as well as different player-type frameworks and instruments. The dataset and analyses reported in the present manuscript are unique to RESC 2022–2023.

3. Results

3.1. Global Dimension-Level Changes

Here we first summarize the dimension-level effects (Table 3). Across the three dimensions, pre–post gains were uniform and large: Wilcoxon tests remained significant after Holm adjustment across the three dimensions, and matched rank-biserial effect sizes were at the upper end of the scale (r_rb = 0.98–1.00). The Hodges–Lehmann estimates indicate educationally meaningful improvements for a typical participant—on the order of half a Likert point for Present, and about one to one-and-a-half points for Future, and especially Past. Median increases were accompanied by IQR compression, showing greater consensus at post rather than change driven by a few outliers. The Wilcoxon statistics (W = 0) further suggest a consistent shift in the positive direction (no evidence of deterioration in any dimension). Taken together, these global results provide a clear, robust picture of overall improvement in students' retrospective experiences compared to the RESC course (Past),

current attitudes (Present), and prospective self-efficacy and professional outlook (Future), motivating the subsequent item-level analyses by dimension.

Table 3. Global pre–post changes in Past, Present, and Future dimensions.

Dimension	Pre Mdn [IQR]	Post Mdn [IQR]	W	*p* (Holm)	r_rb [95% CI]	HL Δ [95% CI]
Past	2.75 [0.94]	4.62 [0.38]	0	<0.001 *	1.00 [1.00, 1.00]	1.62 [1.38, 2.00]
Present	3.88 [0.69]	4.62 [0.38]	0	<0.001 *	0.98 [0.89, 1.00]	0.50 [0.50, 1.00]
Future	3.50 [0.50]	4.67 [0.50]	0	<0.001 *	1.00 [1.00, 1.00]	1.00 [0.83, 1.17]

Note: Mdn = median; IQR = interquartile range; W = Wilcoxon signed-rank (two-tailed, continuity-corrected) for all dimensions. N = 23 paired observations. *p* (Holm) = Holm step-down family-wise error–adjusted *p*-value across the three-dimension tests, asterisks (*) indicate statistical significance at the 5% level; r_rb = matched rank-biserial effect size; HL Δ = Hodges–Lehmann median paired difference. Bracketed values are 95% bootstrap confidence intervals. Higher scores indicate more positive attitudes; items 8, 9, 17, and 19 were reverse scored.

3.2. Item-Level Changes by Dimension

3.2.1. Past Dimension

The Past dimension (Table 4) contrasts students' pretest evaluations of prior physics/chemistry learning experiences with their posttest evaluations of the RESC course, reflecting changes in how they perceived their learning environment. At the item level, most pre-intervention medians ranged from 3 to 4, indicating neutral to favorable baseline attitudes. Following the gamified intervention, all eight items exhibited statistically significant improvements (Holm-adjusted Wilcoxon), with large matched rank-biserial effect sizes ranging from 0.82 to 1.00.

Table 4. Past dimension: Attitudinal changes in retrospective learning experiences.

Item Number and Statement	Pretest		Posttest		W	*p* (Holm)	r_rb
	Mdn	IQR	Mdn	IQR			
1—In physics and chemistry class, I got answers to questions that intrigued me	3	1.5	5	0	0	<0.001 *	0.99
2—In physics and chemistry class, I could express my own ideas	3	2	5	0	0	<0.001 *	0.98
3—I could get good grades in physics and chemistry without the help of the teacher	2	1	4	2	11	<0.001 *	0.82
4—Physics and chemistry classes fascinated me	3	2	5	0	0	<0.001 *	0.99
5—Physics and chemistry lessons were easy to study	2	0.5	4	1	0	<0.001 *	1.00
6—I had fun learning physics and chemistry	3	1.5	5	0	0	<0.001 *	0.99
7—Physics and chemistry allowed me to understand everyday phenomena	4	1	5	0	0	<0.001 *	0.96
8—For me, it was difficult to learn physics and chemistry (R)	3	1	5	1	3	<0.001 *	0.94

Note: Mdn = median; IQR = interquartile range; W = Wilcoxon signed-rank test statistic (two-tailed, continuity-corrected); *p* (Holm) = Holm step-down family-wise error–adjusted *p*-value within this dimension, asterisks (*) indicate statistical significance at the 5% level; r_rb = matched rank-biserial effect size. Item marked (R) was reverse-worded and was reverse-scored so that higher values indicate more positive attitudes.

Notably, agreement with having curiosity addressed in science classes increased from a median of 3 (IQR = 1.5) to a median of 5 (IQR = 0) (Item 1, r_rb = 0.99). Similarly,

fascination with science lessons rose from a median of 3 (IQR = 2) to a median of 5 (IQR = 0) (Item 4, r_rb = 0.99). Perceptions of the ease of studying physics and chemistry also showed substantial gains, with the median increasing from 2 to 4 (Item 5, r_rb = 1.00). The view that these subjects help explain everyday phenomena similarly improved, with the median rising from 4 to 5 (IQR 1 to 0) (Item 7, r_rb = 0.96). For the reverse-scored difficulty item, the median similarly increased from 3 to 5 (Item 8, r_rb = 0.94). Across all items, interquartile ranges compressed from moderate-to-large intervals to zero or minimal values, indicating increased consensus post-intervention.

3.2.2. Present Dimension

The Present dimension (Table 5) assesses students' current attitudes toward the value, relevance, and personal interest in physics and chemistry. Pre-intervention medians were generally high, typically at 4, suggesting favorable baseline attitudes. After the course, all eight items demonstrated statistically significant increases (Holm-adjusted Wilcoxon), with effect sizes that were predominantly moderate to large.

Table 5. Present dimension: Attitudinal changes in current science perceptions.

Item Number and Statement	Pretest		Posttest		W	*p* (Holm)	r_rb
	Mdn	IQR	Mdn	IQR			
9—Physics and chemistry have no connection to my life (R)	4	2	5	0	0	0.006 *	0.67
10—Understanding physics and chemistry is important for everyone	4	1	5	0	0	0.006 *	0.52
11—I like to read and learn about physics or chemistry through social media, YouTube, or other media	3	1	4	1	0	0.008 *	0.43
12—I think physics and chemistry are interesting	4	1.5	5	1	6	0.008 *	0.49
13—I am interested in explanations of physical and chemical phenomena	4	0.5	5	1	7	0.006 *	0.63
14—Physics and chemistry make our lives healthier, easier, and more comfortable	4	1	5	0	6	0.008 *	0.57
15—The benefits of physics and chemistry outweigh the potential adverse effects	3	1	5	1	0	0.002 *	0.80
16—Physics and chemistry can solve environmental problems	4	1	5	0.5	4	0.042 *	−0.01

Note: Mdn = median; IQR = interquartile range; W = Wilcoxon signed-rank test statistic (two-tailed, continuity-corrected); *p* (Holm) = Holm step-down family-wise error–adjusted *p*-value within this dimension, asterisks (*) indicate statistical significance at the 5% level; r_rb = matched rank-biserial effect size. Item marked (R) was reverse-worded and was reverse-scored so that higher values indicate more positive attitudes.

Most notably, students reported stronger agreement that the benefits of physics and chemistry outweigh potential drawbacks, with the median increasing from 3 to 5 (Item 15, r_rb = 0.80). Greater interest in scientific explanations of physical and chemical phenomena was also evident, with the median rising from 4 to 5 (Item 13, r_rb = 0.63). Items concerning general relevance (Item 10) and personal interest (Item 12) also saw interquartile ranges narrow to zero or near-zero, highlighting increased consensus. For the item on physics and chemistry's potential to solve environmental problems (Item 16), statistical significance was observed; however, the matched rank-biserial effect size was negligible (r_rb = −0.01), likely reflecting ceiling effects on this item. The reverse-scored connection-to-life item (Item 9) also demonstrated a shift toward more positive attitudes, with a moderate effect size (r_rb = 0.67).

