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RECEIVED 19 June 2025

ACCEPTED 29 October 2025

PUBLISHED 21 November 2025

CITATION

Talavera-Mendoza F, Cahuana Suni NR and
Cayani Caceres KS (2025) Fostering
ecological awareness
and pro-environmental intentions through
gamification in high school students.
Front. Educ. 10:1650480.
doi: 10.3389/feduc.2025.1650480

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Fostering ecological awareness and pro-environmental intentions through gamification in high school students

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This study examines the relationship between the perception of a gamified experience and the ecological awareness of high school students, using the serious game ABCCI (Aprendizaje Basado en la Creatividad Científica; Learning Based on Scientific Creativity). A quantitative correlational design was applied with 197 students who interacted with the game and subsequently completed two questionnaires to assess both their perception of the gamified experience and their ecological awareness. The results revealed a strong and significant positive correlation between a positive perception of the gamified experience and higher self-reported ecological awareness ($r = 0.725$, $p < 0.001$). These findings indicate that gamified elements can effectively enhance student engagement and environmental consciousness in educational contexts. However, as the evidence is correlational and based on self-reported data, it does not allow conclusions about long-term behavioral changes beyond the classroom. The study provides empirical support for the association between gamified learning and ecological awareness, offering valuable implications for the design of educational environments that aim to promote pro-environmental attitudes among students.

KEYWORDS

gamification, serious games, ecological awareness, sustainability, environmental education, environmental consciousness, game-based learning

1 Introduction

Education for Sustainable Development (ESD) must be an urgent priority within curricula, as we are currently witnessing multiple global challenges that highlight the planet's fragility and the need for more responsible environmental behavior. Climate change, biodiversity loss, and ecological disasters are consequences of misguided human decisions, whose effects we still do not fully understand, complicating the possibility of reversing them (Janakiraman et al., 2018). To achieve ESD, it is essential to foster ecological awareness, which leads to adopting a responsible attitude toward nature (Sovhira, 2023). This scenario demands a transformation in education that allows students to understand the impact of their present actions and prepares them to make ethical and sustainable

decisions that ensure the wellbeing of future generations (Palomino et al., 2023). In response to this need, a gamified serious game has been implemented for science learning, offering students not only to acquire knowledge but also to reflect on pro-environmental attitudes and ecological actions toward care and preservation. In this sense, gamification is a strategy often associated with the promotion of ecological behaviors by engaging students through challenges and rewards in an immersive and appealing manner (Charkova, 2024), which makes it crucial to identify the factors influencing sustainable behavior (Bhattarai et al., 2024).

For terminological clarity, the terms environmental awareness and ecological awareness have been used interchangeably. While closely related, they are not synonymous. This explains the interest in the processes of formation and change of ecological awareness, which includes beliefs, attitudes, intentions, and effective behaviors (Corraliza and Collado, 2019). Environmental awareness, in general terms, refers to understanding environmental issues and the impact of human activities on the environment. Creating this awareness is crucial to promote sustainable practices and mitigate irreversible future consequences (Novo et al., 2024). Ecological awareness involves recognizing environmental issues and making decisions that do not harm the environment, which can lead individuals to adopt more sustainable lifestyles (Ouariachi et al., 2020); while ecological awareness involves a deeper understanding of the interrelationships within ecosystems and the intrinsic value of nature. It implies a profound sense of connection with all forms of life, influencing moral actions and pro-environmental behavior (Yin et al., 2022). Therefore, knowledge and opinions are important to determine ecological awareness, which has its roots in environmental knowledge (Alamsyah et al., 2020). In this sense, our study focuses on ecological awareness, considering the scope of study.

The literature review suggests that the use of learning-based games is linked to knowledge acquisition, attitudinal development, and behavior. For example, (Tan and Nurul-Asna, 2023) report that such games can foster these outcomes, while (Chugh and Turnbull, 2023) note their connection to higher student motivation. Similarly, in a review of empirical studies, (Schrader, 2023) concluded that gamification can have a positive effect on motivation, concentration, cognition, affect, and prosocial behavior.

In light of these encouraging results, the need arises to generate meaningful learning scenarios that foster responsible environmental behaviors and ecological awareness through innovative resources such as game-based learning. Therefore, we propose a solution through ABCCI, a gamified serious game designed to achieve scientific education through an inquiry-based learning approach combined with gamification elements, featuring environmental sustainability questions that promote sustainable decisions within a safe and simulated environment, where students become active agents of change. Sustained by the fact that more experimental studies are needed to analyze gamification from the students' experience for personalized learning (Dos Santos et al., 2024), as well as to evaluate environmental behaviors with ecological mini-programs (Zhang et al., 2024). In Latin America, the implementation of digital games applied to science and sustainability learning is still scarce (Vecchio and Greco,

2023), revealing an important educational gap that urgently needs attention.

Game-based learning proves to be a tool that can achieve a variety of desirable learning outcomes, including sustainability and attitude change (Scurati et al., 2023). Many studies suggest that if gamified systems are designed to suit user profiles, they can improve their experience and learning (Dos Santos et al., 2024). In this sense, this study, based on gamified instructional design, aims to assess, after the interaction of secondary school students in the VI cycle with the ABCCI game, their perception of the user experience sustained by gamification elements and gamification mechanisms adopted for ecological behavioral change.

