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Narrative-Driven Digital Gamification for Motivation and Presence: Preservice Teachers' Experiences in a Science Education Course

Gregorio Jiménez-Valverde *, Noëlle Fabre-Mitjans and Gerard Guimerà-Ballesta

EduCiTS Innovation and EMA Research Groups, IRE-Faculty of Education, Universitat de Barcelona, 08035 Barcelona, Spain; nfabre@ub.edu (N.F.-M.); gerard.guimera@ub.edu (G.G.-B.)
* Correspondence: gregojimenez@ub.edu

Abstract

This mixed-methods study investigated how a personalized, narrative-integrated digital gamification framework (with FantasyClass) was associated with motivation and presence among preservice elementary teachers in a science education course. The intervention combined HEXAD-informed personalization (aligning game elements with player types) with a branching storyworld, teacher-directed AI-generated narrative emails, and multimodal cues (visuals, music, scent) to scaffold presence alongside autonomy, competence, and relatedness. Thirty-four students participated in a one-group posttest design, completing an adapted 21-item PENS questionnaire and responding to two open-ended prompts. Results, which are exploratory and not intended for broad generalization or causal inference, indicated high self-reported competence and autonomy, positive but more variable relatedness, and strong presence/immersion. Subscale correlations showed that Competence covaried with Autonomy and Relatedness, while Presence/Immersion was positively associated with all other subscales, suggesting that presence may act as a motivational conduit. Thematic analysis portrayed students as active decision-makers within the narrative, linking consequential choices, visible progress, and team-based goals to agency, effectiveness, and social connection. Additional themes included coherence and organization, fun and enjoyment, novelty, extrinsic incentives, and perceived professional transferability. Overall, findings suggest that narrative presence, when coupled with player-aligned game elements, can foster engagement and motivation in STEM-oriented teacher education.

Keywords: digital literacy; gamification; motivation; narrative; player type; presence; science education; self-determination theory; STEM; teacher training

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1. Introduction

Attitudes toward science can be understood as relatively stable affective dispositions that reflect students' feelings towards science, which can influence their decisions, motivation, and engagement with scientific learning [1]. Fostering favorable attitudes is therefore pivotal, both for sustaining public belief in science and for enabling better academic outcomes [2,3]. Yet preservice elementary teachers (PETs) often enter university programs with low motivation and persistent negative attitudes towards science, patterns that impede engagement and learning [4,5] and that have been repeatedly observed across different contexts [6]. Contributing factors to these attitudes include transmissive school experiences, limited content knowledge, and fragile self-efficacy [7,8], all of which can crystallize into anxiety and avoidance. Because teacher preparation shapes future classroom practice and broader educational outcomes [9], strengthening both disciplinary understanding and confidence is crucial [10–12]. Emotions and attitudes are integral to pedagogical content knowledge—effective science teaching depends not only on methods but also on affective dimensions that support scientific literacy [13].

The robust literature documents a gradual decline in students' science attitudes with age [14,15] and shows how teacher-centered instruction exacerbates disaffection [16]. Among PETs, negative emotions are particularly salient in domains such as physics and chemistry, fostering avoidance of these subjects in later teaching [17,18]. Emotional variables—such as anxiety, boredom, or the perception that science is irrelevant—have been shown to strongly predict students' disengagement from science learning [1,19,20]. In addition, students' motivation and persistence are shaped by the ways in which science identities are constructed in the classroom and by the underlying beliefs about who can or should "do science". Teachers' conceptions of the nature of science, their classroom practices, and the implicit messages they transmit influence not only students' understanding of scientific knowledge, but also their sense of belonging and identification with science [21].

Nevertheless, attitudes are malleable: well-designed interventions can improve views and motivation [22], especially when they emphasize inquiry, collaboration, and real-world relevance—approaches linked to more positive affective outcomes and to deeper understanding and achievement [23–27]. Teachers' positive attitudes not only correlate with higher self-efficacy [28], but their professional disposition also models both knowledge building and emotional engagement for their pupils [29,30]. Instructional methodology can shift attitudes [31], and fostering motivation through active and emotionally positive methodologies is essential for enhancing preservice teachers' commitment to and willingness to teach science [32]. This motivates gamification as an affectively rich strategy to foster PETs' motivation and reconfigure their relationship with science.

1.1. Gamification

Educational gamification can be defined as the use of game elements in educational contexts to enhance learners' motivation and engagement [33,34]. Game elements function as scaffolds that nudge learners to interact with content and progress toward valued goals [33,35]. Motivation is consequential: it organizes the initiation, direction, intensity, persistence, and quality of goal-directed behavior [36], and in education it is linked to deeper understanding and higher achievement [37]. Motivated science learners assume responsibility for their own progress [38]; positive attitudes and motivation co-evolve, with social context shaping both [39]. Empirically, gamification has been associated with increased motivation and other benefits in education broadly [40] and in science education specifically [41,42].

That said, these benefits are not automatic. Design quality is pivotal: poorly implemented gamification, where for example, game elements function as mere add-ons—often referred to as "chocolate-covered broccoli" [43]—can disengage learners or even erode existing motivation by over-relying on extrinsic rewards (e.g., points, badges) [44,45], which in fact can trigger the "overjustification effect" [46], reducing students' interest once rewards are removed [47]. Effective gamification must also be tailored to learner diversity [48]; a "one size fits all" approach can exacerbate disengagement [49,50]. Ensuring that game elements resonate with all participants requires careful design that accounts for variables such as age, prior knowledge, and, most notably, player type [51–53]. Frameworks such as Bartle's taxonomy [54] and the HEXAD model [55] offer valuable starting points for understanding different patterns of player engagement. Personalized gamification shows promise for increasing motivation, engagement, and satisfaction [56], particularly when digital tools are used to adjust game mechanics and narratives to individual profiles [57]. In fact, digital gamification—that is, the integration of game elements via digital tools and platforms such as Classcraft [58]—offers several advantages over non-digital approaches, including greater autonomy and adaptability, improved visualization and appealing media formats [59], immediate feedback [60], and even the facilitation of collaboration across distances [61].

Self-Determination Theory (SDT) is the most frequently cited lens for educational gamification [62] and is widely used to guide design [63,64]. SDT distinguishes intrinsic motivation—engaging in an activity for its inherent interest from extrinsic motivation—engaging for external rewards [65,66]. While intrinsic and extrinsic motives can sometimes coexist productively [67], striking an appropriate balance is nontrivial, and several studies caution that extrinsic add-ons may dampen intrinsic motivation [68]. According to SDT, intrinsic motivation flourishes when three basic psychological needs are satisfied: autonomy (volition), competence (effectiveness), and relatedness (social connection) [69]. A well-designed gamified environment with a thoughtful selection of game elements can be tailored to support these three psychological needs. For example, customizable avatars may enhance autonomy, badges and leaderboards can satisfy the need for competence by providing feedback on achievements, and team-based challenges with a shared goal can foster social relatedness [44].

1.2. Narrative

Among the many game elements available for gamification, narrative is especially promising for STEM education—not only for the demonstrated benefits of narrative approaches in science education (see [70,71] for thorough reviews), but because narrative can substantially enhance motivation [72], and foster problem-solving skills [73]. In the context of gamification, narrative refers to a meaningful story or storyline that embeds activities and characters within a broader fictional or real-world context, thereby providing them with significance and purpose that goes beyond the accumulation of points or achievements [44]. Recent work underscores the importance of implementing rigorous, narrative-centered frameworks that support personalization and experiential learning, and leverage storytelling to deepen user engagement and motivation [74].

With regard to SDT needs, narrative-driven gamified environments can promote autonomy (meaningful choices, agency) [75–77], competence (progressive, skill-building arcs) [75,78,79], and relatedness (emotional connection with characters, collaboration, shared adventure) [44,75,76,79,80].

Beyond its capacity to satisfy SDT needs, integrating narrative elements into gamified environments gives rise to "presence"—the subjective sense of being in the narrative world and responding to its events and characters as if they were real [75,81]—through a process known as narrative transportation, in which individuals become mentally and emotionally absorbed in the story [82]. Presence in games/gamification is a multidimensional construct comprising physical, emotional, and narrative facets [75]. While physical presence refers to the sensation of being "inside" the narrative environment, and emotional presence to the depth and authenticity of affective engagement, narrative presence encapsulates the extent to which learners feel part of the unfolding story, experiencing a sense of agency and identification with characters, and responding to narrative developments as meaningful and impactful [83,84].

The interplay between narrative presence and SDT needs is particularly noteworthy: when students perceive themselves as active participants in the story, they are more likely to report autonomy, competence, and relatedness [44,85], so high levels of narrative presence can enhance motivation and engagement, fostering a learning context in which students become protagonists of their educational journey [86–88]. This immersion in the narrative frame supports students' willingness to persist with challenging tasks, increases their openness to new perspectives, and promotes deeper emotional involvement with both content and peers [76,89]. Research also indicates that presence is more strongly correlated with perceived learning effects than enjoyment alone, suggesting that the subjective sense of "being there" directly contributes to educational effectiveness [90].

