The Effects of Ecological Gamification on Learners' Engagement

Lucas Fellipe dos Santos, Anderson Corrêa de Lima, Amaury Antônio de Castro Junior and Wilk Oliveira

***Abstract*—Personalization of gameful environments such as game-based and gamified learning environments has garnered significant attention in contemporary discourse. Nonetheless, the outcomes remain inconsistent, exhibiting positive, negative, or no effects. At the same time, most of the research has been limited to using traditional gamification strategies (*e.g.*, those involving points, badges, and leaderboards). To tackle this issue, we examined how ecological gamification (*i.e.*, a novelty gamification design strategy based on the gamification elements chance, imposed choice, economy, rarity, and time pressure) influences students' engagement (*i.e.*, focused attention, perceived usability, aesthetic appeal, and reward), according to their gamification profiles (*i.e.*, Philanthropist, Socializer, Free-spirit, Achiever, Player and Disruptor). A quasi-experimental investigation was carried out with 104 participants utilizing a gamified learning platform, with data examined via partial least squares structural equation modeling. Notably, our findings were two-folded revealing that *i)* ecological gamification had a beneficial impact on Disruptors' perception of usability and *ii)* enhanced Players' feelings of being rewarded. Based on the results, we also indicated a series of practical implications and provided various recommendations for future studies. These insights contribute to learning technology and gamified learning, shedding light on the nuanced personalization of gamified educational systems.**

***Index Terms*—Gamification, game-based learning, learning technologies, engagement, quasi-experiment**

I. Introduction

THE process of gamification occurs when services, activities, and systems are transformed to promote motivational benefits similar to those found in games [1], [2]. In the last few years, the use of gamification has stood out in various fields of study, such as health [3], virtual reality [4], and education [5]–[7]. Especially in education, gamification has been widely used to increase learners' concentration, motivation, engagement, and other experiences in different educational contexts [8]–[10].

However, an important part of the studies reported that gamification could also provoke negative effects on learners' experience [11]–[13]. The negative effects of gamification are directly related to the fact that different users (*i.e.*, individuals with diverse preferences), may react differently when using a gamified educational environment [14]–[16]. Facing this problem, in the last few years some studies focused on analyzing how different gamification designs affect users' experience and help to personalize gamification [17]–[19]. However, the results are still mixed (*i.e.*, positive, negative, or null) [20]–[22] and the studies usually focus on analyzing only classic gamification designs (*e.g.*, based on points, badges, and leaderboards) [23]–[25].

To face this challenge, we conducted a quasi-experimental study (thus, privileging a study in a real environment) to understand the effects of ecological gamification (*i.e.*, a novelty type of gamification related to the environment in which gamification is implemented and constituted by the elements rarity, economy, imposed choice, chance, and time pressure [26]) on the learners' engagement (*i.e.*, focused attention, perceived usability, aesthetic appeal, and sense of reward [27], [28]) according to their gamification user type (*i.e.*, achiever, disruptor, free spirit, philanthropist, player, and socializer, based on the Hexad framework [29]). Considering a sample composed of 104 subjects enrolled in a course in a gamified educational system (with a design based on ecological gamification), we use partial least squares structural equation modeling (PLS-SEM) to analyze the effects of ecological gamification on the learners' engagement.

The main results of the study are two-folded indicating that *i)* ecological gamification positively affected Disruptors' sense of perceived usability, and *ii)* positively affected Players' sense of reward, thus, demonstrating that ecological gamification positively affects the engagement of specific user types. Based on the results, we provide some practical implications and propose recommendations for future studies. Our study contributes to learning technology and personalized gamification by demonstrating the effects of ecological gamification types on learners' engagement and providing insights on how to personalize gamified educational systems.

II. Background

In this section, a brief review of the main topics related to this research is presented (*i.e.*, gamification designs in education, with special attention to ecological gamification). We also present and discuss some recent related work.

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The second author is a partner at the company that granted the rights to use the system Eagle-edu free of charge for research purposes in this project. The authors utilized generative artificial intelligence (*i.e.*, Microsoft Copilot) to improve the grammatical quality of the text.

A. Gamified education

Gamification (*i.e.*, the design of systems, services, and activities to provide motivational benefits similar to those games usually create [1], [30]) have been extensively researched in recent years [1]. Therefore, over the years, different gamification designs have been used [1], [14], [23]. The use of different gamification designs in education is associated with the personalization of gamification, which occurs when gamification elements are chosen by designers or the gamified system itself, considering the information provided by users [31]–[33]. Thus, personalized gamification is a possibility to address the shortcomings of the "one-size-fits-all" approach [22], [34], [35].

