

Article

Digital Gamification to Foster Attitudes Toward Science in Early Childhood Teacher Education

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Abstract: Integrating technology-enhanced gamification into teacher education can significantly foster motivation and reshape perceptions toward science learning. This mixed-methods case study explores how a 14-week course for preservice early childhood teachers, supported by the digital gamification platform FantasyClass and enriched with a cohesive narrative structure, impacted students' motivation and attitudes towards science. The course featured structural gamification elements—such as experience points, digital collectibles, and team-based challenges—combined with immersive storytelling that contextualized scientific tasks within a fantasy adventure. Quantitative data from pre- and post-intervention surveys revealed statistically significant improvements in attitudes toward science and perceived teaching competence. Thematic analysis of qualitative feedback highlighted enhanced engagement, enjoyment, and relevance of science learning. These findings suggest that intelligent integration of gamified technologies and narrative design in science teacher initial training can address motivational barriers and foster positive emotional engagement. While context-specific, this study offers insights into how digital gamified learning environments can support the development of positive attitudes towards science among future early childhood educators.



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Keywords: gamification; technology-enhanced learning; motivation; science education; teacher education; FantasyClass; narrative gamification; structural gamification; self-efficacy; preservice teachers

1. Introduction

Attitudes and emotions are central to the effective teaching and learning of science, especially within early childhood teacher preparation programs. Historically, pedagogical content knowledge (PCK) was primarily understood as stemming from mastery of subject matter and instructional techniques [1]. More recent insights, however, recognize that emotional dimensions are integral to PCK as well [2]. Cultivating motivation and positive attitudes is key to sparking student interest in scientific ideas, nurturing curiosity, and sustaining long-term engagement [3]. Thus, successful science education extends beyond delivering content or employing sound pedagogical strategies; it also involves fostering affective connections that support the development of scientific literacy [4].

Despite a growing consensus on the importance of such emotional and attitudinal factors, many preservice early childhood teachers (PECTs) enter university programs with a relatively low enthusiasm for science compared to other subjects [5]. This disinterest often originates in earlier schooling experiences characterized by teacher-centered instruction focused on memorization rather than conceptual understanding [6]. These experiences,

compounded by a lack of supportive environments and persistent self-doubt, can lead to anxiety or even aversion toward science [7]. If these beliefs go unchallenged, they risk being passed on to future generations, reinforcing patterns of disengagement with science learning [8]. Furthermore, limited prior exposure to scientific content contributes to low levels of scientific literacy and confidence, hindering PECTs' ability to apply science effectively in both teaching and everyday contexts [9–11].

As a result, many PECTs feel underprepared and insecure, which may lead them to reduce instructional time devoted to science in their future classrooms [5,12,13]. Moreover, teachers' attitudes and behaviors profoundly influence their students by serving as role models not only in the construction of knowledge but also in fostering motivation, emotional engagement, and positive dispositions toward learning [14,15]. Addressing these issues within teacher training is therefore essential for developing effective and emotionally supportive science teaching practices in early childhood education.

1.1. Gamification as a Motivational Strategy

A promising strategy to enhance preservice teachers' motivation is the incorporation of gamification into teacher education programs [16]. Gamification refers to the integration of game design elements (e.g., points, badges) into non-game contexts with the goal of increasing engagement and motivation [17]. Two main forms are commonly distinguished: content gamification, which applies game elements directly to the content to make it more engaging, and structural gamification, which gamifies the structure around the content to motivate learners, without altering the content itself [18]. In higher education, gamification has demonstrated positive effects on motivation and learning outcomes [19,20]. In science education specifically, it has been shown to bolster motivation [21,22], support the development of scientific reasoning [23], and align well with active pedagogical models such as inquiry-based learning [24].

Understanding how gamification drives motivation requires a theoretical lens, and the Self-Determination Theory (SDT) offers a comprehensive framework in this regard [25,26]. SDT proposes that intrinsic motivation flourishes when three basic psychological needs are met: autonomy (feeling in control and aligned with personal values), competence (feeling capable and effective), and relatedness (feeling connected to others). In educational contexts, well-executed gamification can meet these needs, thereby promoting intrinsic forms of motivation [27,28].

Structural gamification includes elements such as challenges, feedback systems, and decision-making opportunities that enhance perceptions of competence, autonomy, and social relatedness [17,29]. Through mechanisms like goal setting and immediate feedback, students often experience increased competence [30]. Autonomy is supported through meaningful choices and control over learning activities, and relatedness through social interactions and collaborative elements [31].

Content gamification, too, can contribute to satisfy these psychological needs. For example, adding a narrative as a game element to the educational content (narrative gamification) provides a meaningful context that ties game components (such as points, badges, or leaderboards) to learning activities through a coherent storyline, thereby enhancing student engagement and satisfaction [32,33]. Embedding educational content within a narrative helps foster greater commitment and immersion in the learning process [34,35]. This approach makes learning more enjoyable while helping students organize and recall information, as narratives often make scientific concepts more understandable and memorable [36]. Narratives offer motivational support by reinforcing autonomy, as students perceive their actions as meaningful and aligned with a broader purpose [33,37], compe-

tence through clear and achievable challenges [38], and relatedness through collaborative goals and engagement with narrative characters [33].

1.2. Narrative Gamification in Early Childhood Teacher Training

The use of narrative in science education has theoretical foundations in the constructivist approach, as proposed by Bruner [39,40]. Bruner emphasized that narratives give shape and meaning to human experience by organizing actions and events in ways that resonate with learners. Within science education, narratives can bridge the gap between abstract, logical forms of knowledge and the lived, temporal experience of learners [41]. This connection enhances students' ability to situate scientific knowledge within broader personal and social contexts [42]. Narratives have also been shown to foster emotional involvement, which is instrumental in developing a deeper understanding of scientific concepts [43].

Incorporating narrative-based gamification and role-playing into teacher education helps PECTs engage more meaningfully with science content while also modeling pedagogical strategies that promote critical thinking and informed decision-making [44]. When narratives are emotionally engaging, they enhance not only conceptual understanding but also memory retention [36]. Since university students often emulate the teaching methods they have experienced [45], exposure to gamified, narrative-rich learning environments can encourage them to adopt similar approaches when teaching science to children. This is particularly relevant in early childhood education, where play is a natural and essential part of learning [46], and where engaging, play-based methods, such as integrating science through guided imaginative play, can foster early interest and foundational skills in science [47,48].