The research conducted contributes to the field of science education in a Peruvian context through a quantitative approach. It also accounts for the pedagogical use of the serious game ABCCI, contributing to filling the gap in the literature on gamification in environmental education in secondary education, where the formation of ecological habits needs to be fostered, based on the conviction that climate protection and the mitigation of environmental issues depend on individual commitment and motivation in their thinking and actions in relation to the planet, contributing to structural change. This individual approach and the firm commitment to strengthening each citizen's ability to think and act on environmental issues drove the development of the project, which also aimed to democratize knowledge about everyday actions for adopting a more ecological lifestyle (Novo et al., 2024), as well as how gamified interventions influence behavior and motivation in specific contexts, providing valuable insights into gamification as a behavior change strategy (Oliveira and Hamari, 2025).

2 Literature review

2.1 Gamification of serious games and their elements

The game strategy incorporates gamification elements to engage users (Ma and Zhang, 2023), with the specific goal of ensuring participation and enjoyment of the activity. This is achieved by considering a meticulous design based on objectives and context, as well as the expressed needs of students, so that the integration of technology with gamification successfully meets its objectives (Polat, 2023). Gamification can take various forms, such as the use of narratives, the creation of social competition, and behavior incentives through badge and reward systems (Sailer and Homner, 2020). Gamification is a tool that, when used properly, can transform learning into a holistic activity. The application of gamification in the classroom could allow students to be motivated to learn or enjoy performing tasks that would otherwise be considered boring (Hanus and Fox, 2015), by trying to capture, exploit, and apply these properties of games through the use of gamification techniques.

Education and teaching that use video games as game elements are personalized and provide better guidance of processes toward desired objectives, which are highly useful for students (Ccoa et al., 2023; Gómez Urquiza, 2019). This enables less-trained instructors, for instance, to easily adopt methods such

as programming game schedules where feedback can also be automated, meaning a complete and enjoyable experience is not required (Cvetkovic et al., 2025). Gamification has undoubtedly served as a new step along with the growing use of technology to harness people's behavior, and its impact can now even be seen at the level of environmental protection (Miao et al., 2022). Suggests a serious game to present players with the hidden carbon emissions of the internet and associated activities, promoting actions that raise awareness of the impact of their daily activities on the environment. In this context, gamification can take many forms, such as using narratives, creating social competition, and encouraging behavior through badge and reward systems.

As a result of the literature, it is supported that gamification increases the motivation level of students, improving constructive behaviors toward learning using unconventional teaching methods. Empirical findings suggest that there is a strong effect of serious games and game-based learning on students' motivation, affect, and cognitive outcomes (Lopez et al., 2023; Schrader, 2023). Recent studies related to serious games in science education help in the acquisition of knowledge as well as foster pro-environmental perception and behavior change (Ma and Zhang, 2023; Viza et al., 2025).

2.2 Ecological behavior integrated into gamified serious games

The ecological paradigm combines human activities for modern civilization in relation to the environment, considering the negative impact of operating from a perspective of care and protection (Donmez-Turan and Kiliclar, 2021). It is more related to the granular enjoyment that the user experiences while participating in the experience, which elevates them to a positive emotional state: eco-engagement (Zhang et al., 2024). Eco-engagement, in turn, leads to conservation actions and fosters recognition of sustainability (Zhang et al., 2024). Environmental Sustainability Education (ASE) aims to ensure that adolescents actively care for the environment, urging them to understand the need to foster a world that is sustainable for all.

From a socio-scientific perspective, this engagement seeks to harmonize social, environmental, and ecological relationships while fostering empathy, critical awareness, and respectful practices toward the environment (Janakiraman et al., 2018). As a result, educational games should be designed with authentic challenges that replicate real-world problems, which learners can solve through sustainable actions, biodiversity restoration, and collective action (Novo et al., 2024; Okada and Gray, 2023).

Digital Game-Based Learning (DGBL) has proven effective in enhancing engagement, motivation, and even the development of ecological skills among students. GoBeEco, GAIA, and EduPARK are illustrative games that incorporate elements of challenge, reward, interactive missions, and augmented reality to promote knowledge, behavioral change, and ecological awareness (Mylonas et al., 2023; Novo et al., 2024; Palomino et al., 2023). These resources place learners in a gamified environment where they can make decisions, thus promoting active learning, safe experimentation, and critical reflection. The Razali report noted that educational level moderates the relationship between environmental learning

and pro-environmental behavior. There is an increasing number of gamified and digitized activities aimed at lessons focused on education through sponsored posts using the United Nations Sustainable Development Goals (SDGs). An ecological educational game environment can help promote sustainability literacy as reported by Haerani and Suhartini (2023) and Mylonas et al. (2023).

This study focuses on a gamified instructional design, which presents two aspects: the first evaluates the effects of gamification on the satisfaction of psychological needs based on SDT activity theory, involving learning activities designed around the three psychological needs of the student: Autonomy, competence, and relatedness (Luo, 2022). where it harmonizes with skills and challenges (Oliveira and Hamari, 2025). From another perspective, the activity theory model derives three elements: Participation, immersion, and feedback. The second refers to types of motivation, and we will emphasize self-determination theory (Ryan and Deci, 2000), which distinguishes intrinsic motivation, extrinsic motivation, and demotivation. Intrinsic motivation drives activities for individual interest and satisfaction, while extrinsic motivation refers to engaging in an activity for enjoyment (Camacho-Sánchez et al., 2022; Luo, 2022). In contrast, demotivation is the lack of volitional drive to participate in any activity (Camacho-Sánchez et al., 2022). Intrinsic motivation more effectively increases engagement and performance compared to extrinsic motivation. When students enjoy the logic of the game, learning is experienced as an enjoyable situation, so intrinsic motivation increases. Using game mechanics such as feedback, curiosity, enjoyment, achievement, fun, among others, can increase both external and internal motivation for students to participate in these learning situations. Intrinsic motivation is associated with flow, motivation to learn, and engagement with an activity so that the game becomes a successful motivational enhancer, with both intrinsic and extrinsic reinforcers (Camacho-Sánchez et al., 2022). This game experience promotes freedom to experiment, control their immersion, and enjoyment (Luo, 2022) (see Figure 1).