While many users and contextual information affect gamified experiences, previous research in personalized gamification has focused on a single user feature/dimension [34]. Over the past years, several classifications have been proposed for gamification personalization [36]–[38]. These classifications, commonly implemented as different gamification designs use different gamification elements (individually or together) to affect different human behavior aspects positively [39].

At the same time, a diversity of gamification designs have been proposed and implemented over the years [23]. These gamification designs are usually composed of different gamification elements (also called game elements) [17]. These gamification designs are proposed aiming to create specific experiences (*e.g.*, increasing motivation, creating a social experience, and increasing collaboration between peers) [15], [23], [40]. In education, they are generally used to stimulate specific aspects related to student learning [26], [39].

B. Ecological gamification

A novelty gamification design recently proposed is called "ecological gamification", a type of gamification design related to concepts that serve as properties of the environment [26]. These concepts can be implemented subtly to engage users in following the desired behavior [26], [39]. The elements within this dimension include chance, imposed choice, economy, rarity, and time pressure, which can be represented as properties [26], [39].

The ecological gamification design is related to the environment in which gamification is being implemented [26]. EG consists of five elements [26]: **1: Chance** (also known as randomness, luck, fortune, or probability): This element is related to the randomness of a particular event or outcome. **Imposed choice** (also known as choice, judgment, and paths): In the application of this element, the user must decide to advance in the environment. **Rarity** (also known as collection, limited items, exclusivity): This element is related to the limitation of resources within a gamified environment. **Time pressure**: This element is represented through timers, deadlines, or countdown clocks. The application of this element is related to the use of time itself as a way to limit students' actions; time pressure is considered one of the most irrelevant elements, as it can potentially disengage the student. **Economy** (also known as market, transactions, exchange): The application of this element is related to any "commercial" transaction that may occur in the environment.

This gamification design is related to concepts that act as properties of the environment that can be implemented in a subtle way to engage the users to follow the desired behavior. They can be supported by the elements in the Measurement/Feedback Dimension, to ensure the behavior is followed [39]. However, most of these elements must be designed with care since they can affect the learners' interactions drastically [39]. Regarding this gamification design, it is related to concepts that act as properties of the environment that can be implemented in a subtle way to engage the users to follow the desired behavior [39].

C. Related work

In recent years, a few studies have explored novel gamification designs in education. In this section, we focus on presenting recent works that have contributed to exploring the effects of different gamification designs on learners' experiences.

Different examples of gamification designs and types of studies can be found, for instance, exploring challenge-based gamification (*e.g.*, based on points, levels, challenges, and leaderboards) on the teaching and learning of statistics [7] or also the relationship between gamification user types and various gamification designs to understand how user orientation is linked to preferences and a sense of personal achievement [16].

In these studies, the findings suggested a positive effect on student learning, particularly among female students [7] and revealed patterns of associations that were not consistently comprehensible [16]. Legaki *et al.* [7] investigated the impact of gamification elements such as points, levels, challenges, and leaderboards on student learning. The experiment involved 365 students from Electrical and Computer Engineering and Business Administration programs. Results indicated that challenge-based gamification significantly improved student learning outcomes compared to traditional methods, with a more pronounced effect on female students and those in Electrical and Computer Engineering.

Santos *et al.* [16] examined how different user types, based on the Hexad model, relate to various gamification designs. The study involved 331 participants and used 21 different game elements across five gamification designs to measure preferences and perceived sense of accomplishment. The results suggest that different user types have distinct preferences and responses to various gamification designs, emphasizing the need for personalized gamified systems to enhance user engagement effectively. The study provides recommendations for tailoring gamification elements to match user types and highlights the importance of further research in personalized gamification.

Recent studies also investigated the effects of different gamification designs on students' flow experience, motivation, and engagement [41], [42]. Oliveira *et al.* [41], investigated how gamer types from the BrainHex taxonomy (*i.e.*, Achiever, Conqueror, Daredevil, Mastermind, Seeker, Socializer, and Survivor) moderate the effects of personalized/non-personalized gamification on users' flow experience (*i.e.*, challenge-skill balance, merging of action and awareness, clear goals, feedback, concentration, control, loss of self-consciousness and *autotelic* experience), enjoyment, perception of gamification and motivation, and literacy. In turn, Legaki *et al.* [42] developed a software consisting of interactive charts and tools designed to teach data literacy in four different versions: challenge-based (badges), immersion-based (avatars; story), and social-based (competition) gamification.