3.2.3. Future Dimension

The Future dimension (Table 6) measures prospective self-efficacy and the professional value students attribute to teaching physics and chemistry in primary education. At the item level, the most pronounced changes occurred for perceived capability to teach physics and chemistry to primary pupils (Item 21) and belief in having sufficient content knowledge (Item 22), both increasing from a median of 2 to a median of 5 with very large effect sizes (r_rb = 1.00 and r_rb = 0.99, respectively). Other items also showed significant improvements. Support for allocating more instructional time to science increased, with the median rising from 3 to 4 (Item 18, r_rb = 0.64), as did recognition of the importance of these subjects for future professional development, with the posttest median at 5 (IQR = 1 to 0) (Item 20, r_rb = 0.34).

Table 6. Future dimension: Attitudinal changes in teaching expectations and confidence.

Item Number and Statement	Pretest		Posttest		W	*p* (Holm)	r_rb
	Mdn	IQR	Mdn	IQR			
17—Physics and chemistry should not be taught in primary school (R)	5	0	5	0	0	0.037 *	−0.24
18—More time should be devoted to physics and chemistry in primary school	3	1	4	1	6	0.006 *	0.64
19—I think teaching physics and chemistry to primary school children must be boring (R)	5	1	5	0	12	0.026 *	0.37
20—The physics and chemistry I can learn is important for my future professional development as a primary school teacher	5	1	5	0	0	0.006 *	0.34
21—I feel capable of teaching physics and chemistry content to primary school children	2	1	5	1	0	<0.001 *	1.00
22—I consider that I have sufficient knowledge to teach the physics and chemistry content of the primary education curriculum	2	1	5	1	0	<0.001 *	0.99

Note: Mdn = median; IQR = interquartile range; W = Wilcoxon signed-rank test statistic (two-tailed, continuity-corrected); *p* (Holm) = Holm step-down family-wise error–adjusted *p*-value within this dimension, asterisks (*) indicate statistical significance at the 5% level; r_rb = matched rank-biserial effect size. Item marked (R) was reverse-worded and was reverse-scored so that higher values indicate more positive attitudes.

For reverse-scored items, the item on perceived teaching boredom (Item 19) showed median maintained at ceiling (pretest Mdn = 5, IQR = 1; posttest Mdn = 5, IQR = 0; r_rb = 0.37, *p* (Holm) = 0.026). Despite statistical significance, the small-to-moderate effect size indicates that this result primarily captures reduced variability around an already favorable baseline rather than a substantive shift in central tendency. Finally, the item concerning whether physics and chemistry should not be taught in primary school (Item 17) maintained a ceiling median (Mdn = 5, IQR = 0 at both timepoints). Despite statistical significance (*p* (Holm) = 0.037), the small effect size (r_rb = −0.24) lacks practical interpretability; the result reflects minor individual fluctuations within a distribution already at maximum favorable response, constituting a statistical artifact of severe baseline ceiling rather than meaningful change.

3.3. Perceived Motivation for Gamification Features

To assess the alignment between design intentions and student perceptions, participants rated the perceived motivational value of each FantasyClass feature. Table 7 presents descriptive statistics for all thirteen implemented features. The distribution of ratings revealed meaningful distinctions regarding which features resonated most strongly with

students, patterns that warrant interpretation in light of the tailored gamification design strategy and empirical player-type composition.

Table 7. Perceived motivation by FantasyClass feature at posttest (N = 23).

FantasyClass Feature	Mdn	IQR	% ≥ 4	% = 5	Category
Uplevelling	5	0	100.0	95.7	Progression
Events	5	0	100.0	82.6	Immersion
Wordlet	5	0	100.0	78.3	Risk/Reward
Collections	5	0	91.3	87.0	Incentive
Fortune wheel	5	0	87.0	87.0	Incentive
Narrative	5	1	95.7	69.6	Immersion
Groups	5	1	82.6	69.6	Socialization
Upgrade equipment	4	1	78.3	43.5	Assistance
Battles	4	1.5	73.9	30.4	Risk/Reward
Pets	4	2	65.2	43.5	Assistance
Chests	4	2	60.9	39.1	Risk/Reward
Cards	4	2	56.5	43.5	Risk/Reward
Skills	4	3	56.5	30.4	Risk/Reward

Note: Mdn = median; IQR = interquartile range; % ≥ 4 denotes the proportion of ratings in the upper range (4–5), and % = 5 denotes maximum endorsements (rating = 5). Items rated on a 1–5 Likert scale (1 = not motivating, 5 = highly motivating). Categories follow [35]. Percentages computed over non-missing responses.

The highest-rated features—Uplevelling, Events, Wordlet, Collections, and Fortune Wheel (all Mdn = 5)—achieved ceiling-level median ratings with zero interquartile range. Uplevelling's ceiling performance (Mdn = 5, IQR = 0, 100% ≥ 4, 95.7% rated it 5) is particularly noteworthy given Achievers' minority status (7%): the feature's near-ceiling distribution suggests successful integration of pedagogically necessary continuous-assessment structures with broadly appealing progression feedback, extending motivational benefits beyond the target player type. Events and Fortune Wheel, both implemented as daily chance-based elements intended to support Explorer-oriented dynamics (e.g., surprise and variability), also obtained very high ratings (100% and 87.0% of students rating ≥ 4, respectively), with correspondingly high maximum-endorsement rates, supporting the decision to include surprise-oriented mechanics for the Explorer plurality (39%).

Wordlet, despite its periodic implementation, also achieved a maximum median rating with 100% of students rating it ≥ 4. This performance for a challenge-based puzzle mechanic targeting both Achievers (minority 7%) and Explorers (majority 39%) suggests a successful dual-function design in which skill-based tasks with clear success criteria resonated broadly across player-type profiles. Collections achieved identical ceiling metrics (Mdn = 5, IQR = 0, 91.3% ≥ 4), which may reflect the element's multifaceted implementation addressing Explorers (discovery), Achievers (completion), and Socializers (trading).

Narrative and Groups—the two most strategically emphasized features implemented as daily core mechanics for majority player types (Explorers 39% and Socializers 36%, respectively)—demonstrated robust but not ceiling-level performance. Narrative achieved Mdn = 5 but with IQR = 1, indicating that while the median student provided maximum rating, variability existed across the middle 50% of responses. Nevertheless, 95.7% of students rated Narrative ≥ 4, confirming strong consensus regarding its motivational value. Groups similarly achieved Mdn = 5, IQR = 1, with 82.6% rating ≥ 4, substantiating the cohort-

informed design emphasis whereby deploying structural mechanics intended to align with majority player types successfully translated into elevated perceived motivational impact.

The mid-tier cluster—Upgrade Equipment (Mdn = 4, IQR = 1, 78.3% $\geq$ 4) and Battles (Mdn = 4, IQR = 1.5, 73.9% $\geq$ 4)—demonstrated solid but more variable reception. While 73.9% of students rated Battles as motivating or highly motivating, the elevated IQR (1.5, highest among features with Mdn = 4–5) indicates more heterogeneous perceptions, potentially reflecting differential appeal across the different motivational affordances the element was designed to combine. Upgrade Equipment's performance (Mdn = 4, IQR = 1, 78.3% $\geq$ 4) aligns with its continuous deployment as an Explorer-oriented customization feature. The solid but not exceptional metrics suggest successful engagement of the target majority.

The lower-rated features—Pets (Mdn = 4, IQR = 2, 65.2% $\geq$ 4), Chests (Mdn = 4, IQR = 2, 60.9% $\geq$ 4), Cards (Mdn = 4, IQR = 2, 56.5% $\geq$ 4), and Skills (Mdn = 4, IQR = 3, 56.5% $\geq$ 4)—revealed more moderate perceived motivational impact with elevated interquartile ranges indicating substantial variability in student perceptions. Skills' elevated IQR (3, highest across all features) coupled with only 56.5% rating $\geq$ 4 suggests polarized reactions, wherein the feature strongly engaged some students (consistent with the idea that probabilistic, competitive-leaning mechanics can polarize preferences) while generating more tepid response from others. Cards, Chests, and Pets all demonstrated identical interquartile ranges (IQR = 2) but progressively declining percentages rating $\geq$ 4 (Pets 65.2%, Chests 60.9%, Cards 56.5%), indicating moderate consensus with substantial minorities perceiving these features as less motivating.