Addressing the negative attitudes and lack of confidence that many PECTs have toward science is crucial, as these attitudes can influence their future teaching. If such perceptions persist, they may undermine both instructional effectiveness and student engagement [49,50]. Leveraging gamification and storytelling offers a way to transform these attitudes by providing meaningful, emotionally resonant learning experiences. As highlighted by [51], embedding narrative within a structurally gamified course helps create a cohesive educational environment that promotes continuity and reinforces students' sense of purpose. However, the use of gamified digital tools in early childhood teacher education must also consider ethical and developmental factors, including equitable access to technology, limitations on screen time, and the age-appropriate alignment of learning activities.

1.3. Study Aim and Research Questions

The present study investigates the effects of combining structural and narrative gamification on PECTs' motivation and attitudes toward science. Structural gamification was implemented through the digital platform FantasyClass, while narrative gamification was embedded in a coherent storyline that unfolded across all course activities. By applying a case study approach, this research focuses on a single cohort enrolled in an early childhood education program. This design enables a detailed exploration of how gamification strategies function within a specific context, providing insights that may be applicable to similar settings, rather than aiming for wide generalization.

In this context, the study builds upon previous research by combining structural and narrative gamification within a semester-long course, fully implemented through a digital platform. While prior studies have often examined short-term or isolated gamified activities, this intervention systematically embedded narrative elements and game mechanics across all instructional tasks. This cohesive and immersive approach provides the

context for investigating how gamification may influence PECTs' motivation and attitudes toward science.

The dual objective of the study is to understand how the integration of these two forms of gamification influences PECTs' attitudes toward science, and to identify which specific gamification elements are perceived as most effective in fostering motivation. Accordingly, the following research questions were formulated to guide the investigation:

- RQ1: To what extent does the integration of structural and narrative gamification influence PECTs' motivation and attitudes toward science?
- RQ2: Which specific gamification elements are perceived by PECTs as the most motivating?

2. Materials and Methods

This research was conducted as a case study, combining qualitative and quantitative methods to examine the impact of gamification within a defined and bounded educational context. Quantitative data were collected through pretest and posttest measurements, while qualitative data were gathered to enrich and triangulate the findings through a thematic analysis.

2.1. Participants

The study involved 73 undergraduate students (94.5% women, 4.1% men, and 1.4% non-binary; mean age = 21.1; median age = 20) enrolled in their third year of the Bachelor's Degree in Early Childhood Education at the University of Barcelona (Spain). All participants were taking the course "Knowledge and Exploration of the Natural Environment" (KENE) during the 2022–2023 academic year. Most students were from urban settings, and only 15% had followed a science-oriented high school curriculum.

The gender distribution within this cohort, heavily skewed toward women, reflects broader international trends in early childhood teacher education programs. Male enrollment remains strikingly low in this field, with enrollment rates dropping below 5% in various European countries [52], falling to 2–3% in the UK [53] and, dropping under 1% in New Zealand [54]. This imbalance is widely considered a structural characteristic of early childhood education, shaped by sociocultural factors and prevailing gender norms in professional choices [55].

In the Spanish education system, Early Childhood Education is non-compulsory and designed for children aged 0 to 6, comprising two cycles: ages 0–3 and 3–6. The Bachelor's Degree in Early Childhood Education spans four academic years (240 ECTS credits) and provides comprehensive preparation in pedagogical methods, child development, and curriculum design. Graduates are qualified to teach across both cycles. The program integrates theoretical instruction with practical experiences through internships. Within this framework, the KENE course is a 14-week compulsory, in-person course specifically focused on scientific content. It follows a prior course on experimental sciences and aims to provide preservice teachers with effective pedagogical strategies for introducing science in early childhood classrooms.

2.2. Procedure

The course incorporated both structural and narrative gamification. Structural gamification was implemented through FantasyClass (<https://fantasyclass.app/>, accessed on 25 April 2025), a free digital platform that supports different forms of student interaction through the combination of visual, textual, and interactive elements. This platform manages avatars, experience points (XPs), health points (HPs), gold coins, and collectibles, creating a game-like learning environment [56]. XPs served both as a motivational tool and as part of the assessment mechanism, with students' progress and final performance linked to the XPs

they accumulated throughout the course. Students earned XPs through various activities, including narrative-driven challenges, completing thematic collections, and participating in battles. These battles were structured as group-based quiz competitions against virtual monsters, where students defeated the enemy by correctly answering questions. Each team faced its own designated opponent, requiring them to collaborate, strategize, and recall course content to succeed. Battles were scheduled in advance, giving students time to review content, fostering engagement with the material and promoting teamwork in a competitive yet educational format.

Collaboration was strengthened by enabling students to share resources such as objects and gold coins within their teams, fostering cooperative problem-solving and collective decision-making. To integrate both digital and physical gamification elements, students were also provided with badges and stamps, which were recorded in a group notebook. These physical rewards served as tangible incentives for task completion and reinforced course objectives, demonstrating how traditional classroom elements could complement digital gamification. The notebook, used throughout the semester for exercises and reflective activities, illustrated how gamification mechanics could be adapted to early childhood classrooms through tangible and age-appropriate strategies.

Gold coins were earned through participation in various activities and could be used to purchase pets as avatar upgrades and acquire thematic collectibles, including the “Women Scientists” collection, which reinforced course vocabulary and subject knowledge. Additionally, the wheel of gold introduced an element of chance and unpredictability, allowing students to spin for a random amount of gold coins, influencing their resource management. Random events further enhanced gameplay by introducing unexpected situations that could either reward or challenge students, such as sudden bonuses or temporary penalties, reinforcing engagement through dynamic and immersive mechanics.

Narrative gamification immersed students in an interactive storyline where they embodied anthropomorphic fruit and vegetable avatars (Figure 1) on Chaos Island, a land under the spell of the Dark Witch. The narrative served not only as a contextual framework but also as a structuring mechanism for the entire course, providing a cohesive progression that tied academic activities to story-driven challenges, reinforcing engagement and continuity in learning. To restore the island, students needed to recover five magical amulets, each corresponding to a core topic in the curriculum: sensory education, observation and classification, scientific inquiry, designing educational activities around animals, and planning field trips for hands-on learning.