1.3. Study Aims and Objectives

The primary aim of this study was to examine PETs' motivation and experience of presence following participation in a personalized, narrative-driven gamified intervention in a science education course. By intensifying the narrative dimension, the study aimed to provide both quantitative and qualitative insights into students' motivation and their sense of presence in this gamified narrative context.

Accordingly, the study addressed the following research questions:

- How does participation in a personalized, narrative-based gamified intervention affect preservice teachers' satisfaction of basic psychological needs (competence, autonomy, relatedness)?
- To what extent do preservice teachers experience presence while engaging in activities within a gamified science course organized around a unifying narrative?

2. Materials and Methods

This study followed a convergent mixed-methods design [91], in which quantitative and qualitative data were collected simultaneously, analyzed independently, and then integrated to provide a comprehensive interpretation of the findings. In its quantitative component, the study adopted a descriptive and exploratory non-experimental design [92], specifically structured as a one-group posttest-only design, as no independent variables were manipulated. This strand employed a validated questionnaire to assess participants' satisfaction of core psychological needs and their sense of presence. The qualitative component was designed to complement and enrich the quantitative results through thematic analysis of students' written responses to two open-ended questions. Integration of both strands occurred during the results stage, where qualitative themes were presented alongside quantitative findings, allowing for direct comparison and triangulation.

2.1. Participants

The participant group consisted of 34 fourth-year students (27 women and 7 men; mean age = 21.8 years, median = 21) enrolled in the bachelor's degree in Primary Education at the University of Barcelona (Spain). All participants were taking the course "Recreational and Everyday Science in the School" (RESC) during the 2024–2025 academic year. Participation was voluntary, and all students provided informed consent prior to inclusion in the study.

2.2. Procedure

RESC is a fourth-year elective course within the Primary Education bachelor's degree at the University of Barcelona. Delivered over 15 weeks (6 ECTS credits) in a face-to-face format, it builds on students' prior coursework in physics and chemistry didactics completed two years earlier. With this foundation, the RESC course emphasizes the practical, everyday, and recreational applications of physics and chemistry, aiming to equip future teachers with innovative strategies and resources for engaging primary students in meaningful science learning.

The gamification design in this study was based on the structured approach described in our previous work [56], itself rooted in Marczewski's [55] framework for tailored gamification. In line with this framework, two key phases were implemented: first, participants' predominant player types were identified using the HEXAD model; second, the selection and deployment of game elements was guided by the multidimensional classification of Toda et al. [93], drawing on the associations identified by Santos et al. [94] between specific player types and preferred gamification features.

To translate the selected game elements into practice, we employed FantasyClass (https://fantasyclass.app/, accessed on 1 July 2025), a free online platform designed for structural gamification in educational contexts [95]. The platform offers customizable functionalities—such as avatars, themes, points, leaderboards, rewards, and progression systems (Figure 1)—which were selectively activated and adapted to align with the motivational profiles identified in this cohort. To ensure a smooth onboarding and to prevent cognitive overload, the various functionalities of the FantasyClass platform were introduced gradually over the initial sessions of the course. Rather than presenting all features at once, basic functions (such as avatar creation and points tracking) were enabled first, allowing students to become familiar with the core mechanics. Additional features were progressively activated in subsequent sessions, once students demonstrated comfort with the previously introduced functionalities, in line with the segmenting principle in multimedia learning [96].

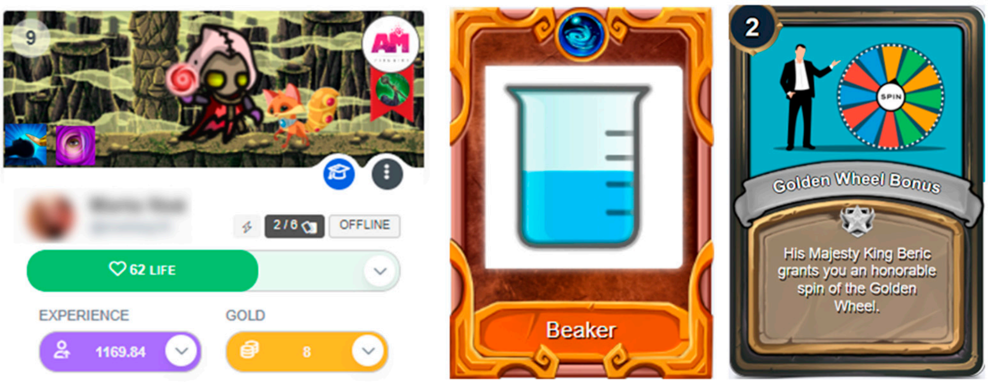

Figure 1. Examples of three FantasyClass features. From left to right: a student's avatar (showing their basic stats, pet, level, and skills), a collectible item, and a card. Completing a full thematic set of collectibles (in this example, laboratory equipment) results in a reward. Both collectibles and cards can be obtained at random from the virtual shop or granted as rewards for leveling up or completing tasks. Additionally, students can trade duplicate collectibles with one another through FantasyClass. The use of these screenshots has been authorized by the creator of FantasyClass.

The HEXAD-12 questionnaire [97] was administered digitally on the first day of the course using its creator's official website [98]. The results for this cohort indicated a marked predominance of Philanthropists (42%), followed by Socializers (24%) and Achievers (18%), with Free Spirits and Players representing smaller subsets (10% and 6%, respectively), and Disruptors entirely absent. Table 1 presents the game elements associated with each prioritized dimension, along with the corresponding FantasyClass functionalities that enabled their implementation.

The Social dimension [93] was prioritized due to the pronounced presence of Philanthropists and Socializers among the participant group (66% combined). Its implementation followed the same structure described in [56], emphasizing sustained collaboration through stable teams of 3 or 4 students with defined roles, cooperative "monster battles" (see Figure 2), and supportive in-game actions. While cooperation was the primary focus, selective competitive elements, including leaderboards and targeted group challenges, were incorporated to encourage self-improvement without undermining teamwork.

Table 1. Overview of the prioritized game elements, organized according to the dimensions defined by Toda et al. [93], along with the corresponding FantasyClass features used to support their implementation.

Dimension	Primary HEXAD Player Types Targeted	Game Element	FantasyClass Feature
Social	Socializers Philanthropists	Cooperation	Teams Roles Battles Collections Cards Skills
		Competition	Leaderboards Teams Cards Skills
Fictional	Socializers	Narrative	Themes
		Storytelling	Challenges Music
Performance	Achievers	Point	Experience Points (XP) Health Points (HP)
		Progression	Map Levels
		Level	Levels
		Acknowledgment	Badges

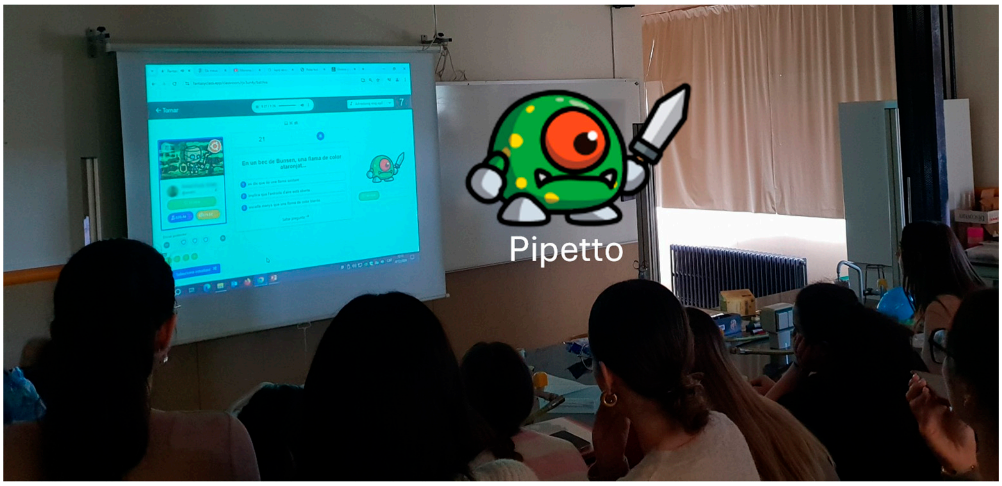

Figure 2. Example of a question during a "monster battle" in the FantasyClass platform. In this case, the question displayed reads: "In a Bunsen burner, a flame with an orange color...". One student, randomly chosen by Pipetto, one of Morgana's monsters, must choose the correct option from three possible answers to complete the sentence within 30 s. If the class succeeds in defeating the monster by answering questions correctly, all students receive the reward.

The Fictional dimension [93] was prominently prioritized in this course, aligning with the motivational profiles of Socializers—drawn to rich, shared adventures [52]—and with the broader aim of enhancing intrinsic motivation. This dimension encompassed both narrative—the overarching storyworld, structure, and opportunities for agency—and storytelling—the delivery, dramatization, and sensory elements that brought the world to life. Building on the previous implementation [56], the present edition intensified immersion by shifting from a linear storyline to a more interactive, student-driven adventure.