In these studies, researchers also identified patterns of characteristics that may contribute to students experiencing a high level of flow [41] and an improvement in student performance [42]. The results of the studies also indicate the effects of gamification on specific experiences, however in none of the cases, was a global effect on the experiences analyzed, regardless of the gamification design implemented in the studies [41], [42]. Table I present the related work.

TABLE I
RELATED WORK'S SUMMARY

Study	**Gamification design**	**Gamification elements**	**Explored outcome**
Legaki *et al.* [7]	Challenge-based gamification	Points, levels, challenges, and leaderboards	Literacy
Santos *et al.* [16]	Performance, Ecological, Social, Personal and Fictional	21 gamification elements organized according to Toda *et al.* [39] Taxonomy	Preference and perceived sense of accomplishment
Legaki *et al.* [42]	Challenge-based gamification	challenge-based, immersion-based, social-based	Learning outcomes
Oliveira *et al.* [41]	BrainHex-based gamification designs	Points, Levels/Stages, Badges, Leaderboards, Prizes and Rewards, Progress bars, Storyline, and Feedback	Flow experience, enjoyment, perception of gamification and motivation

Key: In the study of Santos *et al.* [16], The following elements are part of every gamification design: **Performance**: Point, Progression, Level, Stats and Acknowledgment; **Ecological**: Chance, Imposed Choice, Economy, Rarity and Time Pressure; **Social**: Competition, Cooperation, Reputation, Social Pressure; **Personal**: Sensation, Objective, Puzzle, Novelty, and Renovation; **Fictional**: Narrative, Storytelling.

While these recent studies have advanced the literature by bringing new knowledge to the community regarding the effects of different gamification designs on learners' experience, little is still known about the use of novelty gamification design in engaging learners in real environments according to learners' user types. As far as we know, **our study is the first to investigate the effects of ecological gamification on learners' engagement according to their gamification user types** in a real educational setting.

III. Study Design

This study is designed to understand the effects of ecological gamification on learners' engagement according to their gamification user types. To achieve this objective, we conducted a quasi-experimental study (to favor study in a real environment) using PLS-SEM.

A. Materials and method

We used the gamified educational system Eagle-edu[1] to conduct this study. Eagle-edu is a gamified educational system where 21 gamification elements are available (following the taxonomy proposed by Toda *et al.* [26]) and allows the teacher to enable or disable each of these elements according to their objectives. The system allows gamification elements to be enabled or disabled individually or in groups according to the gamification designs proposed by the taxonomy proposed by Toda *et al.* [26].

The system was chosen because, to the best of our knowledge, it is the only one with these elements, as well as allowing personalization. At the same time, the system being widely used both commercially and in scientific studies *e.g.*, [43]–[45]. The system was provided free of charge for research purposes in this study. The gamified educational system serves as an interactive platform designed to enhance the learning experience through gamification principles, integrating gamification elements into educational activities. In this study, we personalized the system with ecological gamification elements, *i.e.*, the design composed of the elements: chance, imposed choice, economy, rarity, and time pressure.

The element **chance** is displayed on the Learn page. Students have different types of choices to do, *e.g.*, choosing between chests. The element **imposed choice** appears on the Learn page and is represented by the random option offered to the user to increase their prize. At certain (random) times, before starting a mission, the user is informed that if they completes that specific mission without any mistakes. The element **economy** appears on all pages (in the fixed header) and is represented by coins that can be used to make in-game purchases (see the implementation of the Rarity element). The element **rarity** appears on the Store page and is represented as a series of shields. The element *time pressure* is present on the homepage and is represented by a weekly countdown (thus associated with the Competition element). Figure 1 presents examples of the gamification elements used in our study.

The course used in this study was a Logical Reasoning course structured to cater to varying levels of difficulty, ensuring a comprehensive engagement with logical reasoning concepts. The course was divided into three distinct levels: easy, medium, and difficult. Each level comprised four missions, with each mission containing two questions, resulting in a total of 24 questions. The gradual increase in difficulty across these levels aimed to progressively challenge the students,