To earn these amulets, the students completed academic challenges integrated into the course structure. For instance, during the scientific inquiry unit, the students participated in a plant-growing contest organized by the Queen of the island, investigating how environmental factors such as acid rain, drought, soil pollution, and flooding affected plant growth. Each team focused on a specific environmental condition—such as drought, acid rain, soil contamination, or flooding—and conducted experiments tailored for young learners. Findings were presented to the Queen, and teams received an amulet upon successful completion of the task. Rewards, including XP and gold coins, were distributed based on the quality of the presentation and scientific reporting.

The course concluded with a final unit plan project, designed to synthesize the semester’s learning. This culminating task required students to develop an original science unit for early childhood education, incorporating both scientific content and pedagogical strategies. The final project involved a written component and a group presentation in which students activated their collected amulets to defeat the Dark Witch.

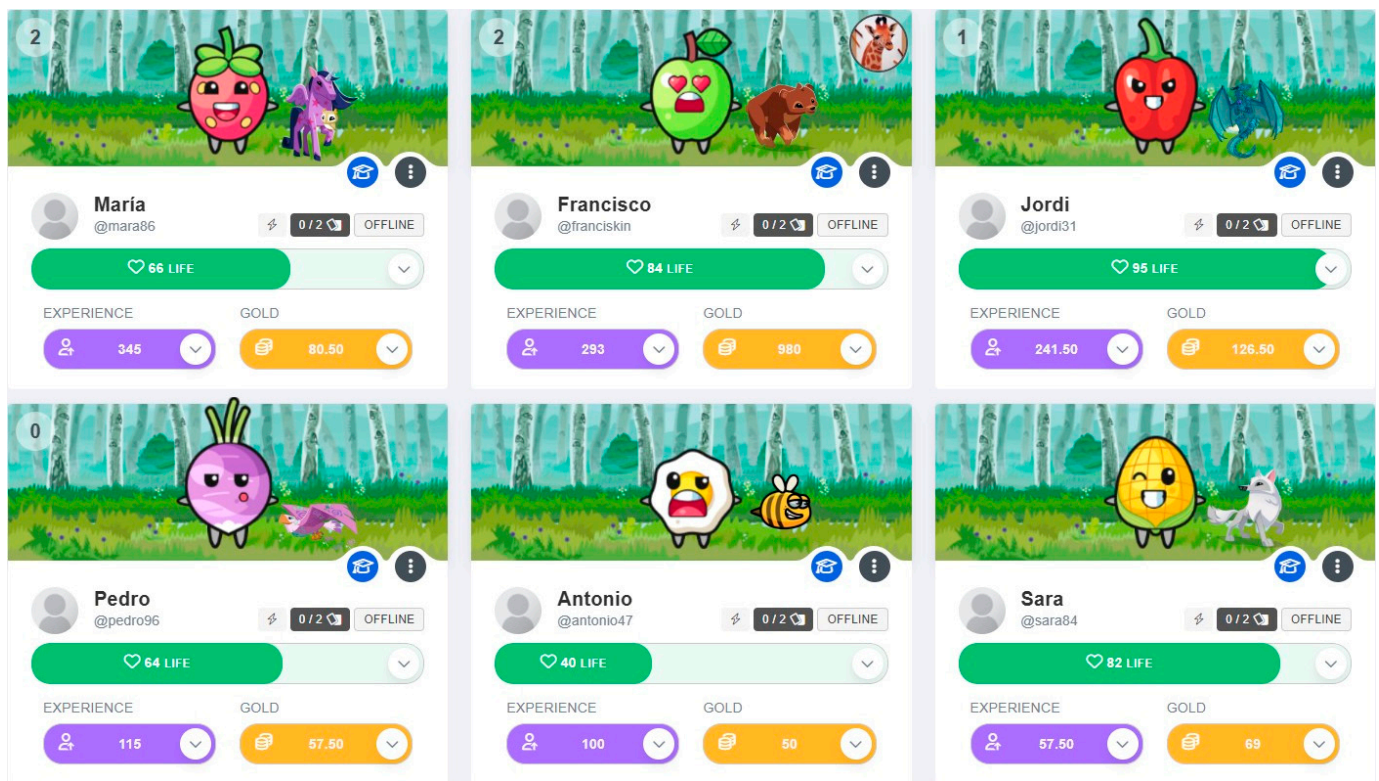


Figure 1. Example of student avatars from the FantasyClass platform. Each avatar represents an anthropomorphic fruit or vegetable character, as part of the course narrative that immersed students in a magical storyline on Chaos Island. The use of this screenshot has been authorized by the creator of FantasyClass.

2.3. Instrument

The instrument used to assess the impact of the gamified course on the students' attitudes towards science was an adaptation of the "Questionnaire on Attitude and Motivation of Preservice Primary Education Teachers Towards Physics and Chemistry" [57]. This adapted version was specifically tailored to measure attitudes towards science in PECT, maintaining the structure of the original instrument but modifying its focus from physics and chemistry to general science, as well as adapting it for PECT. For example, item 21 in the original version stated, "I feel capable of teaching physics and chemistry content to primary school children", and was adapted as "I feel capable of teaching science content to children in early childhood education".

The adapted questionnaire included 22 statements where participants indicated their level of agreement using a five-point Likert scale, ranging from 1 ('strongly disagree') to 5 ('strongly agree'). The questionnaire was structured around three temporal dimensions: past, present, and future. The past dimension prompted participants to reflect on their earlier experiences with science education, providing a retrospective view of their previous exposure and perceptions. The present dimension focused on their current attitudes as university students and members of society. The future dimension invited participants to project their attitudes towards science into their future roles as early childhood educators, specifically how they envisioned integrating science into their teaching practices.

The questionnaire was administered digitally at two points during the study: at the beginning of the course as a pretest, and at the end as a posttest. In the posttest, minor adjustments were made to the wording of the items in the past dimension to refer specifically to the experiences within the KENE gamified course. For instance, the item "In

science class, I could express my own ideas” was rephrased in the posttest as “In KENE course, I could express my own ideas”.

The internal consistency of the adapted questionnaire was evaluated using Cronbach’s alpha, which demonstrated high reliability: 0.907 for the pretest and 0.855 for the posttest.

In the posttest, two additional sections were included. The first one consisted of a self-report questionnaire [58] in which the students were asked to indicate their level of perceived motivation regarding various features of the FantasyClass platform or specific aspects of the gamification implementation, using a 5-point ordinal scale ranging from 1 (not at all motivating) to 5 (highly motivating). The second section consisted of an open-ended question aimed at gathering the students’ opinions on whether their view of science teaching had changed after completing the gamified course.