The narrative remained organized around four kingdoms—Science, Chemistry, Energy, and Challenges—each corresponding to one of the RESC course's curricular blocks and ruled by one of four central characters: Clarissa of Curiosity, Elixia of Essence, Beric the Brilliant, and the antagonist Morgana the Schemer, respectively. The plot centered on Morgana's invasion, which had disrupted the balance of scientific knowledge across the realms. To restore order, students embarked on a collaborative journey through the kingdoms, solving challenges and completing missions tied to course content. The adventure culminated in a final confrontation at Morgana's castle, where students showcased the finished STEM products they had developed (Figure 3), determining whether peace would be restored to the kingdoms. To ensure individual accountability within these cooperative projects, a combination of peer assessment and self-assessment was employed, allowing the final grade to be adjusted fairly to reflect each member's actual involvement and responsibility [99].

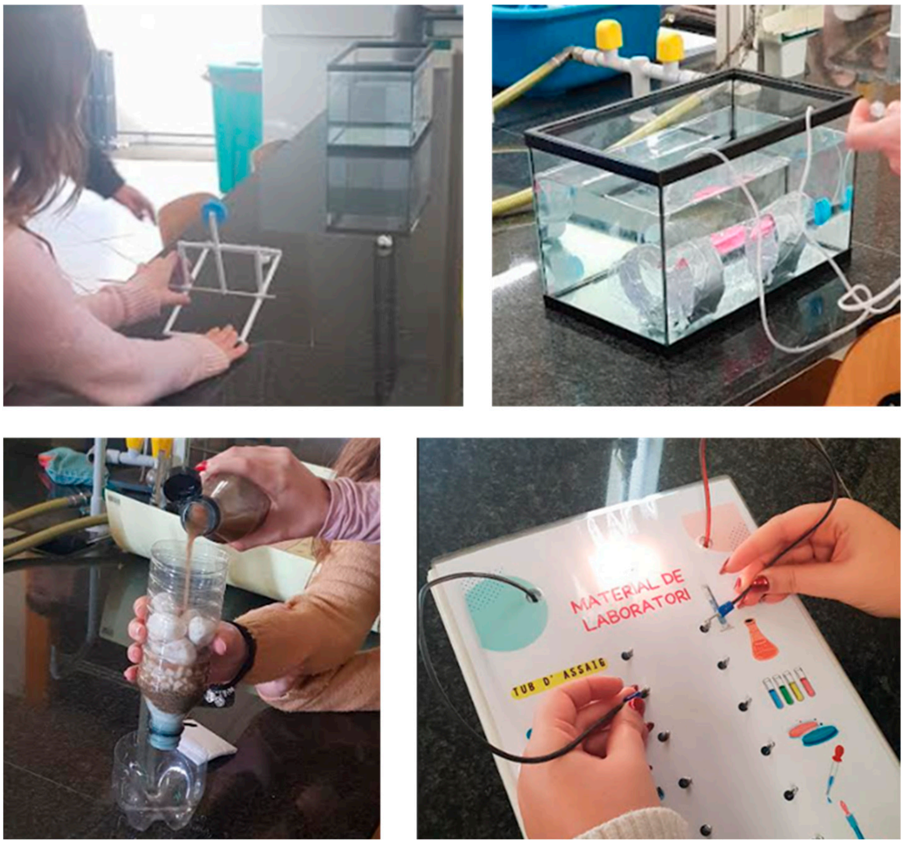

Figure 3. Examples of STEM projects presented by students. From left to right and top to bottom: catapult, submarine, water filter, and electric quiz boards that light up when the correct pairs are matched.

Narrative and storytelling components were deliberately crafted to strengthen presence [75]. Physical presence was fostered through AI-generated illustrations and avatars, cinematic videos, medieval-style background music played not only during storytelling sessions but also during laboratory activities, and sensory cues such as lavender scents in classroom scenes set in lavender fields.

Emotional presence was reinforced through direct interaction with the four main characters, from whom students received personalized emails generated with AI-based tools, providing scaffolding to overcome specific challenges or advance their STEM projects.

Beyond academic support, students initiated contact to negotiate in-game deals beyond the FantasyClass platform—such as exchanging unwanted cards for gold coins, trading collectibles for virtual shop items, or even secretly allying with Morgana to gain extra XP in exchange for HP via a "dark spell." These requests were routed to a dedicated GPT-4o chat and drafted in-character. The instructor determined whether to accept, reject, or counter each proposal and provided the constraints and tone; GPT-4o then produced a draft that was reviewed (and, when appropriate, edited) before sending it to students. When operating within the same chat thread, drafts could draw on prior exchanges with the same student. This created the impression of engaging with autonomous, contextually responsive characters whose decisions carried both memory and personality, deepening students' sense of co-presence, emotional investment, and attachment to the characters [100]. All AI-mediated, in-character replies were produced in a teacher-in-the-loop workflow with clear disclosure to students and bounded AI roles (e.g., no grading decisions). This operationalization aligns with current guidance for transparent, human-centered use of generative AI in education [101,102].

Narrative presence was heightened through frequent, consequential branching dilemmas and plot choices that shaped missions, rewards, and the story's path (Figure 4). This design transformed the course into a dynamic "choose-your-own-adventure," fostering collective agency and ensuring that this cohort experienced a unique storyline, thereby increasing the likelihood of sustained narrative transportation and high levels of presence.

Message from H.M. Queen Elixia

"Brave heroes and warriors, you have successfully overcome Morgana's first challenge. They are waiting for you in Slimehaven—it is urgent!"- says de Queen

You look at your companions… Will you take the straight path, risking an encounter with one of Morgana's monsters, or will you take a detour through the village of Honeyvale? In Honeyvale, a creative contest is being held where you could win gold coins, but it might make you late to Slimehaven..

Figure 4. Example of a narrative slide projected during class, accompanied by medieval-style background music, representing a branching point in the story where the class must make a consequential decision. In this scenario, the students must choose whether to take the direct path—risking an unknown encounter—or to detour through the village of Honeyvale (where they will work on density), knowing this may make them late to Slimehaven (where they will experiment with polymers). Depending on their choice, the story unfolds differently: taking the direct route ultimately leads to a "monster battle" (see Figure 2), while the detour allows them to avoid confrontation but miss out on a timely arrival. . . The picture of this slide was generated with GPT-4o.

The Performance dimension was prioritized to address the needs of Achievers, who are motivated by clear indicators of progress, mastery, and personal accomplishment [93]. To maximize the appeal of this dimension, the platform was configured with a comprehensive framework of points, level advancement, and progression tracking that offered students regular feedback on both learning outcomes and classroom participation. Two types of points were central to this system: HP, which functioned primarily as a classroom management mechanism, incentivizing timely attendance and effective collaboration while discouraging undesirable behaviors through deductions; and XP, which were awarded for academic achievements, directly reflecting effort and quality in course assignments and activities. This distinction ensured that behavioral and academic contributions were recognized separately, allowing students to monitor and regulate both domains of their participation. To support this self-monitoring, students had access to immediate visual feedback via the avatar panel, which displayed their current level, XP bar, and HP status (see Figure 1). In addition, the platform featured a Log page where students could review all actions affecting their progress—including XP/HP changes, item purchases, rewards for completing collectible sets, and other relevant events—each entry accompanied by a timestamp and an expanded description providing additional details about the registered action.

As students accumulated XP, 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. Progression, apart from the levels, was also visually represented through a dynamic map of the four kingdoms, which initially appeared covered in clouds. As students moved through different areas and successfully completed challenges, the clouds in those specific regions dissipated, gradually revealing the territories they had conquered.

Although Free Spirits (10%) and Players (6%) represented smaller segments of the participant group, their motivational needs were also considered in the gamified design. FantasyClass offered substantial opportunities for autonomy and self-expression, allowing Free Spirits to personalize their avatars and make choices within the platform. Students could make deliberate decisions in resource allocation—such as purchases in the virtual shop, equipment upgrades, or collectible cards—that influenced their long-term progression and performance within the gamified environment. These features align with the preference of Free Spirits for flexibility and self-direction [52].

For Players, the integration of Puzzles and Chance elements provided the excitement that motivates this type of player. The Puzzles element was incorporated into FantasyClass through the Wordlet feature, a challenge in which students had to guess a word related to the corresponding lesson topic. The word appears in a crossword-style format and follows a Mastermind-like mechanic, where students receive feedback after each attempt, progressively refining their guesses and obtaining a reward upon completion. The element of Chance played a crucial role in maintaining a dynamic and unpredictable learning environment by incorporating various mechanics that introduced unexpected outcomes. Random events, triggered daily by the instructor, could either benefit or challenge students, adding an additional layer of excitement and uncertainty. Similarly, the virtual wheel awarded a random amount of gold coins, either to pre-selected students or to randomly chosen participants, reinforcing the element of surprise.

By integrating these elements, the course was intended to ensure that even minority motivational profiles had meaningful avenues for engagement and satisfaction within the gamified environment.

2.3. Instrument

To evaluate the motivational impact of the gamified intervention, we employed the Player Experience of Need Satisfaction (PENS) questionnaire, which is grounded in SDT [66] and was specifically designed to assess the satisfaction of core psychological needs—autonomy, competence, and relatedness—as well as the dimensions of intuitive controls and presence during game-based experiences [83]. The PENS has been widely used and validated in research on motivational dynamics in digital and game-based environments [103]. Recent work has also emphasized the value of adapting the PENS framework to educational gamification contexts, particularly for capturing presence alongside need satisfaction and perceived usability [89].