The research conducted contributes to the educational field by investigating, in a Peruvian context, the interaction of gamification and ecological awareness among secondary school students using a quantitative approach in science learning. It also provides empirical evidence of the effectiveness of the serious game ABCCI as a pedagogical resource, thus contributing to addressing the gap in literature on gamification applied to environmental education in secondary education, as there are limited studies on the potential impacts of gamification components (points and badges, levels, feedback, among others) that elevate engagement and motivation (Meng et al., 2024).

The primary purpose of this study is to examine the relationship between students' perceptions of a gamified learning experience and their self-reported ecological awareness. To achieve this, the following objectives were established:

OG. To determine the relationship between the perception of the gamified experience with the ABCCI game and the self-reported ecological awareness of high school students.

OE1. To describe the students' perception of the gamified experience after interacting with the serious game ABCCI.

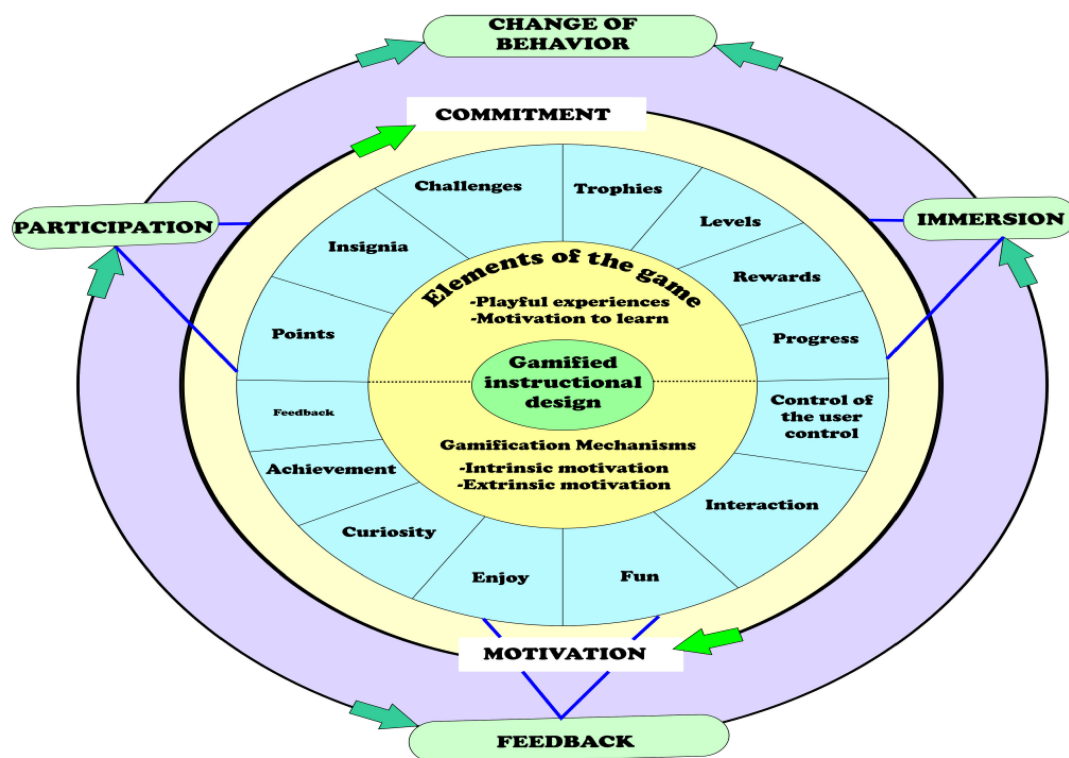


FIGURE 1

Gamified instructional model adapted from Camacho-Sánchez et al. (2022) and Luo (2022).

OE2. To evaluate the average score of self-reported ecological awareness and pro-environmental dispositions among students after the intervention.

and 59 second-year secondary students (29.9%). The age of the participants ranged from 12 to 14 years.

3 Materials and methods

3.1 Study design and implementation

This study follows a quantitative, non-experimental, and cross-sectional correlational design. The aim is to explore the relationship between students' perception of a gamified experience with the serious game ABCCI and their self-reported ecological awareness. The study was conducted with a single group of students in a post-test only format, without a control group. The ABCCI game was implemented in an educational environment to describe student perceptions of its gamification elements and assess their reported ecological awareness.

3.2 Participants

The sample consisted of 197 students from two educational institutions in Arequipa, Peru. Participants were selected through convenience sampling, as they were enrolled in a Science and Technology course where the ABCCI game was implemented as part of their academic activities during the 2024 school year. The sample comprised 138 first-year secondary students (70.1%)

3.3 Techniques and instruments

Two instruments were adapted for this study. The complete wording of all items is available in [Appendix A](#).

The first instrument, Perception of the Gamified Experience, consists of six items adapted from the "Gamification Statements Impacting Ecological Behavior" (Novo et al., 2024). The second instrument, Ecological Awareness and Dispositions, comprises eight items adapted and expanded from the "Ecological Awareness and Behavioral Change Questionnaire" (Novo et al., 2024). For both instruments, the original binary response format was changed to a five-point Likert scale (1 = "Strongly disagree"–5 = "Strongly agree").