3.4. Associations Between Attitudinal Change and Perceived Motivation

To examine relationships between students' attitudinal changes across temporal dimensions and their responses to categorized game design elements, Spearman rank-order correlations (ρ) were computed with BCa bootstrap 95% confidence intervals. Table 8 presents the results for all pairings between the three temporal dimensions (Δ Past, Δ Present, Δ Future) and six gamification element categories (Assistance, Immersion, Incentive, Progression, Risk/Reward, Socialization).

The correlation matrix revealed predominantly weak associations between temporal motivation dimensions and gameful design element categories. Only one correlation achieved statistical significance after Holm adjustment for multiple testing: Immersion elements with Δ Future demonstrated a moderate positive correlation (ρ = 0.531, 95% CI [0.195, 0.776], p (Holm) = 0.027). This finding indicates that students who reported greater positive motivational change regarding future science teaching also showed more positive responses to Immersion-category elements (Narrative and Events).

One additional correlation approached statistical significance in the raw analysis but did not survive correction: Socialization elements with Δ Past showed a moderate positive association (ρ = 0.419, 95% CI [−0.012, 0.710], p (Raw) = 0.0464; p (Holm) = 0.139), suggesting a potential link between appreciation for group-based mechanics and retrospective attitudinal gains, though this association is not statistically defensible after controlling for multiple comparisons. All remaining correlations (16 of 18) demonstrated weak magnitudes ($|\rho| < 0.40$) with p (Raw)-values exceeding 0.10, indicating absence of significant linear relationships. No statistically significant correlations emerged for Assistance, Incentive, Progression, or Risk/Reward categories with any temporal dimension after Holm correction.

Taken together, the correlational analyses indicate that only Immersion showed a moderate, statistically robust association with pre–post change in the Future dimension, whereas other associations were weak or not statistically significant after adjustment. High

self-reported motivational ratings for several feature categories may have limited between-participant variability, which may reduce the sensitivity of correlational tests to detect differential associations across components. This pattern motivates the discussion of how immersive framing may relate to future-oriented self-efficacy, while underscoring the need for component-focused comparative designs to test these mechanisms.

Table 8. Spearman Correlations Between Attitudinal Change Dimensions and Perceived Motivation for Gamification Feature Categories.

Category	Δ Dimension	ρ [95% CI]	*p* (Raw)	*p* (Holm, Within Family)
Assistance	Δ Past	0.061 [−0.368, 0.532]	0.781	1
Assistance	Δ Present	−0.073 [−0.476, 0.404]	0.740	1
Assistance	Δ Future	0.007 [−0.405, 0.464]	0.976	1
Immersion	Δ Past	0.021 [−0.433, 0.451]	0.923	0.923
Immersion	Δ Present	0.270 [−0.135, 0.604]	0.213	0.426
Immersion	Δ Future	0.531 [0.195, 0.776]	0.009	0.027 *
Incentive	Δ Past	0.196 [−0.307, 0.544]	0.371	1
Incentive	Δ Present	−0.029 [−0.494, 0.468]	0.896	1
Incentive	Δ Future	0.133 [−0.360, 0.539]	0.545	1
Progression	Δ Past	−0.308 †	0.152	0.456
Progression	Δ Present	0.049 †	0.825	0.923
Progression	Δ Future	0.161 †	0.462	0.923
Risk/Reward	Δ Past	0.003 [−0.424, 0.469]	0.988	1
Risk/Reward	Δ Present	0.003 [−0.474, 0.478]	0.989	1
Risk/Reward	Δ Future	0.331 [−0.116, 0.711]	0.123	0.369
Socialization	Δ Past	0.419 [−0.012, 0.710]	0.046	0.139
Socialization	Δ Present	0.233 [−0.152, 0.550]	0.285	0.285
Socialization	Δ Future	0.358 [−0.002, 0.645]	0.093	0.187

Note: ρ = Spearman rank-order correlation; Δ = post-pre change scores; CI = 95% bias-corrected and accelerated (BCa) bootstrap confidence interval (B = 5000). *p* (Raw) = uncorrected two-tailed *p*-value; *p* (Holm) = Holm step-down family-wise error-adjusted *p*-value. N = 23 paired observations. * *p* (Holm) < 0.05. † Bootstrap CI could not be computed due to extreme ties and ceiling effects.

3.5. Qualitative Analysis of Student Responses

Thematic analysis of students' open-ended responses (see Appendix A, Table A1) identified six emergent themes reflecting key dimensions of students' experiences and perceived impacts of the gamified intervention (n = 15 voluntary respondents). The most prevalent theme—motivational uplift and increased enjoyment (93.3% of these respondents)—encapsulates students' overwhelmingly positive affective response to the course. Many framed it as the most energizing experience of their degree program and emphasized sustained engagement throughout the semester. Representative quotes include: "By far, this is the course that has motivated me the most in my degree; gamification kept me connected and motivated in physics and chemistry" and "Honestly, I really liked it." The recurrent emphasis on fun, interest, and momentum suggests that gamification did not merely make activities more entertaining; it helped maintain attention and effort across the semester, consolidating students' willingness to engage with physics and chemistry.

Nearly half (46.7%) reported positive change in attitude towards science, narrating a move from indifference—or even aversion—to curiosity and appreciation. Students often attributed this shift to the format and atmosphere of the course: "I was one of those who, at the beginning, did not like Physics and Chemistry, but now I can recognize it was because I had never been taught in such a dynamic, motivating and interesting way." Others highlighted how their reappraisal spilled beyond the classroom into everyday conversations: "My perception of physics and chemistry has drastically changed; during the course I couldn't stop telling those around me everything I was learning and why many things happen." For a few, the change included overcoming long-standing anxiety: "I am very happy I chose this course and have lost my fear of science."

Pedagogical approach and teacher impact (53.3% of respondents) were foregrounded by more than half the cohort, who pointed to hands-on laboratory work connected to everyday phenomena, clear and enjoyable explanations, and a well-structured, non-monotonous sequence of sessions. Typical remarks included: "I would highlight the lab practices in everyday physics and chemistry; they are very useful and attractive for our future pupils and for ourselves" and "The course is well focused and structured; it never became boring because every class was different." These comments indicate that instructional craft—variety, clarity, and purposeful alignment with real-world contexts—was central to both understanding and engagement.

Looking to their professional trajectory, 40.0% highlighted future-oriented transfer to teaching, stating clear intentions to adopt the course's approach and reporting a ready "toolbox of ideas" for primary classrooms. Illustrative quotes include: "Everything I have learned I am sure I will take to my classroom when I become a teacher!" and "Thanks to the experiments and activities we did, I now have a toolbox full of ideas to use with my future students." These accounts foreground the perceived sustainability of the intervention, with anticipated benefits extending beyond the present cohort into their professional practice.

Two lower-frequency themes—everyday relevance (20.0% of respondents) and personal growth and self-efficacy (6.7% of respondents)—appeared less prominently but underscore depth of change for some participants. Students described how science became visible in their daily lives: "Today I see physics and chemistry everywhere I go; science is recreational and everyday." Others spoke of individual transformation and increased confidence: "Now I feel more capable and confident to teach science in primary school." Although less prevalent than motivational themes, these patterns signal that the course helped anchor science in everyday perception and bolstered confidence for future teaching among a meaningful subset of the cohort.

4. Discussion

This mixed-methods study examined whether a narrative-driven digital gamification intervention grounded in the MDA framework and Bartle's player typology was associated with improvements in preservice elementary teachers' attitudes toward science and explored which game elements participants perceived as most motivating. By systematically triangulating quantitative pre–post attitudinal assessments, game-element motivation ratings, and qualitative open-ended responses, the findings provide convergent evidence of substantial improvements across past, present, and future temporal dimensions, alongside consistent emphasis on progression, narrative immersion, and collaborative structures as key motivational affordances. The integration of these complementary data strands provides a nuanced understanding of not only the magnitude of attitudinal change but also the lived experiences and pedagogical contexts through which such transformations may have occurred, contributing empirical evidence for narrative-enhanced digital platforms as research-based pedagogical innovations [15,20].