The instrument consisted of 21 items distributed across five subscales: Competence (items 1–3), Autonomy (4–6), Relatedness (7–9), Intuitive Controls (10–12), and Presence/Immersion (13–21). Each item was rated on a 7-point Likert-type scale ranging from 1 (“not at all true”) to 7 (“very true”), with 4 indicating “somewhat true.” All items were minimally contextualized to the course (for example, the original “I feel competent at the game” was adapted to “I felt competent during the gamified course”), ensuring that the core construct meaning remained unchanged. The adaptation process included translation into the target language and minor wording or contextual modifications to enhance clarity and fit for our educational setting, but no structural changes (e.g., item addition or removal) were made. This approach aligns with recognized best practices in test adaptation, which emphasize maintaining equivalence of meaning and contextual appropriateness [104].

PENS is intended to capture in situ, state-like experiences of need satisfaction and presence; therefore, a single post-administration immediately after the intervention is methodologically appropriate for our descriptive and associative aims. Accordingly, the PENS questionnaire was administered digitally at the end of the course as a posttest, consistent with established practice [103]. Participation was voluntary, all students provided informed consent, and responses were collected anonymously.

Reliability in the present sample was high. The internal consistency of the overall questionnaire was excellent (Cronbach’s alpha = 0.927), and each subscale also demonstrated strong reliability for the adapted wording in this cohort: Competence ($\alpha = 0.847$), Autonomy ($\alpha = 0.822$), Relatedness ($\alpha = 0.880$), Intuitive Controls ($\alpha = 0.823$), and Presence/Immersion ($\alpha = 0.943$).

To complement the quantitative data, two open-ended questions were included: “Can you explain how FantasyClass motivated you in the course?” and “Can you explain how the narrative of the activities in the course motivated you?” This qualitative component allowed participants to elaborate on the specific aspects of gamification and narrative design that influenced their motivation, providing a deeper understanding of the mechanisms at play.

2.4. Data 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). Subscale composite scores were computed at the participant level as the mean of the constituent items after reverse-scoring where required, following the original PENS scoring convention [83] and standard practice for summated Likert scales treated as approximately interval when aggregating multiple items [105,106]. 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. Associations among motivational dimensions were examined using Spearman rank-order correlations (ρ) between the five subscale composites ($k = 10$). All correlations were computed on complete cases with $N = 34$ participants (listwise). We report two-tailed p-values and 95% bias-corrected and accelerated (BCa) bootstrap confidence intervals (CI) with $B = 5000$ resamples, resampling at the participant level, and we adjusted p-values using the Benjamini–Hochberg false discovery rate (FDR) procedure ($q = 0.05$).

The qualitative analysis followed a hybrid thematic analysis approach [107], supported by Atlas.ti v.25, combining deductive codes—derived from the study's aims and the five PENS subscales—with inductive codes emerging directly from students' responses. This approach was chosen to address the dual aims of examining motivational dimensions explicitly targeted by the intervention while remaining open to unanticipated aspects of students' experiences. The analytic process followed Braun and Clarke's framework for thematic analysis [108]. For reporting frequencies, a student was counted once per theme (themes may co-occur in a single student's response). The percentage for each theme reflects the proportion of students whose responses included that theme; since one student could refer to multiple themes, percentages may sum to more than 100%.

3. Results

The results are presented by PENS subscales, integrating descriptive statistics with qualitative themes for each dimension. Full thematic tables for both open-ended questions are available in Appendix (Tables A1 and A3). After addressing each subscale, we report correlations and present additional themes that emerged inductively from the qualitative data but were not part of the original PENS framework.

3.1. PENS Subscales

3.1.1. Competence

Students reported a high sense of competence in relation to the gamified intervention (Table 2). The median for this subscale was 6.67 (IQR = 1.42), indicating responses clustered toward the upper end. Examining the individual items, the median score for feeling competent during the gamified course (item 1) was 7 (IQR = 1.25), and the same median of 7 (IQR = 2) was observed for feeling very capable and effective during the course (item 2). The item regarding the perceived match between students' abilities and the challenges presented (item 3) had a slightly lower median of 6 (IQR = 1.25) but still reflected high perceived competence across the group. Overall, interquartile ranges were small to moderate, suggesting limited dispersion in students' perceptions.

Table 2. Competence subscale.

Item Number and Statement	Mdn	IQR
1—I felt competent during the gamified course.	7	1.25
2—I felt very capable and effective during the gamified course.	7	2
3—My ability to engage in the gamified activities was well matched with the challenges they presented.	6	1.25
Competence global value	6.67	1.42

Note: Mdn: median; IQR: interquartile range.

In the first open-ended question, focused on FantasyClass as a motivational tool, the theme of competence emerged in 47.1% of student responses. Students frequently described how the system of earning experience points, leveling up, and completing collections or voluntary tasks encouraged them to progress, strive for improvement, and master course content. This sense of challenge was especially salient, as many saw FantasyClass as a form of healthy competition—both with themselves and, at times, with their peers. Comments such as, "I felt motivated to keep progressing and improving myself. I saw it as a competition and it made me try harder," and "The collections helped me learn vocabulary from the subject," exemplify how the platform supported a feeling of academic achievement and self-improvement. Several students also remarked that working toward these goals led to greater satisfaction and a deeper understanding of the subject matter.

In the second open-ended question, which explored the impact of the narrative, 23.5% of students referenced competence-related experiences. Here, students discussed how deciphering character intentions, solving narrative problems, and applying what they learned to story-based experiments made them feel capable and successful. As one student noted, "It motivated me because I had to understand and distinguish the intentions of each character to progress," while another wrote, "It was very interesting to apply what I learned to the experiments and the story." For many, overcoming narrative challenges fostered not only a sense of accomplishment but also increased confidence and pride in their ability to engage with complex, creative learning scenarios.

Taken together, the quantitative results—showing a high global competence value alongside consistently elevated item medians—and the qualitative accounts—highlighting game elements (e.g., XP, levels, collections) and narrative problem-solving as drivers of mastery—converge to depict a coherent picture of students experiencing strong efficacy, challenge–skill balance, and achievement throughout the intervention.

3.1.2. Autonomy

Students reported high levels of perceived autonomy in relation to the gamified activities (Table 3). The global median for the Autonomy subscale was 6.67 (IQR = 0.75), indicating scores concentrated near the upper end. Looking at the individual items, students reported that the gamified activities and the FantasyClass platform provided them with interesting options and choices (item 4: median = 7, IQR = 1), as well as allowing them to do interesting things (item 5: median = 7, IQR = 0). Slightly lower, but still high, was the sense of experiencing a lot of freedom during the gamified activities (item 6: median = 6, IQR = 1). This combination of high central tendency and minimal dispersion points to broad agreement about the presence of meaningful choice, freedom, and the ability to act independently in the gamified context.

Table 3. Autonomy subscale.

Item Number and Statement	Mdn	IQR
4—The gamified activities in the course and the FantasyClass platform provided me with interesting options and choices.	7	1
5—The gamified activities in the course and the FantasyClass platform allowed me to do interesting things.	7	0
6—I experienced a lot of freedom during the gamified activities and when using FantasyClass.	6	1
Autonomy global value	6.67	0.75

Note: Mdn: median; IQR: interquartile range.

In the first open-ended question, focused on FantasyClass as a motivational tool, autonomy was a key theme for 35.3% of students. Many participants described how FantasyClass fostered a sense of agency and meaningful choice—most notably, the ability to select which voluntary tasks to pursue, when to participate, and even which character to adopt at the beginning of the course. Students highlighted the motivational value of being able to "choose my character at the beginning of the course" and "decide which extra tasks I wanted to do to gain experience points or coins." This sense of control and personal decision-making appeared to support engagement, as the platform allowed them to chart their own learning paths rather than simply following externally imposed activities. Students commented, "FantasyClass motivated me because I could decide how to participate and which activities to focus on," and emphasized how being "the main agent and having to make decisions all the time" was associated with greater involvement and responsibility. This student-centered, flexible environment appeared to support ownership and self-direction, fostering both motivation and perseverance.

In the second open-ended question, which examined the impact of narrative elements, 20.6% of students referenced autonomy-related experiences. Here, autonomy was often described in terms of opportunities to make choices and influence the direction of the story. Students valued the freedom to decide how to respond to narrative events or challenges: "You feel part of the class and can decide different events freely." Others pointed to the need to apply their own strategies to overcome narrative obstacles, reinforcing the sense of control and active participation: "I had to apply different strategies to overcome challenges in FantasyClass." For these students, the narrative's flexibility was described as motivating and as strengthening their sense of ownership over the learning process, allowing them to engage more deeply with the content and the unfolding story.

Overall, the high median scores for all Autonomy items and the frequent qualitative references to meaningful choice—both in gameplay and in narrative decision-making—converge to depict students perceiving abundant opportunities for self-direction and describing concrete ways in which these choices enhanced their engagement, agency, and personal investment in the course.