The Ecological Awareness and Dispositions scale was designed to assess self-reported environmental awareness (EA) and dispositions related to pro-environmental actions. According to the framework used, higher EA scores reflect greater perception, knowledge, positive attitudes, and pro-environmental behaviors.

Conversely, lower EA scores describe an acceptable cognitive level but a lack of perceived pro-environmental values or beliefs, leading to passive attitudes and behaviors that are not respectful of the environment (Zhang et al., 2024).

To ensure the content validity of the adapted instruments, a quantitative evaluation was conducted by a panel of three expert judges (two with expertise in natural sciences and one in

educational informatics) using the Aiken's V coefficient. The judges evaluated the relevance and clarity of each item concerning the construct being measured. The analysis yielded an average Aiken's V coefficient of $V = 0.99$ for the set of instruments, indicating an excellent level of content validity.

3.4 Procedure

The application of the serious game ABCCI began on November 27, 2024; each class intervention lasted approximately 90 min or 2 teaching hours, as part of a regular science class session. During these sessions, students interacted with the ABCCI game, navigating through its mechanics and game elements. In first grade, the topics were "Soil Degradation" and "Glacier Melting;" in second grade, "Respiratory Diseases" and "Acid Rain." These missions were designed to promote greater environmental responsibility, reinforcing students' ecological awareness from both scientific and playful perspectives. Unlike other experimental designs, no pre-tests were administered in this study. Instead, participants completed all instruments after the intervention. The questionnaires were distributed via a link shared through WhatsApp groups for each classroom, as well as through printed QR codes posted in each classroom, allowing students to respond to the questionnaires regarding their perception of the gamified experience and their self-reported ecological awareness. The response collection period lasted until January 6, 2025.

3.5 ABCCI serious game proposal in a gamified environment

The architecture of the ABCCI game is designed to be accessible, intuitive, and easy to use, aiming to maximize the player experience. The interface is clearly organized and functional, allowing smooth navigation and quick access to all key features of the game. Below are the main components: (a) Intuitive and User-Friendly Design: The interface is created so players can easily interact with the game without prior experience. Visual elements are clear and well-distributed, ensuring users can enjoy the game efficiently and without confusion. (b) Tutorial and Mission

Selection According to Grade: Users receive an interactive tutorial that teaches the basic game mechanics, with missions adapted to their educational level, ensuring the challenges are appropriate for their knowledge level. (c) Organization of Visual and Interactive Elements: Game elements are organized into clear categories or levels, allowing players to navigate between them easily. The visual layout highlights actions the player needs to take, such as mission selection, viewing rewards, and monitoring progress. (d) Ease of Navigation and Clarity of Instructions: The interface allows players to move between different game menus easily. Instructions are clear and easy to understand, helping players follow the prompts and understand the objectives of each mission or challenge.

On the main screen, players can access several key game functions: (i) Main Screen: Provides direct access to the tutorial and the store, where players can customize their avatar or purchase game upgrades. (ii) User Registration and Customization: Players can register, create a profile, and customize their nickname. This information is used to track their performance metrics and progress. (iii) Mission Selection: Players can choose missions based on their academic grade, ensuring the challenges are suitable for their level of knowledge. (iv) Progress Bar: A visual bar showing the player's progress within the game, highlighting their advancement through missions and the accumulation of points and rewards. (v) Return to Main Menu Button: Allows players to easily return to the main menu to review other options or make changes to their settings. (vi) Music and Sound Settings: Players can adjust the game's settings, such as background music and sound effects, to personalize their game experience (see Figure 2).

The following images highlight key gamification elements incorporated into the game, including: (a) Progress bar showing player advancement. (b) Points and badges, with rewards given for successfully completing missions. (c) Missions and challenges, with activities designed to encourage eco-friendly decision-making.

3.6 Gamification implementation in the study

During the game sessions, the first stage is based on an inquiry-based learning approach, with four levels. In one part of the

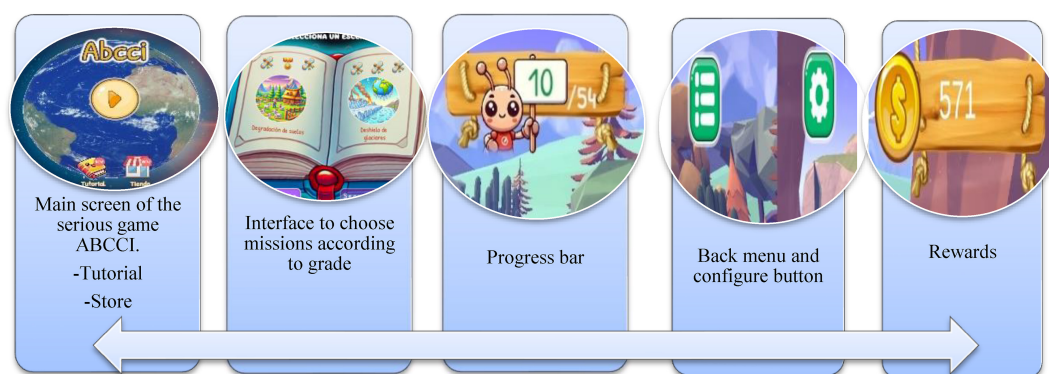


FIGURE 2
Functions of the ABCCI gamified serious game.

game, students must interact with the virtual laboratory elements, performing activities such as handling containers, mixing materials, and observing the effects of their actions. At each level, interactive questions are presented to assess the participant's understanding of the proposed topics.