4.1. Observed Shifts in Science Attitudes and Perceived Teaching Self-Efficacy: Convergent Quantitative-Qualitative Evidence

The quantitative data indicate statistically significant gains with uniformly large effect sizes across all three temporal dimensions of science attitudes, with matched rank-biserial coefficients approaching unity, indicating near-universal upward movement within the sample, although these estimates should be interpreted as indicative, given the cohort size (N = 23) and the observed ceiling effects at post-test. Given the one-group pretest–posttest design, these differences are interpreted as within-participant changes following course participation, not as causal effects attributable to gamification. The direction and magnitude of these changes are broadly in line with meta-analytic patterns reported for gamification effects on affective outcomes in higher-education and STEM contexts [20], while recognizing that the present design does not permit causal attribution.

In response to RQ1, this pre–post pattern is documented both at the dimension level (Table 3) and at the item level within each temporal dimension (Tables 4–6). Crucially, these numerical patterns are corroborated by participants' qualitative narratives describing attitudinal transformation, providing rich, situated evidence that the observed psychometric gains may reflect genuine shifts in emotional stance, intellectual curiosity, and epistemological positioning—rather than merely socially desirable responding or measurement artifacts [5,51]. Taken together, the convergent strands support the plausibility of meaningful affective change, while underscoring the need for comparative designs in future work.

The Past dimension exhibited large gains ($r_{rb} \approx 1.00$; Table 3), reflecting substantial improvements in students' retrospective perceptions of their prior science learning experiences. Items assessing curiosity during school science classes, enjoyment of science, and fascination with scientific phenomena all showed median increases from 3–4 to 4–5, suggesting that participants developed more positive recollections of their own science education. This retrospective reappraisal is strikingly evident in qualitative accounts in which students described drastic changes in their perceptions of physics and chemistry, contrasting the RESC course's dynamic and motivating nature with their prior transmissive instruction characterized as monotonous and teacher centered [52]. It is crucial to note that the pre-test 'Past' dimension established a baseline comprising the students' entire history of physics and chemistry education—including recent university-level inquiry-based courses completed in their second year. The fact that the RESC experience (measured at post-test) was associated with such a marked divergence from this accumulated baseline is consistent with participants experiencing the RESC course as qualitatively distinct from their accumulated

prior physics/chemistry learning experiences. Furthermore, while exploratory analyses suggested a potential link between the Socialization category (working in groups) and these retrospective gains, this association did not retain statistical significance after conservative correction for multiple comparisons. However, given that Socializers constituted a substantial portion of the cohort (36%), qualitative evidence suggests that the collaborative structure may have played a supportive role in reducing anxiety, aligning with findings that cooperative learning environments can ameliorate negative attitudes toward science [53].

In contrast to the Past dimension's retrospective revaluation, the Present dimension reveals the study's most distinctive finding. The results resonate with other FantasyClass and narrative implementations, yet reveal a critical distinction. While Fabre-Mitjans et al. [54] and Jiménez-Valverde et al. [55] documented improvements in Past and Future dimensions, the present study uniquely achieved large effect sizes with median-level improvements across all three dimensions, including the Present dimension (r_rb ≈ 0.98; Table 3)—a finding not replicated in these other implementations, where either no significant changes [54] or no observable median shifts [55] were observed in present-moment attitudes. This distinction reflects pedagogical content specificity rather than differences in gamification infrastructure. The content-contextualization strategy—deliberately grounding physics and chemistry in recognizable, quotidian phenomena (e.g., why aircraft achieve flight, polymers in our lives, diaper absorption, household acids and bases)—may be consistent with a stronger association between gamification and present-moment attitudes. These findings suggest that pedagogical content specificity may be an important contextual factor shaping how gamified designs relate to present-moment attitudes, supporting the view that instruction embedded within authentic contexts enhances attitudinal outcomes [56,57] and aligns with research linking context-based science teaching to improved affective outcomes [58,59].

The Future dimension exhibited substantial gains (r_rb ≈ 1.00; Table 3), with items measuring confidence in teaching science content to primary pupils and adequacy of subject-matter knowledge both increasing from disagreement to strong agreement, representing significant shifts in teaching self-efficacy. Qualitative data enrich this pattern: participants described feeling more capable and confident in teaching science classes and having acquired "a toolbox of ideas" to implement with future students. Importantly, many accounts explicitly attributed these shifts to the course's gamified and narrative framing (e.g., the format, atmosphere, and engagement structure). However, these self-reported attributions are interpretive evidence of perceived mechanism rather than causal proof, and they cannot exclude alternative explanations (e.g., instructor effects, novelty, or maturation). Multiple students emphasized that the learning experience extended beyond scientific knowledge to encompass pedagogical craft, describing how they had never been taught in such a dynamic, motivating, and interesting way. These narratives suggest not merely cognitive appraisal of capability but early professional identity work—participants appear to be articulating hoped-for possible selves as more confident and reform-minded primary science teachers [60–62] and are consistent with self-efficacy theory emphasizing mastery and vicarious modeling as key sources of efficacy beliefs [63].

4.2. Motivational Affordances: Player-Type Alignment and Element Perceived Effectiveness

Addressing RQ2, participants' self-reported perceived motivational relevance ratings are summarized at the feature level in Table 7 and at the level of six theory-driven game-element categories in the Results. Quantitative ratings of game-element motivation revealed uniformly high endorsement across most features, with progression, narrative events, Wordlet, and collectibles achieving median scores of 5 and interquartile ranges of zero. Among six element families, Progression, Immersion, and Incentive emerged as

most consistently motivating (Mdn = 5), whereas Assistance and Risk/Reward showed more variability. These patterns align with player-type and motivational-affordance research indicating that competence-oriented (progression, challenge) and narrative-oriented (immersion, storytelling) features tend to appeal broadly across learner profiles, while social-competitive and chance-based mechanics can polarize preferences [15,35,64]. As noted in Section 2.3, Bartle's typology informed cohort-level feature selection and configuration; individual player-type classifications were used only to derive the cohort distribution and were not retained at the participant level for analysis and therefore were not used for subgroup or moderation analyses.

Specifically, the 'Skills' mechanic exhibited the highest interquartile variability (IQR = 3), likely reflecting a friction between the cooperative course ethos and the competitive affordances typically associated with 'Killer'-aligned motivation in the literature [33]. This underscores the challenge of balancing varying motivational needs within a single cohort and highlights that "one-size-fits-all" gamification carries the risk of alienating user segments whose motivational needs are not met [28,30,65]. In practical terms, this finding supports the rationale for adopting tailored digital gamification approaches grounded in user modeling to account for individual differences and mitigate the risks of one-size-fits-all designs, while maintaining bounded, pedagogically appropriate mechanics for classroom feasibility [36,66]. In the present study, however, "tailoring" should be understood as cohort-informed design rather than individualized adaptation.

The qualitative data triangulate and deepen these perceptual ratings by revealing the experiential mechanisms underlying high motivation. Students' descriptions consistently emphasized sustained engagement and contrast with prior instruction. Addressing RQ3, exploratory correlational analyses (Table 8) indicate that motivation for Immersion (narrative and ambient features) showed a moderate, statistically robust association with pre–post change in the Future dimension ($\rho = 0.531$, p (Holm) = 0.0273), whereas other associations were weak or not statistically significant after adjustment. Qualitative data contextualize this association: students who described gamification as offering opportunities to engage students in more enjoyable science teaching demonstrated an understanding of narrative's pedagogical potential that extended beyond personal enjoyment to professional application [67]. This convergence is consistent with the theoretical proposition that narrative may function as a cognitive–affective organizer supporting identity alignment—students who engaged with the storyline may have enacted a "teacher-innovator" identity that bridged learner and practitioner roles, potentially aligning with professional self-efficacy. Narrative's capacity to render abstract concepts personally consequential and situate learning within meaningful, emotionally resonant contexts has been documented in science education [68], and the present triangulated evidence extends this understanding to professional identity formation in teacher education.