3.1.3. Relatedness

Results for the relatedness subscale (Table 4) showed more variability than for the previous dimensions. The global adjusted median for this subscale was 6.33 (IQR = 2.50), indicating moderately high but somewhat dispersed perceptions of social connection. For individual items, students reported a median of 6.5 (IQR = 2) for finding the relationships formed during the gamified course fulfilling (item 7), and a median of 6 (IQR = 3) for considering these relationships important (item 8). In contrast, the negatively worded item, "I did not feel close to other classmates" (item 9), had a median of 2 (IQR = 3). This low median on the negative item actually reflects a positive experience: most students reported feeling close to their classmates.

Table 4. Relatedness subscale.

Item Number and Statement	Mdn	IQR
7—I found the relationships I formed during the gamified course fulfilling.	6.5	2
8—I found the relationships I formed during the gamified course important.	6	3
9 *—I did not feel close to other classmates.	2	3
Relatedness adjusted global value	6.33	2.50

Note: Mdn: median; IQR: interquartile range. * = negatively worded.

In the first open-ended question, which focused on FantasyClass as a motivational tool, the theme of relatedness appeared in 26.5% of student responses. Students frequently highlighted the social and collaborative aspects of the platform, describing how working in teams and experiencing a positive classroom climate appeared to enhance their engagement. Typical comments included, "We formed groups to work together in a more fun classroom environment," and "I liked being part of a group with a shared goal in the adventure." Relatedness emerged through both formal teamwork—"We could work in teams to complete challenges"—and informal social dynamics, as one student described: "The classroom atmosphere was more enjoyable and we all participated together." Several students directly linked this sense of community to increased motivation: "Feeling like you are all in it together makes you want to put in more effort." Sharing a storyline and collective goals was described as contributing to a sense of belonging and, in some cases, students described "helping each other to advance in the adventure." In sum, the collaborative dimension was portrayed as turning learning from an individual pursuit into a shared journey.

In the second open-ended question, focused on the narrative, 29.4% of students referenced relatedness. Here, motivation was driven not only by collaboration with classmates but also by emotional bonds with the story's characters. Several students noted the sense of group cohesion created by having a common enemy or working toward shared narrative objectives: "We all had a common enemy, which made the experience more immersive." Others described forming personal connections with particular characters: "The characters make you feel important in the narrative. I even became 'team Morgana'." The narrative's social dimension helped establish a classroom environment in which students felt part of something larger than themselves, supported not just by their peers but by the fictional world as well.

Overall, the moderately high global median score for relatedness—paired with frequent qualitative accounts of teamwork, shared goals, and emotional bonds—suggest convergence between strands. Students' perceptions of fulfilling and important relationships were reinforced by vivid narratives of collaborative problem-solving, mutual support, and connection with fictional characters, underscoring the social dimension as a salient contributor to motivation in this context.

3.1.4. Intuitive Controls

This dimension also received consistently high ratings from students (Table 5). The global median for Intuitive Controls was 6.33 (IQR = 1.67), reflecting an overall perception of the platform as accessible and user-friendly. Specifically, students reported a median of 6 (IQR = 2) for both finding it easy to learn the controls of FantasyClass (item 10) and for describing the controls as intuitive (item 11). The highest score was observed for remembering how to perform actions within the platform (item 12: median = 7, IQR = 1), with particularly low dispersion for this item, suggesting a widespread and positive experience with the platform's usability. Together, these results indicate that students experienced FantasyClass as easy to use and that technical barriers to participation were minimal. No explicit references to intuitive controls or usability appeared in the open-ended responses, which may indicate that usability was taken for granted or was not especially salient in students' motivational reflections.

Table 5. Intuitive Controls subscale.

Item Number and Statement	Mdn	IQR
10—Learning the controls of FantasyClass was easy.	6	2
11—The controls of FantasyClass were intuitive.	6	2
12—When I wanted to do something in FantasyClass, it was easy to remember the corresponding control.	7	1
Intuitive Controls global value	6.33	1.67

Note: Mdn: median; IQR: interquartile range.

3.1.5. Presence/Immersion

Presence/Immersion, the most extensive subscale in the questionnaire with nine items, received generally high ratings from students (Table 6). The global adjusted median for this subscale was 5.89 (IQR = 1.17), indicating substantial immersion with modest dispersion. Students reported feeling transported to another time and place (item 13: median = 6, IQR = 1), exploring the narrative world as if taking a real journey (item 14: median = 6, IQR = 2), and feeling as if they were actually present in the narrative (item 15: median = 6, IQR = 2.25).

Table 6. Presence/Immersion subscale.

Item Number and Statement	Mdn	IQR
13—When engaging with the narrative-based activities, I felt transported to another time and place.	6	1
14—Exploring the world of the narrative felt like taking an actual trip to a new place.	6	2
15—When engaging with the narrative, I felt as if I were actually there.	6	2.25
16 *—I was not emotionally impacted by events in the narrative.	2	3
17—The narrative-based course experience was emotionally engaging.	7	1.25
18—I experienced emotions during the narrative-based activities as intensely as I have in real life.	6	2
19—When participating in the narrative-based activities, I felt as if I were part of the story.	6	2
20—When I accomplished something in the narrative-based activities, I experienced genuine pride.	7	1
21—I had reactions to events and characters in the narrative-based activities as if they were real.	6	2
Presence/Immersion adjusted global median	5.89	1.17

Note: Mdn: median; IQR: interquartile range. * = negatively worded.

Across items, students reported substantial immersion and emotional involvement. Notably, the negatively worded statement "I was not emotionally impacted by events in the narrative" (item 16: median = 2, IQR = 3) received low agreement, further supporting the overall pattern of high emotional engagement. Other items indicated high engagement: students widely agreed that the narrative-based course was emotionally engaging (item 17: median = 7, IQR = 1.25), that they experienced emotions during activities as intensely as in real life (item 18: median = 6, IQR = 2), and that participation in the narrative felt like being part of the story (item 19: median = 6, IQR = 2). Additionally, students reported experiencing genuine pride in their accomplishments (item 20: median = 7, IQR = 1) and reacting to events and characters as if they were real (item 21: median = 6, IQR = 2).

In the first open-ended question, focused on FantasyClass as a motivational tool, the theme of presence and immersion appeared in 28.4% of student responses. Many participants described their learning experience as "like being inside a story" or "like playing a role-playing game where your decisions could benefit or hurt you." Students commented that this immersive, narrative-driven approach was described as transforming the course from a series of isolated lessons into a coherent, engaging adventure. Students also linked immersion directly to increased attention, curiosity, and enjoyment, as in: "FantasyClass made the subject more engaging; you feel like the main agent and have to make decisions all the time." Others described how their engagement extended beyond class time, with students checking the platform for updates, rewards, or new story developments. Thus, the sense of "being there" in the course was associated in students' accounts with higher motivation and was accompanied by concrete behaviors such as extra participation, anticipation, and greater emotional investment.

In the second open-ended question, which explored the impact of the narrative itself, presence and immersion was the most frequently coded motivational dimension, cited by 38.2% of students. Students described feeling like the protagonist of an unfolding adventure: "It made me feel like the protagonist of the process and experience everything firsthand." Others explained how the story was described as transforming routine lessons into an emotionally engaging, magical world: "The narrative made me feel immersed in this magical world, like I was truly part of the story." For these students, learning was portrayed as active, meaningful, and full of narrative suspense, and students described heightened curiosity, attention, and their willingness to participate throughout the course.

The strong alignment between the global Presence/Immersion median and the richness of qualitative accounts is consistent with convergence: statistical evidence of immersion is reinforced by vivid descriptions of feeling embedded in the story world, suggesting —based on students' reports—that the narrative design was associated with deep engagement at multiple experiential levels.

3.2. Subscale Correlations

We examined associations among the five PENS subscale composites (Table 7).

Table 7. PENS subscale associations.

Subscale 1	Subscale 2	ρ	95% CI (Low)	95% CI (High)	*p*	q (FDR)
Autonomy	Presence/Immersion	0.619	0.270	0.818	0.000	0.001 *
Competence	Presence/Immersion	0.579	0.240	0.776	0.000	0.001 *
Competence	Autonomy	0.570	0.248	0.782	0.000	0.001 *
Intuitive Controls	Presence/Immersion	0.543	0.186	0.754	0.001	0.002 *
Relatedness	Presence/Immersion	0.529	0.104	0.748	0.001	0.003 *
Competence	Intuitive Controls	0.522	0.182	0.739	0.002	0.003 *
Competence	Relatedness	0.431	0.075	0.684	0.011	0.016 *
Autonomy	Intuitive Controls	0.400	0.030	0.685	0.019	0.024 *
Relatedness	Intuitive Controls	0.268	−0.101	0.556	0.125	0.134
Autonomy	Relatedness	0.262	−0.092	0.550	0.134	0.134

Note: Values are Spearman's ρ; N = 34 for all pairs. 95% bias-corrected and accelerated (BCa) bootstrap confidence intervals are shown in brackets; B = 5000 resamples, resampling at the participant level. *p*-values were adjusted using the Benjamini–Hochberg FDR procedure; associations with $q < 0.05$ are considered statistically significant (*).