3.7 Assessment and measurement of results

The game design is based on three main pillars of gamification: interactivity, immediate feedback, and rewards. Through practical activities, players can answer inquiry-based learning questions with instant feedback on their performance, promoting active learning (see Figure 3).

The evaluation is conducted through a combination of inquiry question responses and analysis of the decisions made during the simulations. Success indicators include: (a) Accuracy in answering inquiry questions. (b) The ability to apply ecological concepts during practical activities within the game (e.g., correctly managing soil or designing sustainable solutions). (c) Interactivity: Players interact with various game elements, such as simulating the creation of different types of soils (clay, gravel, garden soil), allowing them to experience the impact of over-exploitation on soil degradation. (d) Immediate feedback: Players receive real-time feedback on their performance during activities, promoting continuous learning (see Figure 4).

Rewards include medals that recognize the knowledge gained (e.g., Environmental Awareness Medal, Sustainability Medal), which are visible on the game interface. The ABCCI game

includes different levels or stages, each focused on a different ecological theme. Participants must advance through these levels by answering questions and completing challenges that reinforce acquired knowledge. As players progress, they earn medals and prizes that reflect their performance. Continuous interaction with these elements reinforces ecological concepts in a playful and engaging way (Figure 5).

3.8 Data analysis

Data analysis was conducted using SPSS statistical software (Version 27).

First, descriptive statistics were calculated to address the specific objectives. For the Perception of the Gamified Experience scale, frequencies and percentages were used to describe student responses. For the Ecological Awareness and Dispositions scale, means and standard deviations were calculated.

The internal consistency (reliability) of both adapted scales was assessed using Cronbach's Alpha coefficient. The results, presented in Table 1, showed adequate to high internal consistency for both the Gamification Elements scale ($\alpha = 0.781$) and the Ecological Behavior scale ($\alpha = 0.875$).

To test for normality of the data, the Kolmogorov-Smirnov test was used, given the sample size ($n > 50$). As the data did not follow a normal distribution ($p < 0.05$), Spearman's rank correlation coefficient (ρ) was used to determine the relationship between the perception of the gamified experience and ecological awareness.

A post-hoc power analysis was conducted using G*Power 3.1 to ensure the sample size was adequate to detect the observed

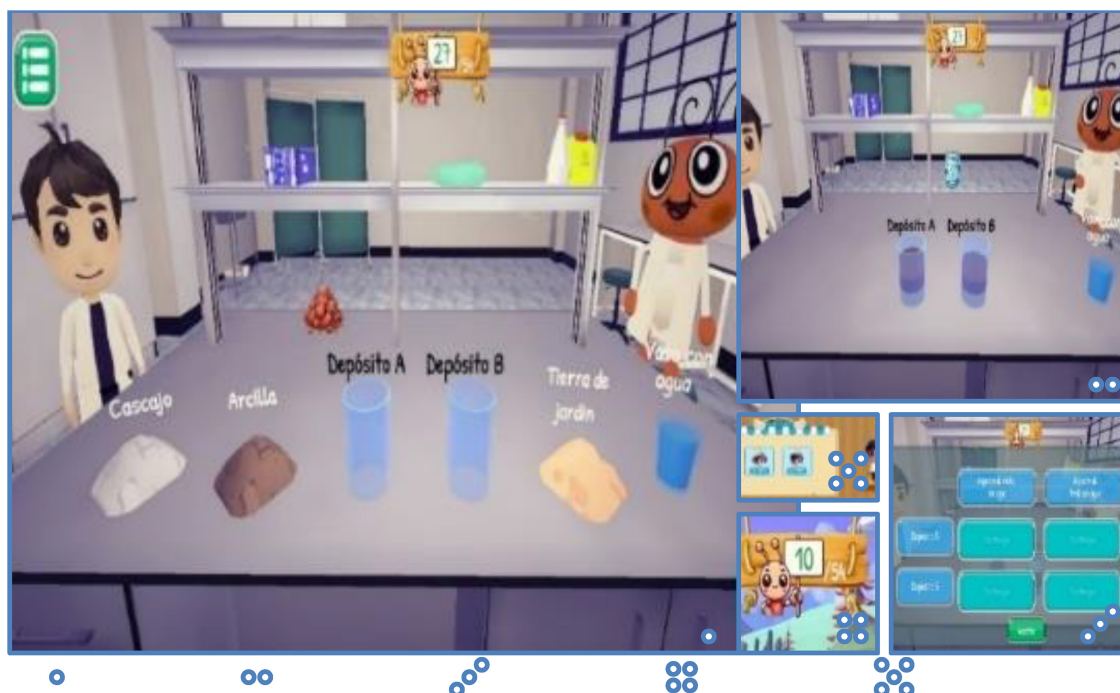


FIGURE 3

(a) Experimenting in the lab using various materials. (b) Following instructions in the lab. (c) The results of their experiments are placed in a double-entry table.



FIGURE 4
Immediate feedback from the ABCCI game.