4.3. Pedagogical Quality as Essential Context: Gamification as Potential Amplifier, Not a Substitute

A critical insight emerging from triangulation is that gamification's apparent association with positive outcomes was closely intertwined with the broader pedagogical design and students' opportunities to engage meaningfully with disciplinary content. Quantitatively, all three attitude dimensions improved significantly, but qualitatively, students foregrounded not only game mechanics but also pedagogical features. Participants emphasized how hands-on activities, laboratory-based experimentation, engaging explanations, and the instructor's approach were perceived as helping them deepen their understanding of physics and chemistry, which is consistent with prior evidence linking more frequent hands-on work and laboratory experiments to more positive attitudes toward science [69,70]. In this light, the triangulated findings support a crucial design principle: gamification may

have been associated with an amplification of, rather than replaced, research-based content pedagogy [23].

The intervention layered digital game elements onto a course already rich in inquiry-based laboratory work, constructivist approaches, everyday-science connections, and clear scaffolding—features known to be associated with improved attitudes among preservice elementary teachers [1,5]. Participants described acquiring not only scientific knowledge but also pedagogical approaches, highlighting how practices and experiments had given them numerous ideas to implement with future students. The convergence of quantitative gains and qualitative emphasis on hands-on experimentation and real-world relevance suggests that gamification's motivational affordances may have been realized in contexts where tasks were cognitively meaningful and authentically situated [2]. Students did not simply earn points for trivial activities; they completed challenging laboratory investigations and engaged in conceptual problem-solving—all framed within the gamified structure. This integration resonates with constructivist and situated-learning perspectives emphasizing that attitude change may be mediated by authentic participation, social scaffolding, and cognitive reappraisal [5,71]. The finding aligns with recent reviews warning that gamification is not a pedagogical panacea; its effectiveness appears to hinge on alignment with learning objectives, transparent feedback, meaningful task design, and instructional quality [21,23].

Our findings also offer a plausible account of how this amplification may have occurred by linking the observed pattern of change to the attitude-change mechanisms introduced in the Introduction. From an ELM perspective, the large attitudinal gains align with predictions of central-route processing: students engaged with content through meaningful, goal-directed laboratory tasks embedded within a coherent narrative, prioritizing elaboration over superficial engagement. This design would predict greater durability of attitude change [9]. Additionally, the observed pattern is consistent with cognitive dissonance resolution [10]: participants' positive, mastery-laden experiences directly contradicted their moderately negative baseline beliefs about science (Past pretest Mdn = 2.75), a pattern consistent with attitudinal realignment. Finally, consistent with the TPB [11], improvements in attitudes were accompanied by behavioral intentions: qualitative evidence reveals participants' heightened willingness to adopt gamification and active-learning strategies in future teaching, with the magnitude of attitude-to-intention effects evident in Future-dimension gains and consistent with evidence that first-hand gamified experiences during initial teacher education have been linked to stronger preservice teachers' acceptance of gamification and their intention to use it in future classrooms [72,73]. Collectively, these mechanisms—elaboration, dissonance resolution, and intention formation—offer complementary explanations for the observed transformation, reinforcing the interpretation of narrative-driven gamification as a coherent pedagogical system rather than motivational decoration [74].

From a practical standpoint, the findings point to a design stance in which gamification is treated as a coherence-building layer that amplifies strong disciplinary pedagogy rather than substituting for it. Consistent with the qualitative themes reported in Appendix A (Table A1), participants frequently described narrative continuity, transparent progression, and collaborative structures as providing a shared motivational frame for sustained engagement, whereas more polarizing mechanics were described with more heterogeneous reactions and therefore warrant careful boundary-setting in teacher-education contexts.

4.4. Potential Mechanisms of Professional Development

Building on this interpretation of narrative-driven gamification as an integrated pedagogical system, the pronounced gains in Future-dimension self-efficacy, coupled with

qualitative evidence of emergent professional identity, are consistent with several interpretive mechanisms discussed below, suggesting that the gamified course may have been experienced simultaneously as a content-learning environment and a pedagogical apprenticeship. By transparently modeling research-based, need-supportive design principles and embedding reflective opportunities, the course may have been associated with participants developing readiness to engage students using innovative approaches. This dual positioning aligns with teacher education scholarship on the apprenticeship of observation, which suggests that preservice teachers may default to replicating familiar pedagogies unless those experiences are surfaced and examined through structured critical reflection and inquiry [75,76]. Students' narratives revealing "I had never been taught this way" suggest that exposure to dynamic, gamified, narrative-rich instruction may have served as a powerful modeling experience [77]. This mechanism may help account for why participants simultaneously improved their attitudes toward science and demonstrated emerging capacity to imagine themselves as innovative science educators.

The convergence of quantitative and qualitative findings also highlights that the intervention may have changed situational cues plausibly relevant to stereotype threat and performance anxiety, which disproportionately affect preservice elementary teachers in physics and chemistry domains [3,4]. By embedding science tasks within a collaborative narrative framework and a mastery-oriented motivational climate, the gamified design may have altered situational cues that typically heighten evaluative vigilance—shifting emphasis from individually diagnostic performance toward purposeful contributions to shared goals and a sense of belonging. This recontextualization may have reduced ego-involvement by moving from individual performance-comparison (am I smart enough?) toward collaborative, meaningful action (am I contributing to the story?). In Steele's terms [78], stereotype threat is a situational pressure—"a threat in the air"—that is activated when a negative group stereotype becomes relevant for interpreting oneself or one's performance in an identified-with setting; importantly, he argues that reducing a stereotype's interpretive relevance in the setting may attenuate the threat and its detrimental effects. Consistent with this account, the collective narrative and mastery framing may have lowered the immediate salience and interpretive weight of negative stereotypes, while identity-safe cues that signal one's social identity will not be a liability could plausibly reduce identity-related concerns (e.g., belonging, devaluation) that sustain threat in academic contexts [79].

4.5. Limitations and Future Directions

Several design features warrant acknowledgment as limitations. First, the study employed a pre-experimental one-group design without a concurrent control or comparison condition. While common in educational innovation research, this design limits the ability to rule out maturation effects or external variables as causes of the observed changes, representing a constraint on internal validity [80]. Related threats include history effects (concurrent experiences during the semester), measurement reactivity (sensitization from repeated testing), and expectancy or demand characteristics (participants' awareness of the intervention goals). Second, the sample comprised 23 fourth-year preservice teachers in an elective course, implying self-selection that may limit generalizability to mandatory foundational courses or cohorts with lower baseline interest or higher science anxiety. The small sample restricts statistical power and precludes subgroup analyses. Ceiling effects were evident at post-test: three items exhibited zero variance, and multiple dimensions showed compressed distributions. While this indicates near-universal positive attitudes—a desirable outcome—it complicates statistical analysis by reducing variance and attenuating correlations. The qualitative data were limited to brief open-ended written responses rather than in-depth interviews, constraining depth. Although participants frequently attributed

change to the gamified experience, these accounts should be interpreted as perceived explanatory narratives rather than as evidence that rules out competing explanations (e.g., instructor charisma or novelty effects). Moreover, the intervention was implemented in a single Spanish university context by a single instructor, limiting ecological generalizability. Finally, player-type personalization relied on Bartle's framework, originally developed for multi-user game environments. Alternative frameworks explicitly designed for educational gamification contexts, such as HEXAD [81], may provide further insights in future research. Despite these constraints, the convergence of large quantitative effect sizes with consistent qualitative corroboration supports cautious confidence that the observed patterns are consistent with genuine attitudinal transformation rather than artifact.