The strongest associations involved Presence/Immersion, which correlated positively with Autonomy (ρ = 0.619, q = 0.001), Competence (ρ = 0.579, q = 0.001), Intuitive Controls (ρ = 0.543, q = 0.002), and Relatedness (ρ = 0.529, q = 0.003). Autonomy was also positively associated with Competence (ρ = 0.570, q = 0.001) and with Intuitive Controls (ρ = 0.400, q = 0.024). Competence correlated positively with Relatedness (ρ = 0.431, q = 0.016) and with Intuitive Controls (ρ = 0.522, q = 0.003). Two pairs did not survive FDR at $q < 0.05$—Autonomy–Relatedness (ρ = 0.262, q = 0.134) and Relatedness–Intuitive Controls (ρ = 0.268, q = 0.134). Taken together, the pattern shows consistent, moderate-to-strong positive associations between Presence/Immersion and all three SDT needs plus perceived usability, and a similarly robust link between Autonomy and Competence in this cohort. All associations are correlational.

3.3. Emergent Themes Beyond the PENS Framework

In addition to the dimensions captured by the PENS questionnaire, the thematic analysis of students' open-ended responses identified several inductively derived themes not directly encompassed by the PENS framework (Tables A2 and A4). These themes provide further insight into students' experiences with the intervention.

Coherence and narrative organization were reported by nearly a third of students (29.4%), who emphasized how the story provided a unifying thread that helped them organize, contextualize, and connect activities across sessions: "Following the story and this path helped me find connections between all the sessions and put each activity into context." Students described this organizational clarity as supporting memory, understanding, and engagement, making otherwise isolated tasks feel like a meaningful and continuous learning journey.

Fun and enjoyment were salient (26.5%), with many students emphasizing the playful, entertaining aspects of the narrative. They described the story and its characters as making activities more enjoyable: "It was super fun and entertaining to get to know all the characters and interact with them." Enjoyment was often linked in students' accounts to humor, creativity, and unexpected events, highlighting the role of affective and playful elements for sustaining motivation.

Critical or mixed experiences were reported by 11.7% of students across both open-ended questions (2.9% in the first, 8.8% in the second). Some students stated they were not particularly motivated by the game-based elements—"It didn't motivate me much because I've never liked challenge-based games or leveling up"—while others cited moments of confusion or perceived the narrative as artificial or less engaging: "The narrative part didn't motivate me much. I guess it's because I felt it was a bit fake, although I'm sure it would be especially attractive for children." A number of students noted that, despite initial reservations, their motivation improved by the end of the course.

Motivation by novelty and variety (11.8%) was also mentioned, as students described how the unpredictability and freshness of the evolving story helped them keep interest and excitement: "Every day was a new story with a new challenge, always with the same characters, making the narrative meaningful."

Extrinsic motivation (11.8%) also featured in students' accounts, with reports that points, rewards, and especially the impact of FantasyClass on the final grade were perceived to add motivation: "What you achieved in FantasyClass affected your final grade and that added extra motivation," explained one student. These accounts suggest the coexistence of intrinsic and extrinsic motives in a blended gamified environment, and that rewards and assessment may matter for some students.

Finally, professional transferability was mentioned by 8.8% of students, who saw FantasyClass as a motivating, innovative tool for future classroom use: "FantasyClass is a very engaging and motivating tool to use in primary classrooms and generate very enriching learning experiences." These reflections point to the perceived real-world educational value and professional relevance of the intervention.

4. Discussion

This study investigated how a personalized narrative gamification framework, implemented via the FantasyClass platform, was associated with PETs' satisfaction of basic psychological needs (competence, autonomy, relatedness) and experiences of presence in a science education course. Our mixed-methods analysis yielded three pivotal insights: (1) students reported exceptionally high levels of competence and autonomy satisfaction, with moderately strong relatedness; (2) narrative presence was interpreted as a central motivational catalyst, with patterns consistent with emotional immersion as conduit; and (3) the synergy between personalized gamification and narrative depth was perceived as supporting SDT need satisfaction (without isolating the independent effect of each element). Below, we contextualize these findings within theoretical frameworks, prior research, and practical implications, while addressing limitations and future directions. Given the one-group posttest design and small single-cohort sample (N = 34), the findings are best interpreted as exploratory and descriptive/associative; they do not support causal inference and should be generalized beyond similar contexts with caution.

Anchored in SDT and contemporary accounts of narrative engagement, the observed profile—near-ceiling competence and high autonomy alongside strong presence/immersion—fits a mechanism in which meaningful, self-endorsed choice and clear progress feedback afford basic need satisfaction, while narrative presence operates as a proximal affective-cognitive bridge to high-quality motivation. We therefore read the covariation among needs and presence as evidence of a mutually supportive motivational ecology in this cohort, which frames the subsections that follow.

4.1. Basic Psychological Needs

Consistent with SDT, the intervention was experienced as supporting students' basic psychological needs. Quantitatively, Competence showed near-ceiling central tendencies, while Relatedness was positive yet more variable. These patterns align with SDT's claim that optimal motivation emerges when learners experience effectiveness, meaningful choice, and social connection [66], and they compare favorably with typical effect levels reported in education-focused gamification syntheses [40,44,109].

Gains in competence were described by students as linked to two mutually reinforcing design moves that students themselves highlighted. First, progressive mastery architectures—XP leveling, scaffolded challenges, and clear success criteria—were intended to create "optimal challenge," [110], supporting frequent experiences of effectiveness [66]. This aligns with flow theory principles, where balanced challenge-skill ratios promote sustained engagement and intrinsic motivation [111]. FantasyClass's leaderboards, level progress bar and the cloud-reveal world map made progression visible, which students reported as helpful for tracking mastery at a glance. Research on progress feedback mechanisms confirms that visible advancement indicators significantly enhance learners' perceived competence and task persistence [112]. Second, the dual-track feedback system deliberately separated behavioral regulation (HP) from academic performance (XP). This was intended to avoid conflating classroom management with learning quality and may have provided cleaner informational feedback loops—an approach that can inform assessment policies seeking to balance formative engagement indicators with evidence of mastery. This separation aligns with contemporary assessment literature emphasizing the importance of disaggregating academic achievement from behavioral compliance to preserve intrinsic motivation [113,114].

The very high autonomy ratings are consistent with a choice architecture that made agency consequential at multiple levels: elective tasks and pacing, avatar customization, resource-allocation decisions, and frequent, branching narrative choices (including morally charged ones such as bargaining with the antagonist). In SDT terms, these features are consistent with fostering self-endorsement—the felt sense that one's actions reflect personal interests and values [115]. Research on autonomy-supportive design confirms that meaningful choice provision significantly enhances intrinsic motivation and learning outcomes [116,117]. This is pedagogically salient for preservice elementary teachers, who often experience science as prescriptive or externally driven [7]; in our context, students' accounts suggest that the course design helped them feel like authors of their trajectory rather than mere recipients of tasks. Studies of preservice teacher motivation specifically highlight the importance of agency and choice in overcoming science anxiety and building teaching self-efficacy [118,119].

Relatedness was positive yet more variable. The qualitative data help explain why: stable teams with defined roles, cooperative "monster battles," and shared narrative goals were described as fostering "we-intentions," classroom warmth, and mutual assistance. Students' language ("we felt like comrades fighting Morgana together") resonates with positive interdependence in cooperative learning, where individual success is tied to group success [120]. Similarly, a recent study using ClassCraft, a gamification platform functionally similar to FantasyClass, found that cooperative gamification with shared goals and teamwork more effectively promotes a positive classroom social climate than competitive gamification [121]. At the same time, variability likely reflects individual differences: our cohort's HEXAD distribution (42% Philanthropists; 24% Socializers) favored highly social mechanics, which can feel less essential to learners who prefer solo mastery. Studies of player typologies confirm that individual differences in social preference moderate the effectiveness of collaborative game elements [122]. This echoes cautions in personalization research that tailoring should balance majority and minority profiles rather than over-fitting to the dominant cluster [53].

Correlational evidence is consistent with mutually supportive needs: in this cohort, Autonomy and Competence tended to co-occur, suggesting that when students felt able to make meaningful choices, they also reported a stronger sense of effectiveness, and vice versa. In addition, Competence and Relatedness covaried positively, consistent with a cooperative, team-based climate in which feeling effective and connected reinforce one another. As with all analyses here, these links are correlational rather than causal. This pattern mirrors findings in gaming research showing significant positive correlations between Autonomy and Competence satisfaction, suggesting these needs operate synergistically rather than independently [83,123].

Design-wise, the course appears to have struck a productive balance: cooperative structures and shared goals sustained relatedness without allowing competition to crowd out social bonds; competitive elements (e.g., leaderboards) were framed for self-improvement rather than social comparison, preserving a collaborative climate. Meanwhile, competence was supported by scaffolded, visible progression, and autonomy by meaningful, multi-level choices. Together, these features were described as creating a motivational ecosystem in which effectiveness, agency, and connection reinforced one another—a pattern SDT would be predicted to foster high-quality engagement and persistence [66,109].