2.4. Data Analysis

IBM SPSS Statistics v.27 was used for the quantitative data analysis. Initially, the normality of the data distribution was assessed using the Kolmogorov-Smirnov test, which indicated that the data did not follow a normal distribution ($p < 0.05$). Consequently, non-parametric tests were used for subsequent analyses. The Wilcoxon signed-rank test was employed to analyze the data, with the results reported alongside median values and interquartile ranges (IQR) for each of the three dimensions: past, present, and future. For items with significant differences, Cliff’s delta (δ) was calculated as a measure of effect size, given its robustness and suitability for ordinal data and non-normal distributions, as encountered in this study’s Likert-scale responses. Following the methodology outlined by Meissel and Yao [59], Cliff’s delta (δ) was calculated using their dedicated web application (<https://cliffdelta.shinyapps.io/calculator>). Effect sizes were categorized as follows: negligible ($\delta < 0.15$), small ($0.15 \leq \delta < 0.33$), medium ($0.33 \leq \delta < 0.47$), and large ($\delta \geq 0.47$). This classification allowed for a nuanced understanding of the magnitude of change.

For the qualitative analysis, a thematic analysis approach was conducted [60] using ATLAS.ti v.22. 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 process followed an iterative and inductive coding strategy, starting with an initial familiarization phase in which responses were reviewed several times to develop a holistic understanding of the data. Next, meaningful segments were identified and assigned preliminary codes, which were progressively refined through several cycles of coding. Codes were then grouped into broader themes based on conceptual similarities, and these themes were reviewed and refined to ensure coherence and internal consistency. The emergent themes were triangulated with the quantitative findings to strengthen the validity of the results and provide a richer understanding of the impact of the gamified intervention.

3. Results

3.1. Quantitative Analysis

The analysis of the pretest and posttest questionnaires is divided into two sections. First, the results from the adapted 22-item questionnaire, which measured changes in the students’ attitudes toward science, are detailed. Subsequently, the results from the additional posttest section, which assessed the perceived motivational impact of various FantasyClass features, are provided.

The analysis of the questionnaire on attitudes and motivation of PECT towards science revealed varying degrees of change across the three temporal dimensions: past, present, and future. In the past dimension (Table 1), which reflects the students’ retrospective perceptions of their previous experiences with science education, several noteworthy changes emerged.

Initially (pretest), the students generally held positive perceptions of their prior experiences with science education. They agreed that, during their previous science classes, they received answers to questions that intrigued them (Item 1, $M = 4$) and were able to express their own ideas (Item 2, $M = 4$). They also agreed that they had fun learning science (Item 6, $M = 4$) and that science helped them understand everyday phenomena (Item 7, $M = 4$). However, their perceptions were more neutral ($M = 3$) regarding the fascination of science classes (Item 4), the ease of studying science lessons (Item 5), and the difficulty of learning science (Item 8). Additionally, they agreed that they could achieve good grades in science without the teacher's help (Item 3, $M = 4$), which suggests a sense of academic confidence.

Table 1. Changes in attitudes and motivation towards science before and after a gamified course: past dimension.

Item Number and Statement	Pretest		Posttest		W	p	δ
	M	IQR	M	IQR			
1—In science class, I got answers to questions that intrigued me	4	(1)	4	(1)	188.5	<0.001 *	0.32
2—In science class, I could express my own ideas	4	(1)	4	(1)	51	<0.001 *	0.55
3—I could get good grades in science without the help of the teacher	4	(1)	3	(1)	519.5	0.617	—
4—Science classes fascinated me	3	(1)	4	(1)	371	0.003 *	0.27
5—Science lessons were easy to study	3	(2)	4	(1)	260	<0.001 *	0.46
6—I had fun learning science	4	(1)	4	(1)	162	<0.001 *	0.38
7—Science allowed me to understand everyday phenomena	4	(1)	4	(1)	406.5	0.736	—
8—For me, it was difficult to learn science	3	(2)	2	(1)	230.0	<0.001 *	−0.39

Note: M = median, IQR = interquartile range, W = Wilcoxon signed-rank test statistic, $p = p$ -value, $\delta =$ Cliff's delta. Asterisks (*) indicate statistical significance at the 5% level; δ is reported only for items with statistically significant differences.

After completing the gamified course, significant changes were evident in several items within the past dimension (Table 1). Notably, the students reported an increased fascination with science classes, as the median for finding them fascinating (Item 4) rose from 3 to 4 ($p = 0.003$), with a small effect (Cliff's $\delta = 0.27$). The ease of studying science lessons (Item 5) also improved, with a shift from 3 to 4 ($p < 0.001$) with a medium effect (Cliff's $\delta = 0.46$) and the IQR decreasing from 2 to 1, indicating greater consensus among the students. The perception of difficulty in learning science (Item 8) decreased significantly, with the median dropping from 3 to 2 ($p < 0.001$), with a medium effect (Cliff's $\delta = -0.39$), suggesting that the participants found science less challenging after the gamified intervention. While the medians for receiving intriguing answers (Item 1), expressing their own ideas (Item 2), and having fun learning science (Item 6) remained at 4, significant p -values ($p < 0.001$ for Items 1, 2, and 6) suggest internal shifts toward stronger agreement within the same median category, with small-to-medium effects (Cliff's $\delta = 0.32, 0.55,$ and 0.38 , respectively). However, confidence in achieving good grades without teacher assistance (Item 3) saw a non-significant decrease in median from 4 to 3 ($p = 0.617$), possibly reflecting a heightened appreciation for teacher support. Overall, the items in the past dimension showed small to medium improvements, particularly in relation to enjoyment of science and perceived ease of learning it. These findings will be further contextualized in the discussion section, where they are considered in light of the qualitative responses.

Unlike the significant improvements in the past dimension, the present dimension (Table 2) showed minimal changes. Prior to the intervention (pretest), the students demonstrated strong positive attitudes toward science in their current lives. They disagreed that science has no connection to their lives (Item 9, $M = 2$), and strongly agreed that understanding science is important for everyone (Item 10, $M = 5$). They agreed that they liked

to learn about science through media (Item 11, $M = 4$) and found science interesting (Item 12, $M = 4$). They also expressed interest in explanations of scientific phenomena (Item 13, $M = 4$), and agreed that science makes life healthier, easier, and more comfortable (Item 14, $M = 4$). The students believed that the benefits of science outweigh potential adverse effects (Item 15, $M = 4$), and that science can solve environmental problems (Item 16, $M = 4$).