Future research should include comparison-groups designs (e.g., quasi-experimental or randomized studies) and employ controlled comparative designs that disentangle the effects of key design components (e.g., the narrative layer, progression/feedback mechanics, and social–collaborative structures) by contrasting component-equivalent versions of the intervention with non-gamified instruction, ideally using concurrent comparison conditions to strengthen causal inference and improve interpretability of null and mixed findings. Such component-focused comparative work is particularly important given that much of the gamification literature evaluates interventions as bundled packages rather than isolating specific affordances [14]. Longitudinal follow-up tracking participants into in-service teaching—via classroom observations, lesson-plan analyses, and self-reported adoption—would assess whether attitudinal gains translate into sustained pedagogical practices potentially influencing primary pupils' outcomes. Individual-difference moderator analyses examining initial anxiety, prior achievement, player-type profiles, or cultural background could inform personalized tailoring [30,35,66]. Design-based research iterations that systematically vary narrative depth, team size, reward schedules, or autonomy-supportive features could help explore design alternatives across cycles and distill transferable design principles, thereby refining evidence-based gamification frameworks for STEM teacher education [82]. Future work should also examine practical drivers and barriers shaping the adoption and implementation of gamification and game-based learning in universities [83].

5. Conclusions

This study indicates that a narrative-driven digital gamification intervention grounded in the MDA framework and informed by Bartle's player typology was associated with substantial improvements in preservice elementary teachers' science attitudes and teaching self-efficacy. Participants reported enhanced motivation, and qualitative narratives suggested early professional identity work, alongside intentions to adopt gamification strategies in their future classrooms. The integration of structural gamification mechanics, player-type-aligned design, and narrative immersion is interpreted as a coherence-building layer that can amplify strong disciplinary instruction in this context, rather than substituting for it. Motivation for narrative and immersion elements showed a moderate, statistically significant association with future-oriented self-efficacy gains, suggesting that carefully designed gamified environments may support pedagogically relevant outcomes while accommodating variability in learner preferences. Given the one-group pretest–posttest design, these findings support an associational interpretation rather than causal attribution to gamification. Future research using experimental or quasi-experimental designs, multisite replication, and longitudinal follow-up will be essential to establish causality and assess the durability and transfer of these gains.

Author Contributions: Conceptualization, G.J.-V.; methodology, G.J.-V. and N.F.-M.; software, G.J.-V. and G.G.-B.; validation, N.F.-M. and G.G.-B.; formal analysis, G.J.-V.; investigation, G.J.-V. and G.G.-B.; data curation, G.J.-V. and N.F.-M.; writing—original draft preparation, G.J.-V. and N.F.-M.; writing—review and editing, G.J.-V., N.F.-M. and G.G.-B.; supervision, G.J.-V.; funding acquisition, G.J.-V. All authors have read and agreed to the published version of the manuscript.

Funding: The research has been funded by the Institute of Professional Development (IDP) of Universitat de Barcelona, grant number REDICE22-3080, and the APC was partially funded by Universitat de Barcelona, through the RIMDA program (2021PID-UB/024).

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

Acknowledgments: The authors gratefully acknowledge Carlos Heras-Paniagua for his contribution to the production of some of the narrative videos used in the gamified intervention.

Conflicts of Interest: The authors declare no conflicts of interest. The authors have no affiliation with FantasyClass; the platform is a third-party tool used for instructional delivery.

Abbreviations

The following abbreviations are used in this manuscript:

BCa	Bias-Corrected and Accelerated
CI	Confidence Interval
ECTS	European Credit Transfer and Accumulation System
ELM	Elaboration Likelihood Model
IQR	Interquartile Range
M	Mean
MDA	Mechanics, Dynamics, Aesthetics
Mdn	Median
RESC	Recreational and Everyday Science in the School
RQ	Research Question
STEM	Science, Technology, Engineering, and Mathematics
TPB	Theory of Planned Behavior

Appendix A

This appendix presents the results of the thematic analysis of students' open-ended responses.

Table A1. Thematic summary (participant-level prevalence).

Theme (Frequency)	Codes	Representative Quotes
Motivational uplift and increased enjoyment (93.3%)	most motivating course, favorite, fun/engaging, sustained interest	"By far, this is the course that has motivated me the most in my degree; gamification kept me connected and motivated in physics and chemistry." "Honestly, I really liked it."
Pedagogical approach and teacher impact (53.3%)	hands-on labs/experiments, everyday phenomena, clear explanations, well-structured/non-monotonous	"I would highlight the lab practices in everyday physics and chemistry; they are very useful and attractive for our future pupils and for ourselves." "The course is well focused and structured; it never became boring because every class was different."

Table A1. *Cont.*

Theme (Frequency)	Codes	Representative Quotes
Positive change in attitude towards science (46.7%)	changed perception/new vision, from dislike/indifference to interest, sharing learning, lost fear of science	"I was one of those who, at the beginning, did not like Physics and Chemistry, but now I can recognize it was because I had never been taught in such a dynamic, motivating and interesting way." "My perception of physics and chemistry has drastically changed; during the course I couldn't stop telling those around me everything I was learning and why many things happen."
Future-oriented transfer to teaching (40.0%)	intent to adopt gamification, toolbox of ideas, usefulness for future pupils	"Everything I have learned I am sure I will take to my classroom when I become a teacher!" "Thanks to the experiments and activities we did, I now have a toolbox full of ideas to use with my future students."
Everyday relevance: science in daily life (20.0%)	see science everywhere, recreational/everyday science, real-world connection	"Today I see physics and chemistry everywhere I go; science is recreational and everyday." ". . .everyday physics and chemistry. . . very useful and attractive for our future pupils."
Personal growth and self-efficacy. (6.7%)	greater confidence to teach, lost fear of science	"Now I feel more capable and confident to teach science in primary school." "I have lost my fear of science."

Note: Frequencies represent the number of unique students endorsing each theme at least once (participant-level; N = 15). Percentages are % of 15 and do not sum to 100% because students often endorsed multiple themes.

References

1. Feille, K. Models of Science Teacher Identity: The Multiple Representations of Pre-Service Elementary Science Educators. *J. Sci. Teach. Educ.* **2025**, *36*, 465–484. [CrossRef]
2. Tytler, R.; Ferguson, J.P. Student Attitudes, Identity, and Aspirations toward Science. In *Handbook of Research on Science Education: Volume III*; Lederman, N.G., Zeidler, D.L., Lederman, J.S., Eds.; Routledge: London, UK, 2023; pp. 158–192. [CrossRef]
3. Brígido, M.; Borrachero, A.B.; Bermejo, M.L.; Mellado, V. Prospective primary teachers' self-efficacy and emotions in science teaching. *Eur. J. Teach. Educ.* **2013**, *36*, 200–217. [CrossRef]
4. Bursal, M.; Paznokas, L. Mathematics anxiety and preservice elementary teachers' confidence to teach mathematics and science. *Sch. Sci. Math.* **2006**, *106*, 173–180. [CrossRef]
5. Settlage, J.; Southerland, S.A.; Smith, L.K.; Ceglie, R. Constructing a doubt-free teaching self: Self-efficacy, teacher identity, and science instruction within diverse settings. *J. Res. Sci. Teach.* **2009**, *46*, 102–125. [CrossRef]
6. Bennett, J.; Hogarth, S. Would you want to talk to a scientist at a party? High school students' attitudes to school science and to science. *Int. J. Sci. Educ.* **2009**, *31*, 1975–1998. [CrossRef]
7. Potvin, P.; Hasni, A. Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. *Stud. Sci. Educ.* **2014**, *50*, 85–129. [CrossRef]
8. Korthagen, F.A.J.; Loughran, J.; Russell, T. Developing fundamental principles for teacher education programs and practices. *Teach. Teach. Educ.* **2006**, *22*, 1020–1041. [CrossRef]
9. Petty, R.E.; Cacioppo, J.T. *Communication and Persuasion: Central and Peripheral Routes to Attitude Change*; Springer: New York, NY, USA, 1986. [CrossRef]
10. Festinger, L. *A Theory of Cognitive Dissonance*; Stanford University Press: Stanford, CA, USA, 1957.
11. Ajzen, I. The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* **1991**, *50*, 179–211. [CrossRef]
12. Eagly, A.H.; Chaiken, S. *The Psychology of Attitudes*; Harcourt Brace Jovanovich College Publishers: Fort Worth, TX, USA, 1993.
13. Glasman, L.R.; Albarracín, D. Forming attitudes that predict future behavior: A meta-analysis of the attitude-behavior relation. *Psychol. Bull.* **2006**, *132*, 778–822. [CrossRef]
14. Koivisto, J.; Hamari, J. The rise of motivational information systems: A review of gamification research. *Int. J. Inf. Manag.* **2019**, *45*, 191–210. [CrossRef]
15. Sailer, M.; Homner, L. The gamification of learning: A meta-analysis. *Educ. Psychol. Rev.* **2020**, *32*, 77–112. [CrossRef]
16. Deterding, S.; Dixon, D.; Khaled, R.; Nacke, L. From game design elements to gamefulness: Defining "gamification". In Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, Tampere, Finland, 28–30 September 2011; ACM: New York, NY, USA, 2011; pp. 9–15. [CrossRef]