4.2. Presence as Motivational Catalyst

The intervention's narrative layer was described by students as a powerful motivational driver. Converging quantitative profiles and qualitative accounts pointed to strong experiences of Presence/Immersion, and many students spontaneously identified immersion in the story as their primary driver of engagement. This interpretation is further supported by recent empirical research, which demonstrates that immersion is not only a key feature of gamified educational environments but also acts as a robust predictor of the satisfaction of basic psychological needs—especially autonomy and competence—and, through these, of student engagement and perceived learning outcomes [124]. Interpreted through contemporary accounts of presence in learning and games, these results support a multidimensional view in which physical presence, emotional presence, and narrative presence are distinct yet mutually reinforcing experiences [75,89]. Consistent with virtual reality-in-education work, presence functions as an affective pathway from immersion to motivation and perceived learning [125]. Complementing these interpretations, experimental work shows that inducing in-game storytelling can increase immersion and overall PENS, with evidence consistent with a pathway where narrative increases immersion, which in turn is associated with greater need satisfaction [76]. This aligns with narrative-transportation models in which being "carried away" by a story heightens attention, affect, and identification [126].

Design features that appealed to the senses—AI-generated visuals and avatars, cinematic vignettes, era-consistent music, and selective scent cues—were reported to support a felt sense of "being there," even during laboratory work. In other words, the intervention deliberately scaffolded physical presence. Although narrative structure and consequential agency likely operated as the core drivers of identification and sustained engagement, these embodied cues appeared to scaffold situational focus and bridged classroom activity with the unfolding fiction, in line with findings in educational media on how crafted sensory environments heighten presence and engagement [127,128]. Recent research confirms that carefully selected background music can further enhance focus, motivation, and immersion in gamified learning environments [129]. Students' own words reinforce these observations (e.g., feeling like protagonists; a continuous narrative thread giving meaning and context to every activity).

A distinctive contributor to motivation was the in-character exchange with AI-mediated personas that students experienced as responsive and "real." Although replies were teacher-directed and AI-drafted (rather than AI-decided), students described the interactions as emotionally engaging—patterns consistent with the idea that emotional presence (a felt co-presence with responsive others) opens the door to deeper transportation [75,130]. In students' accounts, this affective anchoring reframed academic tasks as story-relevant missions (e.g., designing artifacts to "save" a kingdom) and was accompanied by greater willingness to persist. This mechanism resonates with PENS-based accounts of need-satisfying gameplay, where emotional engagement and identification enhance the perceived value of effort [83]. As in SDT-grounded analyses, design choices can afford—or thwart—autonomy, competence, and relatedness depending on implementation and context [85]. Framed ethically, positioning the AI as a bounded drafting instrument under human oversight and transparent classroom norms helps safeguard teacher and student agency, aligning with international guidance for responsible educational AI [101,131].

From a design perspective, the shift from a linear plot to branching, consequential choices was consistently described as moving them from observers to co-authors. Dilemmas that altered missions, rewards, or alliances (including ethically charged options) cultivated a sense of plot ownership and character identification—core ingredients of narrative presence. In SDT terms, meaningful, self-endorsed choice can co-travel with feelings of effectiveness and relevance; in our context, students' accounts portrayed choice as a gateway to immersion, aligning with perspectives that link agency and identification to deeper presence in game-based learning [75]. Empirical research in narrative-centered learning environments similarly shows that active participation and meaningful in-game choices are positively associated with both narrative engagement and learning outcomes [132].

Importantly, presence/immersion sits at the intersection of need satisfaction and usability. Presence/Immersion covaried positively with all three SDT needs. This finding aligns with experimental work showing that in fantasy-based learning games, presence and autonomy mediate the effect of narrative imagination on intrinsic motivation and enjoyment [133]. Consistent with prior literature, narrative-integrated designs are associated with higher reports of SDT need satisfaction in gamified settings, providing a coherent backdrop for interpreting the covariation of Presence/Immersion with Autonomy, Competence, and Relatedness observed in this study [44,77–80]. Qualitative narratives tied "feeling part of the story" and emotion-laden reactions to experiences of effectiveness; opportunities to choose and to pursue personally interesting paths were linked to transportation and "journey-like" engagement; and social bonds—both within stable teams and through attachments to characters—were said to intensify identification with the narrative world. Together, these patterns are associative rather than causal and are consistent with mutually supportive needs.

Beyond need satisfaction, Presence/Immersion also correlated positively with Intuitive Controls, consistent with models that link interface quality and natural mapping of actions to stronger presence [134]. In our design, FantasyClass functionalities were introduced progressively during the initial sessions, reducing extraneous load and likely contributing to the high Intuitive Controls ratings [96,135]. Moreover, the absence of comment about usability in the open-ended responses may reflect its transparency—well-designed interfaces often go unnoticed [136]—supporting a cautious usability-to-presence interpretation.

These interpretations converge with prior work beyond education. Research on narrative transportation highlights how being "carried away" by a story can heighten attention, affect, and identification [77,128]. In game contexts, experimental studies further indicate that inducing in-game storytelling elevates immersion and overall PENS scores, with immersion emerging as the proximal conduit associated with greater need satisfaction [76]. Reviews in gamified settings likewise map immersive narrative worlds—when coupled with appropriate mechanics—onto SDT's three needs [137]. Complementing these perspectives, recent neuroscientific research demonstrates that narrative transportation is underpinned by dynamic changes in large-scale brain networks involved in memory, emotion, and self-related processing [138,139]. Brain imaging using electroencephalography further indicates that narrative transportation engages attention, working memory, emotion, and imagination in a coordinated fashion, underscoring the multidimensional impact of being carried away by a story [140].

Two mechanisms may help explain why students associated presence with motivation-related indicators and learning-relevant engagement. First, narrative transportation can reduce counter-arguing, heighten identification, and increase openness to new perspectives [126,141]. In science-education contexts, such openness may support conceptual change when paired with appropriate scaffolds [142]. Second, following Gao's emphasis on the functional significance of events [89], the four-kingdom arc reframed course activities as purposeful contributions to a shared quest. Students' accounts—emotion-laden reports (e.g., pride) and behaviors (e.g., checking updates outside class)—are consistent with routine tasks being experienced as personally significant missions.

Pragmatically, the findings suggest three design priorities: layer multisensory cues judiciously to scaffold physical presence during hands-on work without distraction; ensure that agency is consequential by implementing branching choices that genuinely alter missions or resource flows to strengthen narrative presence; and use responsive characters for individualized scaffolding and affective co-presence to bolster emotional presence, governed by clear pedagogical norms and oversight to preserve instructional coherence. At the same time, designers should monitor for potential need-thwarting side-effects that have been observed in educational gamification when specific mechanics (e.g., competition) undermine competence or autonomy [85]. In sum, when physical, emotional, and narrative presence are intentionally orchestrated, narrative can function as a central catalyst for motivation—consistent with a pathway from choice and meaning to effort and engagement. Presence, in this design, is not merely "feeling in a world"; it is feeling that one's actions matter within that world, with self-reported motivational dividends.

In summary, these results reinforce the idea that narrative presence does not merely accompany basic need satisfaction, but can serve as a central conduit through which agency, competence, and relatedness are experienced as meaningful and motivationally salient.

4.3. Personalized Gamification and Narrative

Our results indicate that narrative and gamification personalization may be mutually amplifying. Grounding the design in player-typology data (HEXAD) guided the weighting of the Social, Fictional, and Performance dimensions toward the cohort's dominant profiles (66% Philanthropists/Socializers), aligning with students' reports of autonomy/competence and robust social experiences. Beyond shallow gamification (e.g., points, badges, leaderboards), the intervention enacted deeper personalization at three levels: (i) player-aligned mechanics as autonomy amplifiers; (ii) dynamic narrative personalization—teacher-negotiated via AI-drafted, in-character exchanges, addressing concerns that static storylines can feel mechanistic [44] and blurring the line between narrative and adaptive mechanics; and (iii) progress visualization—the cloud-reveal world map coupling mastery feedback to story unlocking. In this study, these affordances were described as pivotal for operationalizing personalization within regular course timetables, without adding undue interface friction. This narrative-centric approach extends prior tailoring work by suggesting that story arcs themselves can adapt to learners—an under-represented dimension in recent reviews [50,74].

For PETs, working inside a structured digital environment (FantasyClass) also meant curating, sequencing, and explaining technology-mediated activities—skills that are increasingly central to their digital pedagogical competence. Several students perceived professional transferability (i.e., intentions and ideas for future classroom use), suggesting that FantasyClass and narrative-driven digital personalization could inform future classroom practice; however, our data do not track actual adoption or long-term effects. This aligns with both systematic and empirical research indicating that hands-on experience with educational technologies during teacher training—such as the use of digital platforms—significantly predicts preservice teachers' future classroom adoption and effective implementation [143–145]. Recent evidence further demonstrates that integrating narrative gamification via FantasyClass not only fosters this prospective transfer, but also leads to significant improvements in preservice teachers' attitudes toward science and their teaching self-efficacy, strengthening their confidence to apply similar approaches in their future practice [95,146]. Finally, the AI scaffold suggests a scalable route to individualized narrative support, provided institutions pair it with pedagogical guardrails to preserve coherence and fairness. Recent research on AI tutoring systems confirms that, when properly designed and monitored, intelligent agents can deliver effective, individualized support at scale while maintaining pedagogical quality [147,148].