Table 2. Changes in attitudes and motivation towards science before and after a gamified course: present dimension.

Item Number and Statement	Pretest		Posttest		W	p
	M	IQR	M	IQR		
9—Science has no connection to my life	2	(1)	2	(1)	273	0.474
10—Understanding science is important for everyone	5	(1)	5	(1)	121	0.579
11—I like to read and learn about science through social media, YouTube, or other media	4	(1)	3	(1)	242.5	0.141
12—I think science is interesting	4	(1)	4	(1)	182	0.405
13—I am interested in explanations of scientific phenomena	4	(1)	4	(0)	218	0.526
14—Science makes our lives healthier, easier, and more comfortable	4	(1)	4	(1)	214.5	0.069
15—The benefits of science outweigh the potential adverse effects	4	(1)	4	(2)	299	0.166
16—Science can solve environmental problems	4	(1)	4	(1)	116.5	0.721

M = median, IQR = interquartile range, W = Wilcoxon signed-rank test statistic, $p = p$ -value. No effect sizes (Cliff's δ) are reported, as no statistically significant differences were observed.

After the gamified course, there were no statistically significant changes in the present dimension (Table 2). Medians for all items remained the same, indicating stable attitudes. The median for liking to learn about science through media (Item 11) decreased slightly from 4 to 3, but this change was not significant ($p = 0.141$). The consistent medians and IQRs suggest that the students' current positive attitudes toward science were already well-established and remained unaffected by the intervention. The lack of significant changes (p -values ranging from 0.069 to 0.736) implies that the gamified course did not significantly influence the students' present perceptions or engagement with science. This issue is addressed further in the discussion section, where qualitative insights help interpret the stability observed in this dimension. However, it is possible—based on the observed patterns—that this dimension, focused on current perceptions, is less sensitive to short-term change than retrospective or prospective dimensions. In any case, the data suggest that the intervention neither reinforced nor diminished students' existing engagement with science in their daily lives.

In the future dimension, exploring the participants' perceptions about teaching science in their future careers (Table 3), significant improvements were observed, particularly in self-efficacy and perceived knowledge. Initially (pretest), the students exhibited a strong belief in the importance of teaching science in early childhood education. They strongly disagreed with the notion that science should not be taught in early childhood education (Item 17, $M = 1$) and that teaching science to young children must be boring (Item 19, $M = 1$). They agreed that more time should be devoted to teaching science in early childhood education (Item 18, $M = 4$). However, their confidence in their ability to teach science content was moderate, with a median of 3 for feeling capable of teaching science to young children (Item 21) and a median of 2 for considering themselves to have sufficient knowledge to teach science content (Item 22). The students strongly agreed that the science they can learn is important for their future professional development (Item 20, $M = 5$).

Table 3. Changes in attitudes and motivation towards science before and after a gamified course: future dimension.

Item Number and Statement	Pretest		Posttest		W	p	δ
	M	IQR	M	IQR			
17—Science should not be taught in early childhood education	1	(0)	1	(0)	83.5	0.627	—
18—More time should be devoted to teaching science in early childhood education	4	(1)	4	(1)	165	0.024 *	0.13
19—I think teaching science to children in early childhood education must be boring	1	(1)	1	(1)	181.5	0.267	—
20—The science I can learn is important for my future professional development as an early childhood teacher	5	(1)	4	(1)	241.5	0.652	—
21—I feel capable of teaching science content to children in early childhood education	3	(1)	4	(1)	106.5	<0.001 *	0.54
22—I consider that I have sufficient knowledge to teach the science content in the early childhood education curriculum	2	(1)	4	(1)	0	<0.001 *	0.74

Note: M = median, IQR = interquartile range, W = Wilcoxon signed-rank test statistic, p = p -value, δ = Cliff's delta. Asterisks (*) indicate statistical significance at the 5% level; δ is reported only for items with statistically significant differences.

Post-intervention, significant improvements were observed in self-efficacy and perceived knowledge in the future dimension (Table 3). The median for feeling capable of teaching science content (Item 21) increased from 3 to 4 ($p < 0.001$), with a large effect (Cliff's $\delta = 0.54$). The median for considering themselves to have sufficient knowledge (Item 22) rose from 2 to 4 ($p < 0.001$), with the largest effect size observed in the study (Cliff's $\delta = 0.74$), indicating enhanced confidence and perceived competence. The median for advocating more time for teaching science (Item 18) remained at 4 but showed a significant p -value ($p = 0.024$), though the effect was negligible (Cliff's $\delta = 0.13$). There was no significant change in the belief that science should not be taught in early childhood education (Item 17, median remained at 1, $p = 0.627$) or that teaching science to young children must be boring (Item 19, median remained at 1, $p = 0.267$), reflecting consistent strong disagreement. The median for the importance of science for professional development (Item 20) decreased slightly from 5 to 4, but this change was not significant ($p = 0.652$). These quantitative improvements in attitudes related to teaching science are further explored in the discussion in connection with students' open-ended responses.

The additional posttest section assessed the perceived motivational impact of various FantasyClass features and other gamification elements (Table 4). Several features were notably effective in engaging students, as indicated by high median scores, low interquartile ranges, and positive feedback. Among these, collectibles, gold coins, group work, and FantasyClass as a gamification tool stood out, each achieving a median motivation score of 5, with consistent responses. Collectibles were rated as either "Quite Motivating" (4) or "Highly Motivating" (5) by nearly 88% of the students, making them one of the most engaging features. Completing collectible sets offered tangible rewards, such as experience points or gold coins, which incentivized the participants to stay engaged. Similarly, gold coins were quite or highly motivating for over 87% of the students, reflecting their importance in maintaining engagement by allowing them to exchange coins for upgrades and rewards. The overall FantasyClass platform was also well-received, with 86% of the participants finding it quite or highly motivating, appreciating how the system integrated the various gamified elements into a cohesive and engaging experience. Group work, too, was highly valued, with 77% of the students finding it either quite or highly motivating, demonstrating the importance of collaboration in maintaining student involvement.