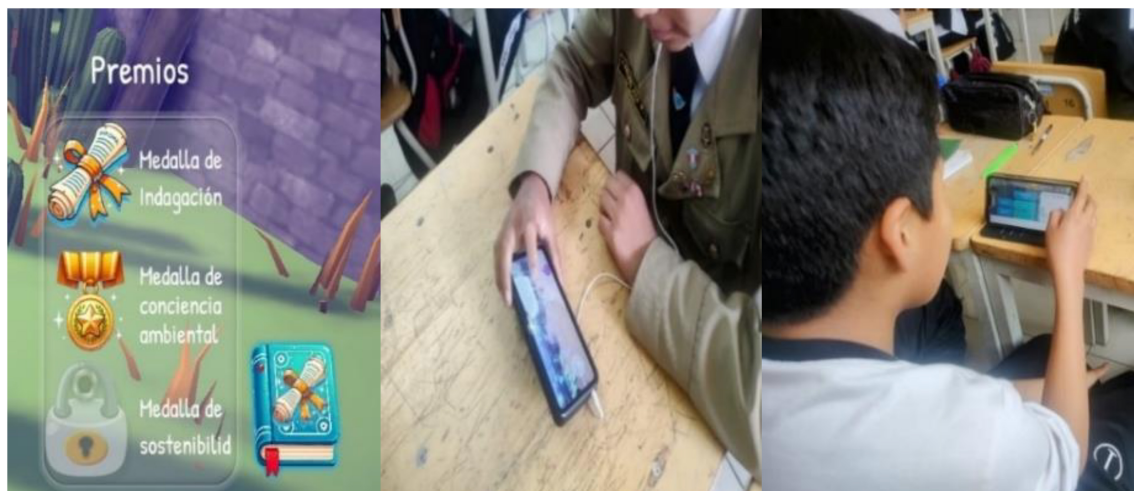


FIGURE 5
Reward system for achievements through medals.

correlation. The Spearman's rho coefficient will be reported along with its 95% confidence interval to provide a robust estimation of the effect size.

3.9 Ethical considerations

The research protocol was reviewed and approved by the Ethics Committee of the National Universidad Nacional de San Agustín de Arequipa (University Council Resolution No. 0045-2022). The study was conducted in accordance with institutional ethical guidelines and principles for research involving human subjects. Prior to data collection, written informed consent was obtained from the parents or legal guardians of all participants. Additionally, informed assent was obtained from the students themselves. Participants were informed about the voluntary nature of their participation, the anonymity of the survey, and their right

to withdraw from the study at any time without penalty. All data were handled with strict confidentiality.

4 Results

4.1 Evaluation of students' perception of the gamification experience

This section presents the descriptive results regarding students' perceptions of the gamified experience with the ABCCI game. As shown in Table 2, the students' reception of the game was highly positive across all evaluated items.

A vast majority of the participants reported positive perceptions regarding the game's association with their ecological behavior and awareness. Specifically, 93% of students agreed or strongly agreed with the statements that the use of ABCCI was positively

TABLE 1 Reliability of the instruments.

Dimension	Cronbach's alpha
Gamification elements	0.781
Ecological behavior	0.875

associated with their ecological behavior and that it was linked to an increased awareness of ecological contexts. Similarly, 93% reported feeling motivated to continue working on environmentally conscious behavior.

The gamification elements were well-received, with 92% of students feeling that the missions and challenges were helpful for their daily actions and that the game inspired them to consider pro-environmental habits. While a substantial 89% of participants found the game “very fun,” this slightly lower percentage might suggest variability in personal gaming preferences. Overall, the low standard deviations (ranging from 0.56 to 0.69) indicate a consistent and positive perception of the gamified experience among the students.

4.2 Ecological awareness and pro-environmental dispositions

This section details the descriptive findings from the scale measuring students' self-reported ecological awareness and pro-environmental dispositions after interacting with the ABCCI game. The results are presented in Table 3.

Overall, the mean scores for all items were high, ranging from 4.18 to 4.27 on a five-point scale, indicating that students generally reported a high level of agreement with the pro-environmental statements. The items with the highest mean scores were related to the game providing clear guidance on ecological habits ($M = 4.27$, $SD = 0.659$) and practical knowledge for ecosystem preservation ($M = 4.26$, $SD = 0.622$).

Students also reported a strong inclination to adopt eco-friendly habits ($M = 4.22$, $SD = 0.661$) and felt they could act as agents of change ($M = 4.18$, $SD = 0.612$). The relatively low standard deviations (ranging from 0.612 to 0.664) suggest a consistent pattern of high self-reported ecological awareness among the participants after the gamified experience.

4.3 Relationship between perception of gamification and ecological awareness

This section analyzes the relationship between students' perception of the gamified experience and their self-reported ecological awareness. First, a normality analysis was performed to determine the appropriate statistical test for the correlation.

4.3.1 Normality test

The Kolmogorov-Smirnov test was conducted to evaluate the normality of the distributions for the two main variables. As shown in Table 4, the results indicated that both the perception of gamification [$D(197) = 0.167$, $p < 0.001$] and ecological awareness

[$D(197) = 0.189$, $p < 0.001$] significantly deviated from a normal distribution. This finding justified the use of a non-parametric correlation test.

4.3.2 Spearman's correlation

A Spearman's correlation analysis was subsequently conducted to examine the relationship between the perception of the gamified experience and self-reported ecological awareness.

The results, presented in Table 5, revealed a strong, positive, and statistically significant relationship between the two variables [$\rho = 0.725$, $N = 197$, $p < 0.001$, 95% CI (0.65, 0.79)]. This finding indicates that students who reported a more positive perception of the gamified elements in ABCCI also tended to report higher levels of ecological awareness. The Spearman's rho coefficient ($\rho = 0.725$) represents a large effect size.

A post-hoc power analysis conducted with G*Power 3.1 confirmed that the sample size was sufficient to detect a correlation of this magnitude, achieving a statistical power greater than 0.99.