17. Seaborn, K.; Fels, D.I. Gamification in theory and action: A survey. *Int. J. Hum.-Comput. Stud.* **2015**, *74*, 14–31. [CrossRef]
18. Kalogiannakis, M.; Papadakis, S.; Zourmpakis, A.-I. Gamification in Science Education. A Systematic Review of the Literature. *Educ. Sci.* **2021**, *11*, 22. [CrossRef]
19. Putz, L.-M.; Hofbauer, F.; Treiblmaier, H. Can gamification help to improve education? Findings from a longitudinal study. *Comput. Hum. Behav.* **2020**, *110*, 106392. [CrossRef]
20. Zainuddin, Z.; Chu, S.K.W.; Shujahat, M.; Perera, C.J. The impact of gamification on learning and instruction: A systematic review of empirical evidence. *Educ. Res. Rev.* **2020**, *30*, 100326. [CrossRef]
21. Dichev, C.; Dicheva, D. Gamifying education: What is known, what is believed and what remains uncertain: A critical review. *Int. J. Educ. Technol. High. Educ.* **2017**, *14*, 9. [CrossRef]
22. Almeida, C.; Kalinowski, M.; Uchôa, A.; Feijó, B. Negative effects of gamification in education software: Systematic mapping and practitioner perceptions. *Inf. Softw. Technol.* **2023**, *156*, 107142. [CrossRef]
23. Van Roy, R.; Zaman, B. Unravelling the ambivalent motivational power of gamification: A basic psychological needs perspective. *Int. J. Hum.-Comput. Stud.* **2019**, *127*, 38–50. [CrossRef]
24. Filatro, A.; Cavalcanti, C.C. Structural and content gamification design for tutor education. In Proceedings of the E-Learn: World Conference on E-Learning, Washington, DC, USA, 14–16 November 2016; pp. 1152–1157.
25. Kapp, K. *The Gamification of Learning and Instruction. Game-Based Methods and Strategies for Training and Education*; Wiley: San Francisco, CA, USA, 2012.
26. Jiménez-Valverde, G. Narrative approaches in science education: From conceptual understanding to applications in chemistry and gamification. *Encyclopedia* **2025**, *5*, 116. [CrossRef]
27. Palomino, P.; Isotani, S. Enhancing User Experience in Learning Environments: A Narrative Gamification Framework for Education. *J. Interact. Syst.* **2024**, *15*, 478–489. [CrossRef]
28. Xiao, Y.; Hew, K.F. Personalized gamification versus one-size-fits-all gamification in fully online learning: Effects on motivational, behavioral and cognitive outcomes. *Learn. Individ. Differ.* **2024**, *112*, 102470. [CrossRef]
29. Hallifax, S.; Serna, A.; Marty, J.-C.; Lavoué, G.; Lavoué, E. Factors to consider for tailored gamification. In Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '19), Barcelona, Spain, 22–25 October 2019; ACM: New York, NY, USA, 2019; pp. 559–572. [CrossRef]
30. Oliveira, W.; Hamari, J.; Shi, L.; Toda, A.M.; Rodrigues, L.; Palomino, P.T.; Isotani, S. Tailored gamification in education: A literature review and future agenda. *Educ. Inf. Technol.* **2023**, *28*, 373–406. [CrossRef]
31. Hunicke, R.; Leblanc, M.G.; Zubek, R. MDA: A Formal Approach to Game Design and Game Research. In Proceedings of the AAAI Workshop on Challenges in Game AI, San Jose, CA, USA, 25–29 July 2004.
32. Palomino, P.T. Theories around gamification in education. In *Gamification Design for Educational Contexts: Theoretical and Practical Contributions*; Toda, A., Cristea, A.I., Isotani, S., Eds.; Springer: Cham, Switzerland, 2023; pp. 49–66. [CrossRef]
33. Klock, A.C.T.; Gasparini, I.; Pimenta, M.S.; Hamari, J. Tailored gamification: A review of literature. *Int. J. Hum.-Comput. Stud.* **2020**, *144*, 102495. [CrossRef]
34. Nacke, L.E.; Deterding, S. The maturing of gamification research. *Comput. Hum. Behav.* **2017**, *71*, 450–454. [CrossRef]
35. Tondello, G.F.; Mora, A.; Nacke, L.E. Elements of gameful design emerging from user preferences. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17), Denver, CO, USA, 6–11 May 2017; pp. 129–142. [CrossRef]
36. Rodrigues, L.; Toda, A.M.; Oliveira, W.; Palomino, P.T.; Pessoa, M.M.; Carvalho, L.; Isotani, S. Personalized gamification: A literature review of outcomes, experiments, and approaches. In Proceedings of the 8th International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM '20), Salamanca, Spain, 21–23 October 2020; ACM: New York, NY, USA, 2020; pp. 699–706. [CrossRef]
37. Bartle, R. Hearts, clubs, diamonds, spades: Players who suit MUDs. *J. MUD Res.* **1996**, *1*, 19–40.
38. Ferro, L.S.; Walz, S.P.; Greuter, S. Towards personalised, gamified systems: An investigation into game design, personality and player typologies. In Proceedings of the 9th Australasian Conference on Interactive Entertainment: Matters of Life and Death (IE '13), Melbourne, Australia, 30 September–1 October 2013; ACM Press: New York, NY, USA, 2013; pp. 1–6. [CrossRef]
39. Creswell, J.W.; Plano Clark, V.L. *Designing and Conducting Mixed Methods Research*, 3rd ed.; SAGE Publications: Thousand Oaks, CA, USA, 2018.
40. Johnson, R.B.; Christensen, L. *Educational Research: Quantitative, Qualitative, and Mixed Approaches*, 7th ed.; SAGE Publications, Inc.: Thousand Oaks, CA, USA, 2020.
41. Kocadere, S.A.; Çağlar, S. Gamification from Player Type Perspective: A Case Study. *Educ. Technol. Soc.* **2018**, *21*, 12–22.
42. The Bartle Test of Gamer Psychology. Available online: https://matthewbarr.co.uk/bartle/ (accessed on 10 December 2025).