Table 4. Perceived Motivational Impact of FantasyClass Features and Gamification Elements. (Percentage of Responses: %1 = Not at all motivating, %5 = Highly motivating).

	M	IQR	%1	%2	%3	%4	%5
Collectibles	5	(1)	0	5.4	7.1	17.9	69.6
Gold coins	5	(1)	0	1.8	10.9	16.4	70.9
FantasyClass	5	(1)	0	1.8	12.5	33.9	51.8
Group work	5	(1)	0	3.6	19.6	17.9	58.9
Monster battles	4	(1)	5.4	7.1	32.1	37.5	17.9
Countdowns	4	(1)	3.6	17.9	26.8	39.3	12.5
Pets	4	(1.25)	0	10.7	26.8	37.5	25.0
Avatars	4	(1.25)	1.8	14.3	25.0	33.9	25.0
Wheel of gold	4	(2)	5.4	8.9	14.3	30.4	41.1
Narrative	4	(2)	0	8.9	23.2	33.9	33.9
Random events	4	(2)	3.6	8.9	23.2	32.1	32.1
XPs	4	(2)	0	10.7	25.0	26.8	37.5
Badges and stamps	3	(1)	1.8	21.4	28.6	26.8	21.4
HPs	3	(1.25)	7.1	17.9	39.3	23.2	12.5

Note: M: median, IQR: interquartile range.

Several other features, with a median of 4 and an IQR of 1 or 1.25, also motivated the students, though with slightly more variability. Monster battles were quite or highly motivating for 55% of the participants, offering an interactive quiz-based challenge where they could earn rewards by answering questions correctly. Countdowns, which added time pressure to certain tasks, were motivating for 52% of the students, highlighting the element of urgency in keeping them focused. Pets, which boosted avatars' abilities, motivated 63% of the participants, and avatars, which allowed for personalization, emerged as quite or highly motivating by nearly 59% of them. These features, although not rated as highly as the top features, still played an important role in engaging the students.

In contrast, other features like the wheel of gold, narrative, random events, and XPs, all of which had a median of 4 and a higher IQR of 2, exhibited more variability in responses. The wheel of gold, which provided random rewards, motivated 71% of the participants, but the element of chance introduced more diverse opinions on its impact. The course narrative, while immersive for many, was rated as quite or highly motivating by nearly 68% of the students, though not everyone found it equally engaging. Random events, which added surprise elements, and experience points, tied to students' progress, were both motivating for about 64% of the participants, though some students found these features less engaging than others.

At the lower end of the motivational spectrum were badges and stamps and HPs, both of which had a median score of 3. Badges and stamps, used as digital or physical rewards, were motivating for 48% of the participants, while HPs, which reflected the students' behavior in class, were motivating for 36%. Although these elements contributed positively to the overall gamification experience, they were less central to student motivation compared to other features.

3.2. Qualitative Analysis

The thematic analysis of student feedback regarding their experiences with FantasyClass and the gamification of the course revealed several key themes that illustrate how gamification reshaped their attitudes toward science education. The analysis is structured

by the frequency of themes, ranging from the most commonly mentioned to those that appeared less frequently but still provide valuable insights.

The most frequently cited impact of FantasyClass and gamification was increased motivation. Many students highlighted that gamification made the learning experience both engaging and enjoyable. For instance, one student commented, "I used to think it was impossible to motivate someone to learn science through apps like FantasyClass, but today, my interest has increased, and my level of involvement is much higher". Another student expressed that the gamified course shifted their perception of attending class, stating, "Instead of seeing the course as something heavy and boring, I came to class eager to find out what we would do today—games, battles, experiments". This reflects the power of gamification to transform what might otherwise be seen as mundane or challenging subjects into interactive and stimulating experiences.

Another dominant theme was the enjoyment and fun derived from the gamified approach. Students repeatedly mentioned how much more they enjoyed the course because of the gamification elements. One student stated, "I had never taken a gamified course before, and I feel it was a really fun experience to go through". Another echoed this sentiment: "It made the classes so much more dynamic and fun that I think it would also be more engaging, interesting, and fun for young children". This indicates that the participants found the playful and interactive nature of gamification to be highly beneficial, both for their own learning and as a potential strategy for teaching science to children in early education.

Engagement and active participation also emerged as significant themes. The students felt that the gamified activities encouraged them to take a more active role in the course. One student remarked, "Gamification made the classes more engaging and generated more interest, which will be very useful when working with children". Another explained, "The gamification in the classroom has been a way to motivate us to complete tasks and stay attentive in class". This highlights the role of gamification in fostering active learning and keeping the students invested in the course content. By incorporating game elements, the course created an environment where the students were not only learning but also actively participating in the learning process.

The fourth theme identified was practical application and pedagogical insights. Several participants noted that the course not only helped them understand science better but also showed them how to teach it to young children. For example, one student mentioned, "I have expanded my knowledge of science and, at the same time, learned how to teach science to children". Another stated, "It has made the lessons more dynamic, and I think, with adaptations, it can be applied in early childhood education". These responses suggest that the students were able to see the direct applicability of gamification to their future teaching careers and recognized its potential for making science more accessible and enjoyable for young learners.

Another important theme was the perception of learning as more meaningful due to the gamified approach. Some participants indicated that learning through gamification made the content feel more relevant and significant. One student observed, "Gamifying a subject makes learning more meaningful and keeps us more interested". Another reflected, "The fact that the course was gamified made it more engaging, and I found the content more interesting". This suggests that gamification helped to enhance the perceived value of the subject matter, as the students felt a deeper connection to the material when presented through interactive, game-like activities.

Lastly, changes in attitudes toward science were noted by several students, particularly those who had not previously been interested in the subject. One student explained, "I have never been particularly interested in science, in fact, I have always been more of a

humanities person. Thanks to the content of this course and doing it through gamification, I became much more interested and more excited to come to class". Another mentioned, "At the beginning of the course, I didn't know what gamification was, and now I know what it is. Through gamification, I've seen that teaching science can be more motivating". These comments indicate a shift in how the students perceive science, particularly those who may have struggled with or avoided the subject in the past. In this context, gamification acted as a tool for reshaping students' attitudes, fostering a newfound interest in science.