This strong positive association suggests that the instructional design of the ABCCI game was well-received by students and is linked to their engagement and reported commitment to pro-environmental dispositions.

5 Discussion

5.1 Interpretation and connection to literature

The primary purpose of this study was to explore the relationship between students' perception of a gamified learning experience with the serious game ABCCI and their self-reported ecological awareness. The results revealed a strong, positive, and significant correlation between these two variables ($\rho = 0.725$), suggesting that students who reported a more positive perception of the game's mechanics and elements also tended to report higher levels of ecological awareness and pro-environmental dispositions. This core finding, representing a large effect size, provides a valuable starting point for understanding the potential of gamified tools in environmental education within the specific context of Peruvian high school students. The strength of this association underscores the relevance of user experience in educational technology, indicating that when students find a learning tool engaging and well-designed, there is a powerful link to their reported attitudes and consciousness regarding the subject matter.

This strong positive association aligns with a growing body of literature that reports positive links between gamification and key educational outcomes. While our correlational design does not permit causal inferences, the result is consistent with studies like (Schrader, 2023), who reported associations between game-based learning and positive affective and motivational outcomes in students. The high scores observed in our descriptive results offer further insight, suggesting that the specific gamified instructional design of ABCCI was well-received. This positive reception is likely a key factor in the strong association with self-reported ecological awareness. Specifically, the game's design, which fosters participation, immersion, and provides constant feedback, appears to activate the very mechanisms that authors like (Chen et al.,

TABLE 2 Perception of the gamification experience in the ABCCI serious game.

Statement	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	% agree/strongly agree	SD
The use of gamified ABCCI positively influenced my ecological behavior.	1	0	13	119	64	93%	0.61
Gamified ABCCI increased my awareness of ecological contexts.	0	0	13	124	60	93%	0.56
Using gamified ABCCI motivates me to continue working on more environmentally conscious behavior.	1	0	13	120	63	93%	0.61
I found the gamified ABCCI game very fun.	1	2	19	107	69	89%	0.69
I felt that the missions and/or challenges helped me improve my daily actions.	0	1	14	125	57	92%	0.58
I believe that after using gamification, it indirectly inspires me to change my habits to care for and preserve the environment.	0	2	13	120	62	92%	0.60

2022; Meng et al., 2024) identify as crucial for engagement. Meng et al. (2024) found that gamification elements like badges and progress indicators are significantly linked to higher motivation and engagement, a finding that our study supports through the strong correlational evidence. The high percentage of students who found the game enjoyable and its missions helpful suggests a successful implementation of these principles. Furthermore, our findings support the idea that effective gamified experiences require a harmony between entertainment and educational content to be associated with the adoption of more sustainable lifestyles (Novo et al., 2024), which in turn is related to sustainable environmental awareness (Faezah et al., 2025). This study contributes by providing robust empirical evidence of this association from a Peruvian context, a region where research on this topic is still scarce (Vecchio and Greco, 2023).

5.2 Theoretical and practical implications

From a theoretical standpoint, the findings are consistent with Self-Determination Theory (Ryan and Deci, 2000), which posits that fulfilling needs for autonomy, competence, and relatedness can enhance intrinsic motivation. The positive reception of ABCCI suggests the game was successful in tapping into these motivational drivers students had autonomy in their decisions, felt competent as they progressed and earned rewards, and potentially felt relatedness to the larger social issue of environmental protection. This intrinsic motivation is, in turn, associated with the positive attitudinal outcomes reported.

From a practical standpoint, the results offer clear guidance for educators and instructional designers. The strength of the association between user experience and reported awareness underscores the importance of focusing on high-quality, user-centered design in educational technology. This implies that for serious games to be effective tools, they must first be effective games: intuitive, engaging, and motivating. For educators, this study suggests that incorporating well-designed serious games like ABCCI into the curriculum can be a valuable strategy to introduce and reinforce complex ecological concepts in a way that resonates with students.

5.3 Limitations and directions for future research

It is crucial to acknowledge the limitations of this study, which also open clear avenues for future research. First, the cross-sectional, post-test-only design is a significant limitation. It does not permit causal conclusions or the measurement of change over time. We can report a strong association, but we cannot claim that the game caused the high levels of ecological awareness. Future research should employ experimental designs with control groups or longitudinal designs with pre- and post-tests to determine if gamified interventions can cause a significant and lasting change in ecological awareness and, more importantly, in observable behavior (Boncu et al., 2022).

Second, this study relied exclusively on self-report measures. While valuable for capturing perceptions and attitudes, these

TABLE 3 Ecological awareness and pro-environmental dispositions reported by students.

Statement	Mean	SD	Skewness	Kurtosis
ABCCI presents clear habits and its application provides good guidance on how these habits can be improved ecologically.	4.27	0.659	−1.333	5.243
ABCCI provides practical knowledge on what can be done to protect and preserve different ecosystems.	4.26	0.622	−1.013	4.080
I believe that ABCCI encourages users to adopt environmentally friendly habits.	4.22	0.661	−0.805	2.288
I feel I could act as an agent of change, encouraging others to protect and preserve the environment.	4.18	0.612	−0.662	2.899
I believe I can change my behavior related to sustainability through the use of the ABCCI serious game.	4.22	0.629	−0.701	2.520
By using the app, my knowledge of ecological contexts has improved.	4.18	0.660	−0.753	2.199
By using the app, I feel motivated to more intensively address the sustainability issue in my life.	4.18	0.646	−1.136	4.844
I have been able to expand my long-term sustainability knowledge.	4.21	0.664	−1.210	4.668

TABLE 4 Normality tests.