4.4. Limitations and Future Directions

First, the one-group, posttest design is well-suited to characterizing in situ experiences with PENS; however, it does not, by itself, support causal attribution or enable comparisons to alternative designs, and leaves open potential confounds (e.g., instructor effects, novelty effects). Second, the small, relatively homogeneous sample of preservice elementary teachers from a single Spanish institution (N = 34; predominantly female) constrains external validity and cultural transferability. Third, outcomes relied primarily on self-report instruments; in the absence of behavioral indicators, performance assessments, or platform-based learning analytics, results remain vulnerable to social desirability and common-method variance. Fourth, because narrative, sensory, and mechanical elements were implemented as an integrated digital package, the study cannot disentangle the unique contributions of each component, and component-level manipulation checks were not conducted. Finally, claims about professional transferability and durability of engagement should be interpreted as short-term self-reports and intentions rather than evidence of actual classroom adoption or long-term outcomes.

Building on these results, future research should pursue rigorous and scalable tests that foreground the digital layer: (a) dismantling/factorial experiments that isolate narrative, sensory, and mechanical components (with non-narrative and non-gamified baselines); (b) randomized or quasi-experimental comparisons of personalized versus non-personalized designs to determine for whom AI-supported tailoring yields the largest gains; (c) multimethod measurement that combines platform learning analytics, behavioral persistence, and performance outcomes to probe mechanisms and discriminant validity. To broaden applicability, cross-cultural and cross-disciplinary replications are needed, including tests of whether fictional frameworks benefit non-science domains and whether rule-based progress and conditional branching contribute to aspects of digital literacy and computational-thinking practice. Given that a non-trivial share of students cited grade-linked rewards as motivating, studies should also optimize the extrinsic–intrinsic balance so that reward schedules remain informational rather than controlling. Finally, as personalization scales, evaluate AI-driven adaptation for feasibility and instructional value, alongside targeted professional development that builds teacher AI-literacy for ethically deploying in-character digital agents.

5. Conclusions

This study provides convergent evidence that a personalized, narrative-centric digital gamification framework was associated with substantial PETs' satisfaction of basic psychological needs while fostering robust experiences of immersion in science education. Grounded in SDT, the design was perceived by students as supporting competence and autonomy alongside moderately high relatedness, and qualitative evidence converged with the quantitative profile, indicating that an emotionally resonant storyline, consequential choice, and a usable, low-friction interface worked together to channel engagement into purposeful academic effort. Taken together, these results are consistent with an account in which narrative presence functions as motivational catalyst that links choice and meaning to persistence, while personalization aligns challenges and feedback with learner profiles.

Beyond needs satisfaction, the narrative served as an organizing thread that lent coherence and purpose to course activities, reframing science in students' accounts as a collaborative quest rather than a sequence of disconnected tasks. Critically, the digital affordances of the platform—rule-based XP/HP, progress visualization via the cloud-reveal map, and conditional branching—bound story progression to assessment states, illustrating how educational technologies can make learning trajectories visible and consequential. In this design, the synergy between mechanics and narrative appeared to matter more than either component alone: agency that genuinely alters missions or resource flows, coupled with clear progress visualization and teacher-directed, AI-drafted in-character guidance, was described as reinforcing identification with the storyworld and reinforced mastery striving. Participants' reports of intended classroom transfer suggest that narrative-driven digital gamification may shape their future pedagogical practice, not only present-course motivation.

For practitioners and developers, a small set of design principles emerges. Narrative should be embedded in assessable outcomes so that story progress tracks curricular milestones; branching "choice cascades" should carry academic as well as narrative consequences; and multisensory cues can judiciously amplify presence during hands-on work when kept subordinate to structure and agency. Personalization should be guided by —but not over-fit to—player-type distributions. Equally, usability is non-negotiable in digital environments: intuitive controls and clear affordances can reduce extraneous load, allowing effort to flow to learning rather than navigation. Positioned within the digital era and STEM literacy agenda, this approach also familiarizes PETs with orchestrating technology-mediated activities (sequencing, conditionality, and transparent feedback)—competencies that modern classrooms increasingly demand. Finally, AI-mediated characters can provide individualized scaffolding and affective co-presence when implemented with transparent pedagogical guardrails and instructor oversight.

In sum, personalized digital narrative gamification—when orchestrated to align agency, usability, and an emotionally engaging storyworld—offers a plausible pathway to address persistent motivational challenges in teacher science education. While stronger causal tests and broader replications are needed, the present study delineates a pragmatic design space for transforming science learning from students' perspective into a meaningful, shared endeavor that PETs may carry forward into their own classrooms.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
BCa	Bias-Corrected and Accelerated
CI	Confidence Interval
ECTS	European Credit Transfer and Accumulation System
FDR	False Discovery Rate
GPT	Generative Pretrained Transformer
HP	Health Point
IDP	Institute of Professional Development
IQR	Interquartile Range
Mdn	Median
PENS	Player Experience of Need Satisfaction
RESC	Recreational and Everyday Science in the School
SDT	Self-Determination Theory
SPSS	Statistical Package for the Social Sciences
STEM	Science, Technology, Engineering and Mathematics
XP	Experience Points

Appendix A

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

Table A1. Thematic Analysis of the Question "Can you explain how FantasyClass motivated you in the course?" (Deductive Coding According to PENS Subscales).

Theme (Frequency%)	Subtheme(s)	Representative Quote
Competence (47.1%)	Motivation to improve/level up	"I felt motivated to keep progressing and improving myself. I saw it as a competition, and it made me try harder"
	Mastering content	"Doing the voluntary tasks helped me learn content that I wouldn't have learned otherwise"
	Completing collections/challenges	"The collections helped me learn vocabulary from the subject"

Table A1. *Cont.*

Theme (Frequency%)	Subtheme(s)	Representative Quote
Autonomy (35.3%)	Choosing voluntary tasks	"I was motivated to all the voluntary tasks to earn experience points and coins"
	Making decisions in progress/avatar	"From the first day you have to choose the avatar who will accompany you throughout the course"
Relatedness (26.5%)	Working in groups	"We formed groups to work together in a more fun classroom environment"
	Sharing the experience	"I liked being part of a group with a shared goal in the adventure"
	Group climate	"The classroom atmosphere was more enjoyable and we all participated together"
Intuitive Controls (0%)	—	—
Presence/Immersion (28.4%)	Feeling part of the story	"I felt like I was in a role-playing game where your decisions could benefit or hurt you"
	Learning as a game/adventure	"FantasyClass made the subject more engaging: you feel like the main agent and have to make decisions all the time"

Table A2. Thematic Analysis of the Question "Can you explain how FantasyClass motivated you in the course?" (Inductive Coding).

Theme (Frequency%)	Subtheme(s)	Representative Quote
Motivation Mainly Extrinsic (11.8%)	—	What you achieved in FantasyClass affected your final grade and that added extra motivation
Applicability to Future Teaching (8.8%)	—	"FantasyClass is a very engaging and motivating tool to use in primary classrooms and generate very enriching learning experiences"
Critical or Mixed Experiences (2.9%)	—	"It didn't motivate me much because I've never liked challenge-based games or leveling up"

Table A3. Thematic Analysis of the Question "Can you explain how the narrative of the activities in the course motivated you?" (Deductive Coding According to PENS Subscales).

Theme (Frequency%)	Subtheme(s)	Representative Quote
Competence (23.5%)	Understanding and progressing in the story	"It motivated me because I had to understand and distinguish each character's intentions to make progress"
	Solving problems/challenges	"It was very interesting to apply what I learned to the experiments and the story"
Autonomy (20.6%)	Making choices in the story	"You feel part of the class and can decide different events freely"
	Applying strategies for challenges	"I had to apply different strategies to overcome challenges"
Relatedness (29.4%)	Sense of belonging/group	"We all had a common enemy, which made the experience more immersive"
	Building bonds with characters	"The characters make you feel important in the narrative. I even became 'team Morgana'"
	Peer and character support	"Receiving rewards from the kings for the services rendered was very gratifying"
Intuitive Controls (0%)	—	—
Presence/Immersion (38.2%)	Feeling like a protagonist	"It made me feel the protagonist of the process and experience everything first hand"
	Emotional and narrative immersion	"The narrative made me feel immersed in this magical world, like I was truly part of the story"
	Lively and 'real' learning	"Being able to talk to the characters made me feel more involved in the course"

Table A4. Thematic Analysis of the Question "Can you explain how the narrative of the activities in the course motivated you?" (Inductive Coding).

Theme (Frequency%)	Subtheme(s)	Representative Quote
Coherence and Sense-Making (29.4%)	—	"Following the story and this path helped me find connections between all the sessions and put each activity into context"
Fun and Enjoyment (26.5%)	—	"It was super fun and entertaining to get to know all the characters and interact with them"

Table A4. *Cont.*

Theme (Frequency%)	Subtheme(s)	Representative Quote
Motivation by Novelty (11.8%)	—	"Every day was a new story with a new challenge, always with the same characters, making the narrative meaningful"
Critical or Mixed Experiences (8.8%)	Not motivated by narrative/characters	"The narrative part didn't motivate me much. I guess it's because I felt it was a bit fake, although I'm sure it would be especially attractive for children"
	Confusion/need for clarity	"Personally, I didn't feel motivated because I found the characters confusing; maybe presenting them in more detail would help"

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