4. Discussion

This study reveals that gamification profoundly reshaped PECTs' science attitudes, self-efficacy, and motivation. By integrating both structural and narrative gamification through the FantasyClass platform and a cohesive storyline, the course effectively enhanced the students' engagement and transformed their perceptions of science education. As a case study, these outcomes reflect both the cohort's unique dynamics and the intervention's design, offering actionable strategies for comparable contexts.

The quantitative results revealed noteworthy changes in participants' attitudes, especially in the past and future dimensions following the implementation of the gamified course. In the past dimension, one of the clearest improvements was a greater sense of fun and fascination with science classes, supported by small to medium effect sizes measured by Cliff's delta. This heightened interest was echoed in the qualitative analysis, where "increased motivation" and "enjoyment and fun" emerged as dominant themes, reinforcing the interpretation that gamification enhanced emotional engagement with science learning. Participants also reported finding science easier to study and less difficult to learn, again supported by small to medium effect sizes. These results are aligned with findings by Sailer and Homner [28], who noted that gamification improves learners' sense of competence by offering clear structures, prompt feedback, and realistic goals—factors that contribute to more favorable attitudes toward learning.

The increased fascination with science suggests that gamified approaches have the potential to transform how students perceive the subject, making it more interesting and accessible [20]. The observed reduction in perceived difficulty implies that gamification can help simplify complex ideas, reducing apprehension and enhancing students' belief in their own ability to learn science. This finding supports the claim by Bressler and Bodzin [23] that gamified science environments can foster confidence by making learning less intimidating and more stimulating. Meanwhile, the small and non-significant decrease in students' belief that they could succeed without teacher assistance might reflect a growing appreciation for instructional support and peer collaboration. This may reflect an increased recognition of the value of instructional and peer support, as suggested by the slight, though non-significant, decrease in item 3.

Conversely, the present dimension showed minimal change. While the students entered the course with generally positive attitudes toward science, the intervention did not significantly alter these existing perceptions. This stability indicates that their positive predispositions were already firmly established and less susceptible to further change. This finding is consistent with research suggesting that gamification tends to have a stronger effect on individuals who begin with neutral or negative attitudes, while those with initially strong positive views may exhibit less change [61,62]. The lack of quantitative movement is echoed qualitatively: no theme suggested a decline in motivation, and comments often noted that science was "already connected to everyday life". Thus, qualitative and quantitative strands converge in portraying present-time attitudes as already highly favorable and less susceptible to change.

The most substantial changes occurred in the future dimension, particularly regarding the students' self-efficacy and perceived competence in teaching science, both of which showed large effects measured by Cliff's delta, reflecting significant improvements in participants' confidence and perceived knowledge after the gamified intervention. Building self-efficacy and content mastery—often reported as challenging for preservice teachers [63]—is essential for fostering inquiry-driven environments in early childhood science education [64,65]. Self-efficacy is a reliable predictor of instructional practice: teachers confident in their subject expertise are more likely to dedicate time to teaching science [11]. Moreover, teacher self-efficacy influences motivation, pedagogical decisions, and ultimately, student outcomes [66,67]. These quantitative results are supported by qualitative findings, particularly the theme of “practical application and pedagogical insights”, in which participants described how the course helped them understand how to teach science to young children. Several noted that they had gained specific ideas and strategies for implementing science instruction in early childhood settings, reinforcing the interpretation that the intervention effectively strengthened teaching-related self-efficacy. These results echo those found by Guimerà-Ballesta et al. [68], who observed increased motivation and a greater readiness to implement innovative practices among PECTs in a gamified course setting.

An essential aspect of this study was the use of technology-enhanced structural gamification through the FantasyClass platform, which not only created an engaging and enriched learning experience but also functioned as a multimodal learning environment, integrating textual, visual, and interactive elements. The high perceived motivational rating (5 out of 5) received by FantasyClass suggests that structural gamification can enrich the educational experience without compromising academic rigor. This quantitative appreciation is mirrored qualitatively: the most frequently cited theme in students' open-ended responses was the “increased motivation” they experienced while using FantasyClass. Typical comments—such as “I used to think it was impossible to motivate someone to learn science through apps like FantasyClass, but today my level of involvement is much higher”—illustrate how the platform transformed routine coursework into an engaging experience. This aligns with findings from Zhang et al. [69], whose meta-analysis concluded that Classcraft—a comparable digital platform based on structural gamification—improves both academic performance and motivation across multiple disciplines. These converging lines of evidence reinforce the role of digital structural gamification as a viable strategy for enhancing student motivation.

The narrative played a crucial role in providing a cohesive structure, linking learning activities and instilling a sense of purpose and continuity in the students' learning. This was evident in the participants' responses to the challenges associated with collecting the five amulets, where the storyline provided meaningful context for each key course topic. The narrative contributed to greater engagement and motivation by connecting educational content to an overarching goal, supporting Bruner's [40] view that storytelling helps learners process and retain information more effectively. These findings are consistent with previous experiences that integrated narrative elements with structural gamification in science courses for preservice primary teachers [56,70], and they align with Filatro and Cavalcanti [71], who emphasized that combining structural gamification with content gamification, such as adding narrative elements to classroom activities, can significantly enhance student engagement and learning outcomes by providing a richer and more immersive educational experience.

The SDT framework offers a valuable perspective for interpreting these findings, particularly regarding how the design of the gamified course might have addressed students' psychological needs of autonomy, competence, and relatedness. The increased sense of competence and autonomy among participants may be attributed to the nature of the

challenges presented, which were designed to be both achievable and stimulating, thereby reinforcing their belief in their abilities. Similarly, immediate feedback, provided through both the digital platform and peer interactions, may have contributed to strengthening their sense of competence. This is in line with Sailer et al. [31], who found that feedback of this nature helps maintain motivation and supports learners' self-perceptions of their skills. Moreover, the opportunity to make meaningful decisions—such as selecting avatars, choosing group strategies, and deciding on in-game rewards—likely supported students' autonomy [72]. The narrative elements also played a crucial role in supporting both autonomy and relatedness. By allowing them to see their actions as significant within the story's context, these elements helped foster a sense of purpose, while encouraging collaboration and shared experiences among peers [33]. These interwoven elements contributed to a gamified environment where motivation was sustained through alignment with core psychological needs.