43. Jiménez, G.; Calafell, G.; Fabre, N.; Heras, C. Desarrollo y validación de un cuestionario sobre actitudes y motivación hacia la física y química en estudiantes de Magisterio. Un análisis comparado. In *Sobre la Educación Científica y el Cuidado de la Casa Común: Necesidades y Perspectivas*; Díez-Ojeda, M., Martínez-Juste, S., Bogdan-Toma, R., Dies-Álvarez, M.E., Ramírez-Segado, A., Jiménez-Fontana, R., García-González, E., Eds.; Dykinson: Madrid, Spain, 2024; pp. 140–161. Available online: https://hdl.handle.net/2445/215006 (accessed on 10 December 2025).
44. Taber, K.S. The use of Cronbach's alpha when developing and reporting research instruments in science education. *Res. Sci. Educ.* **2018**, *48*, 1273–1296. [CrossRef]
45. Nunnally, J.C.; Bernstein, I.H. *Psychometric Theory*, 3rd ed.; McGraw-Hill: New York, NY, USA, 1994.
46. Barbera, J.; Naibert, N.; Komperda, R.; Pentecost, T.C. Clarity on Cronbach's alpha use. *J. Chem. Educ.* **2021**, *98*, 257–258. [CrossRef]
47. Reid, N.; Amanat Ali, A. Beliefs and attitudes: Why do attitudes matter? In *Making Sense of Learning: A Research-Based Approach*; Springer: Cham, Switzerland, 2020; pp. 253–279. [CrossRef]
48. Braun, V.; Clarke, V. *Thematic Analysis: A Practical Guide*; SAGE Publications Ltd.: London, UK, 2021.
49. Jiménez-Valverde, G.; Fabre-Mitjans, N.; Heras-Paniagua, C.; Guimerà-Ballesta, G. Tailoring Gamification in a Science Course to Enhance Intrinsic Motivation in Preservice Primary Teachers. *Educ. Sci.* **2025**, *15*, 300. [CrossRef]
50. Jiménez-Valverde, G.; Fabre-Mitjans, N.; Guimerà-Ballesta, G. Narrative-Driven Digital Gamification for Motivation and Presence: Preservice Teachers' Experiences in a Science Education Course. *Computers* **2025**, *14*, 384. [CrossRef]
51. Paulhus, D.L. Measurement and control of response bias. In *Measures of Personality and Social Psychological Attitudes*; Robinson, J.P., Shaver, P.R., Wrightsman, L.S., Eds.; Academic Press: San Diego, CA, USA, 1991; pp. 17–59. [CrossRef]
52. van Aalderen-Smeets, S.; Walma van der Molen, J. Measuring Primary Teachers' Attitudes Toward Teaching Science: Development of the Dimensions of Attitude Toward Science (DAS) Instrument. *Int. J. Sci. Educ.* **2013**, *35*, 577–600. [CrossRef]
53. Kirikkaya, E.B. Grade 4 to 8 primary school students' attitudes towards science: Science enthusiasm. *Educ. Res. Rev.* **2011**, *6*, 374–382.
54. Fabre-Mitjans, N.; Jiménez-Valverde, G.; Guimerà-Ballesta, G.; Calafell-Subirà, G. Digital gamification to foster attitudes toward science in early childhood teacher education. *Appl. Sci.* **2025**, *15*, 5961. [CrossRef]
55. Jiménez-Valverde, G.; Heras-Paniagua, C.; Fabre-Mitjans, N.; Calafell-Subirà, G. Gamifying teacher education with *FantasyClass*: Effects on attitudes towards physics and chemistry among preservice primary teachers. *Educ. Sci.* **2024**, *14*, 822. [CrossRef]
56. Bybee, R.; McCrae, B. Scientific literacy and student attitudes: Perspectives from PISA 2006 science. *Int. J. Sci. Educ.* **2011**, *33*, 7–26. [CrossRef]
57. Raved, L.; Assaraf, O.B.Z. Attitudes towards science learning among 10th-grade students: A qualitative look. *Int. J. Sci. Educ.* **2011**, *33*, 1219–1243. [CrossRef]
58. Bennett, J.; Lubben, F.; Hogarth, S. Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Sci. Educ.* **2007**, *91*, 347–370. [CrossRef]
59. Osborne, J.; Simon, S.; Collins, S. Attitudes towards science: A review of the literature and its implications. *Int. J. Sci. Educ.* **2003**, *25*, 1049–1079. [CrossRef]
60. Pellikka, A.; Lutovac, S.; Kaasila, R. The change in pre-service primary teachers' possible selves in relation to science teaching. *Eur. J. Teach. Educ.* **2022**, *45*, 43–59. [CrossRef]
61. Hong, J.; Greene, B. Hopes and Fears for Science Teaching: The Possible Selves of Preservice Teachers in a Science Education Program. *J. Sci. Teach. Educ.* **2011**, *22*, 491–512. [CrossRef]
62. Avraamidou, L. Stories we live, identities we build: How are elementary teachers' science identities shaped by their lived experiences? *Cult. Stud. Sci. Educ.* **2019**, *14*, 33–59. [CrossRef]
63. Bandura, A. *Self-Efficacy: The Exercise of Control*; W.H. Freeman: New York, NY, USA, 1997.
64. Laine, T.H.; Lindberg, R.S.N. Designing engaging games for education: A systematic literature review on game motivators and design principles. *IEEE Trans. Learn. Technol.* **2020**, *13*, 804–821. [CrossRef]
65. Subirats, L.; Nousiainen, T.; Hooda, A.; Rubio-Andrada, L.; Fort, S.; Vesisenaho, M. Gamification based on user types: When and where it is worth applying. *Appl. Sci.* **2023**, *13*, 2269. [CrossRef]
66. Hong, Y.; Saab, N.; Admiraal, W. Approaches and game elements used to tailor digital gamification for learning: A systematic literature review. *Comput. Educ.* **2024**, *212*, 105000. [CrossRef]
67. Dvir, N. Using narrative pedagogy for novice teachers' professional development. *Prof. Dev. Educ.* **2024**, *50*, 625–637. [CrossRef]
68. Kokkotas, P.; Rizaki, A.; Malamitsa, K. Storytelling as a strategy for understanding concepts of electricity and electromagnetism. *Interchange* **2010**, *41*, 379–405. [CrossRef]
69. Ornstein, A. The frequency of hands-on experimentation and student attitudes toward science: A statistically significant relation. *J. Sci. Educ. Technol.* **2006**, *15*, 285–297. [CrossRef]
70. Murphy, C.; Ambusaidi, A.; Beggs, J. Middle East meets west: Comparing children's attitudes to school science. *Int. J. Sci. Educ.* **2006**, *28*, 405–422. [CrossRef]

71. Lave, J.; Wenger, E. *Situated Learning: Legitimate Peripheral Participation*; Cambridge University Press: Cambridge, UK, 1991.
72. Buda, A.; Pesti, C. Gamification solution in teacher education. *Acta Educ. Gen.* **2024**, *14*, 1–15. [CrossRef]
73. Guerrero Puerta, L. Preservice teachers' perceptions of future gamification use: A case report. *Societies* **2024**, *14*, 11. [CrossRef]
74. Nicholson, S. A recipe for meaningful gamification. In *Gamification in Education and Business*; Reiners, T., Wood, L.C., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 1–20. [CrossRef]
75. Brunker, N. Learning to Teach without an Apprenticeship of Observation: From Home Education to Initial Teacher Education. *Aust. Educ. Res.* **2024**, *51*, 1291–1309. [CrossRef]
76. Lortie, D. *Schoolteacher: A Sociological Study*; University of Chicago Press: London, UK, 1975.
77. Pozzi, F.; Persico, D. Gamification for Teacher Professional Development: The Case for Narrative Approaches. *Interact. Des. Archit. J.* **2024**, *62*, 26–40. [CrossRef]
78. Steele, C.M. A Threat in the Air: How Stereotypes Shape Intellectual Identity and Performance. *Am. Psychol.* **1997**, *52*, 613–629. [CrossRef] [PubMed]
79. Murphy, M.C.; Taylor, V.J. The role of situational cues in signaling and maintaining stereotype threat. In *Stereotype Threat: Theory, Process, and Application*; Inzlicht, M., Schmader, T., Eds.; Oxford University Press: Oxford, UK, 2012; pp. 17–33. [CrossRef]
80. Taber, K.S. Experimental research into teaching innovations: Responding to methodological and ethical challenges. *Stud. Sci. Educ.* **2019**, *55*, 69–119. [CrossRef]
81. Marczewski, A. *The Gamification Design Handbook. Even Ninja Monkeys Like to Play*; Gamified UK: Brétigny-sur-Orge, France, 2023.
82. Tinoca, L.; Piedade, J.; Santos, S.; Pedro, A.; Gomes, S. Design-Based Research in the Educational Field: A Systematic Literature Review. *Educ. Sci.* **2022**, *12*, 410. [CrossRef]
83. Lester, D.; Skulmoski, G.J.; Fisher, D.P.; Mehrotra, V.; Lim, I.; Lang, A.; Keogh, J.W.L. Drivers and barriers to the utilisation of gamification and game-based learning in universities: A systematic review of educators' perspectives. *Br. J. Educ. Technol.* **2023**, *54*, 1748–1770. [CrossRef]