Variable	Kolmogorov-smirnov ^a statistic	df	Sig.
Gamification elements	0.167	197	0.000
Ecological awareness	0.189	197	0.000

^aLilliefors significance correction.

TABLE 5 Correlation tests.

Gamification elements		Ecological awareness
Rho de spearman	Correlation coefficient	0.725**
	Sig. (bilateral)	0.000
	N	197

**Correlation is significant at the 0.01 level (2-tailed).

measures are susceptible to social desirability bias. This limitation connects to the challenge identified by Zhang et al. (2024), who note the existing gap in establishing how online game interactions translate into real-life behavioral transformations. Future studies would benefit immensely from incorporating objective measures, such as direct observation of pro-environmental behaviors (e.g., recycling habits in the classroom) or performance-based tasks that assess decision-making in simulated environmental dilemmas.

Third, the instrumentation, while showing excellent content validity (Aiken's $V = 0.99$) and good internal consistency, presents a limitation. A structural validity analysis (e.g., factor analysis) was not performed on the adapted scales, representing an important area for future psychometric work.

Finally, the characteristics of our sample (students from a specific region in Peru, with an age range of 12–14 years, and a likely majority being male) limit the generalizability of the findings. Future research should aim for larger, more diverse, and demographically detailed samples to explore how these relationships might vary across different cultural, age, and gender groups. Exploring other factors, such as the social context or the implementation of post-game follow-up activities, could also provide deeper insights into how to strengthen the connection between in-game learning and real-world action.

In conclusion, this study provides strong correlational evidence that a positive perception of a gamified learning experience is significantly associated with higher levels of self-reported ecological

awareness among high school students in a Peruvian context. While the study's design appropriately precludes claims about causality or long-term behavioral change, the findings highlight the significant potential of serious games like ABCCI as engaging and well-received tools to foster pro-environmental attitudes and knowledge. This research reinforces the value of investing in well-designed, contextually relevant gamified educational resources and sets a clear agenda for future studies to rigorously explore the causal links between gamified learning and tangible, observable, and sustainable real-world behaviors.

6 Conclusion

This study found a strong, positive, and statistically significant correlation between students' positive perception of the gamified serious game ABCCI and their self-reported ecological awareness. The findings indicate that a well-designed gamified experience is strongly associated with higher reported pro-environmental attitudes and consciousness in a secondary school setting. Although the cross-sectional nature of the study does not permit causal claims regarding behavioral change, this research provides robust evidence for the potential of gamification as an engaging pedagogical strategy in environmental education. Future research should focus on longitudinal and experimental designs to determine if these positive associations translate into observable, long-term pro-environmental behaviors.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The research protocol was reviewed and approved by the Ethics Committee of the National Universidad Nacional de San Agustín de Arequipa (University Council Resolution No. 0045-2022). This study was conducted in accordance with institutional ethical guidelines and principles for research involving human subjects. Prior to data collection, written informed consent was obtained from the parents or legal guardians of all participants.

Additionally, informed assent was obtained from the students themselves. Participants were informed about the voluntary nature of their participation, the anonymity of the survey, and their right to withdraw from the study at any time without penalty. All data were handled with strict confidentiality. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

FT-M: Methodology, Supervision, Data curation, Writing – review & editing, Software, Investigation, Conceptualization, Writing – original draft, Visualization, Project administration, Funding acquisition, Validation, Resources, Formal analysis. NC: Writing – original draft, Data curation, Software, Formal analysis, Visualization, Resources, Conceptualization, Methodology, Writing – review & editing, Investigation. KC: Project administration, Writing – original draft, Visualization, Data curation, Conceptualization, Writing – review & editing, Methodology, Investigation, Software.

Funding

The author(s) declare financial support was received for the research and/or publication of this article. This research was funded by Universidad Nacional San Agustín de Arequipa,

UNSA-Investiga, Faculty of Education Sciences within the framework of the project “Serious games to promote scientific enquiry in secondary school students” (grant no. PI-007-2023-UNSA).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

Appendix A | Survey instruments.

Instrument 1: Perception of the gamified experience (adapted from [Novo et al., 2024](#)).

Response scale: 1 (strongly disagree) to 5 (strongly agree).

1. The use of gamified ABCCI positively influenced my ecological behavior.
2. Gamified ABCCI increased my awareness of ecological contexts.
3. Using gamified ABCCI motivates me to continue working on more environmentally conscious behavior.
4. I found the gamified ABCCI game very fun.
5. I felt that the missions and/or challenges helped me improve my daily actions.
6. I believe that after using gamification, it indirectly inspires me to change my habits to care for and preserve the environment.

Instrument 2: ecological awareness and pro-environmental dispositions (adapted from [Novo et al., 2024](#)).

Response scale: 1 (strongly disagree) to 5 (strongly agree).

1. ABCCI presents clear habits and its application provides good guidance on how these habits can be improved ecologically.
2. ABCCI provides practical knowledge on what can be done to protect and preserve different ecosystems.
3. I believe that ABCCI encourages users to adopt environmentally friendly habits.
4. I feel I could act as an agent of change, encouraging others to protect and preserve the environment.
5. I believe I can change my behavior related to sustainability through the use of the ABCCI serious game.
6. By using the app, my knowledge of ecological contexts has improved.
7. By using the app, I feel motivated to more intensively address the sustainability issue in my life.
8. I have been able to expand my long-term sustainability knowledge.