The high motivational ratings for collectibles, gold coins, and group work underscore the importance of well-designed game mechanics in fostering student engagement. Collectibles not only served as engaging elements but also incorporated educational content within activities, promoting deeper learning and retention of scientific knowledge [73]. Gold coins, similar to other reward elements, provided immediate feedback and recognition, enhancing students' sense of competence. Group work was also rated highly, emphasizing the importance of relatedness in learning environments. Team-based challenges not only motivated participants but also encouraged social learning, which is essential for future educators aiming to build collaborative classroom cultures [74]. Cooperation among students likely fulfilled their need for social connection, contributing to overall engagement, as supported by Tauer and Harackiewicz [75], who found that collaboration significantly enhances intrinsic motivation in group contexts.

However, not all gamified elements were equally effective. Features such as badges and HPs received lower motivational ratings, possibly indicating they were perceived as less relevant or impactful compared to collectibles or group work. This aligns with research suggesting that not all game elements are equally motivating, and effectiveness depends on alignment with students' needs and preferences [76,77]. Future course iterations may benefit from prioritizing highly engaging features—such as collaborative tasks and narrative immersion—while reducing the emphasis on less effective elements.

Early childhood is a critical period for developing positive attitudes toward science [78], and teachers play a crucial role in this process. The gamified course provided new ways to approach science for PECTs, transforming prior difficulties into opportunities for inquiry and engagement and empowering them to revisit challenging topics and build confidence in simplifying complex ideas for young learners [64]. Experiencing the benefits firsthand may encourage preservice teachers to implement similar strategies in their classrooms. Several participants explicitly described how the course gave them ideas for applying gamification in early childhood contexts—an indication that the development of teaching-related self-efficacy may also support future pedagogical innovation. Studies have shown that teachers employing gamification and active learning techniques are more likely to engage students and foster a lifelong interest in STEM fields [65,79]. Supporting the development of preservice teachers' self-efficacy and content knowledge in science is essential for promoting high-quality instruction, particularly in the early years.

As a novel contribution, this study demonstrates how a fully integrated, semester-long gamified course—combining both structural and narrative elements within a digital platform—can enhance PECT's motivation, engagement, and teaching self-efficacy in science education. By embedding gamification across all instructional tasks rather than using it as an add-on, the intervention offers new insights into how comprehensive gamified

design can support affective and pedagogical development in teacher education programs. Overall, these findings highlight how well-structured and immersive gamified learning environments can meaningfully contribute to the preparation of future early childhood educators, offering both motivational benefits and pedagogical inspiration.

Limitations and Future Directions

This study is deliberately framed as a case study, offering a rich and context-bound exploration of how gamification influences preservice early childhood teachers' motivation and attitudes toward science. While this design enables a deep understanding of participants' experiences within a specific course and institutional setting, it also limits the broader generalizability of the findings. The results should be interpreted considering the particular characteristics of the cohort, the instructor's familiarity with gamification, and the local educational context. In this regard, although demographic data were collected, no subgroup analyses were conducted due to the sample's composition: over 94% of participants identified as women, and only 15% had a science-oriented academic background. Under such conditions, disaggregated analyses would lack statistical robustness and could lead to misleading conclusions.

Another important consideration is the absence of a control group, which limits the ability to attribute the observed changes solely to the gamified intervention. Other factors—such as course content or instructor influence—may also have contributed to the outcomes. However, the qualitative data offer additional insights by capturing students' own reflections on which aspects of the course influenced their motivation and attitudes. This interpretive layer helps to contextualize the quantitative findings. In addition, students' perceived motivational ratings of individual gamification features (as shown in Table 4) further corroborate that these specific elements were experienced as central drivers of engagement and attitude change.

Building on these reflections, future research should consider using quasi-experimental designs or including comparison groups to strengthen causal inferences and validate these interpretations. Studies should also investigate the long-term effects of gamification on preservice teachers' instructional practices. Longitudinal designs that follow participants into their professional careers could yield valuable insights into whether enhanced self-efficacy and positive attitudes toward science persist and are meaningfully applied in real classroom settings. In particular, researchers could examine how prospective teachers internalize and adapt gamified strategies in their own instructional design once they begin teaching. This line of inquiry would help determine the practical transferability of gamified learning experiences from teacher education programs to early childhood classrooms. Additionally, further exploration of the differential effects of specific gamification elements could help refine the design of more effective and targeted interventions, allowing educators to better tailor strategies to diverse learner profiles. Emerging technologies such as artificial intelligence (AI) also warrant investigation for their potential to personalize and enhance gamified learning. AI-driven platforms could dynamically adjust challenges, rewards, and feedback in response to individual engagement patterns, thereby optimizing motivation and managing cognitive load more effectively.

5. Conclusions

This case study demonstrates that integrating gamification into a science education course for preservice early childhood teachers can significantly improve their attitudes toward science, increase their self-efficacy in teaching, and enhance their overall motivation. The gamified approach helped transform students' perceptions of science—from a subject

often seen as difficult or unappealing to one experienced as accessible, enjoyable, and relevant—while also providing practical strategies for engaging young learners.

While context-specific, these findings underscore technology-enhanced gamification's potential as an effective pedagogical approach within teacher education programs. By addressing common challenges such as low confidence and limited prior science knowledge, gamified courses may contribute to strengthening science education at its foundational stages and better prepare future educators to inspire interest and participation in science among young children.

Moreover, the positive reception of specific game elements—such as digital collectibles, collaborative challenges, and the use of a cohesive narrative—highlights the importance of designing learning environments that are not only interactive, but also emotionally resonant. These features can serve as entry points for reengaging preservice teachers with science in ways that feel relevant and motivating, especially for those with limited prior affinity for the subject.

In the context of early childhood teacher education, where pedagogical practices must be developmentally appropriate and emotionally meaningful, this study illustrates how well-structured gamification—supported by digital tools—can be integrated responsibly into university-level instruction. As technology continues to shape educational contexts, thoughtfully designed gamified interventions may offer valuable pathways to foster deeper engagement, enjoyment, and confidence in future educators. This case contributes to the growing body of evidence supporting gamification as a viable and impactful methodology for science teacher education.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
ECTS	European Credit Transfer and Accumulation System
HPs	Health Points
IDP	Institute for Professional Development
IQR	Interquartile Range
KENE	Knowledge and Exploration of the Natural Environment

M	Median
PECT	Preservice Early Childhood Teacher
PCK	Pedagogical Content Knowledge
RQ	Research Question
SDT	Self-Determination Theory
SPSS	Statistical Package for the Social Sciences
XP	Experience Points

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