[1] https://eagle-edu.com.br/

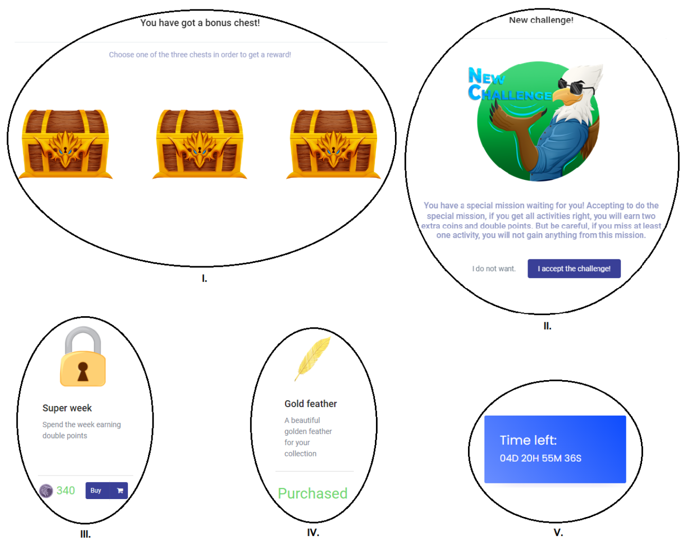

Fig. 1. Ecological gamified elements: I. chance, II. imposed choice, III. economy, IV. rarity, V. time pressure

enhancing their problem-solving skills and logical thinking. By structuring the course in this manner, students were able to build a solid foundation in the easier levels before tackling more complex problems.

The questions utilized in the course were carefully selected from various public service exams, providing a diverse and authentic set of logical challenges. This selection process ensured that the questions were not only relevant and practical but also aligned with real-world applications of logical reasoning. The decision to source questions from public exams added an element of realism and relevance to the course, making the learning experience more meaningful for the students. Moreover, this approach allowed participants to familiarize themselves with the types of questions they might encounter in competitive examinations, thereby enhancing their preparedness and confidence.

To ascertain the gamification user types of the participants, we utilized a metric (*i.e.*, a scale) derived from the Hexad framework [46]. The Hexad scale consists of 24 items, structured on a 7-point Likert scale [47]. Participants were prompted to evaluate the extent to which each item resonated with them, and these items were interspersed throughout the questionnaire to prevent recognition of the elements belonging to the same sub-scale. The Hexad was selected for our investigation as it is a user classification specifically devised for gamification [46], recognized as the most fitting user classification for personalizing gamification experiences [48], and has been effectively implemented in diverse research settings (*e.g.*, [40], [44], [49]–[51]). In this study, we used the Hexad scale in Brazilian Portuguese, which had its psychometric properties analyzed by Santos *et al.* [52], [53].

To identify learners' engagement, the User Engagement Scale (UES) proposed by O'Brien *et al.* [27] was used. The scale comprises 30 questions on a five-point Likert scale [47]. In our study, we employed the Brazilian Portuguese version, whose psychometric properties were analyzed by Miranda *et al.* [28]. Aiming to mitigate threats related to the participants' attention during the study, following the recommendation of Kung *et al.* [54], and stimulated for recent studies in the same field [16], [51], [55], we added an "attention check statement" where we requested a specific response: "This is an attention-check question, if you have read this question, mark option 3".

This work has been organized into four steps: *i)* course creation, *ii)* participants invitation, *iii)* data collection, and *iv)* data analysis. Figure 2 summarize the method.

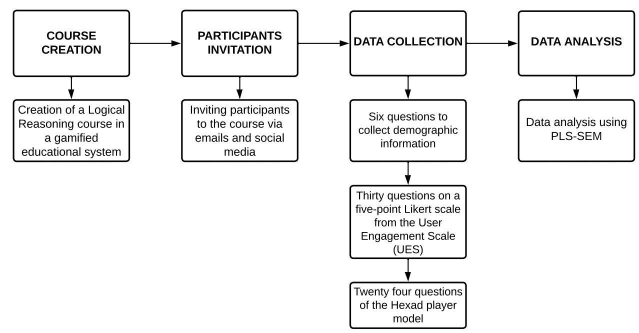

Fig. 2. Study Design

In the *first step*, we created a Logical Reasoning course using the gamified educational system Eagle-edu. This course comprises 24 questions, divided into eight different missions: four missions with a basic difficulty level and four missions with an intermediate difficulty level, each mission containing three questions. The subject of logical reasoning was chosen because it might be a generalist skill required for any learner.

In the *second step*, we invited the participants to the course and subsequent research through emails and social media (aiming to obtain a more demographically varied sample).

In the *third step*, we conducted the data collection through an online form (participants were asked to respond to the UES immediately after using the system). we used six questions to collect demographic information, 30 questions on a five-point Likert scale from the User Engagement Scale (UES), and 24 questions from the Hexad player model.

In the *fourth step*, we analyzed the collected data using the Partial Least Squares Path Modeling (PLS-PM) method, *i.e.*, an SEM method used to estimate cause-effect relationships with latent variables [56].

B. Participants description and data analysis

Initially, we employed the *a-priori* sample size calculation method [57] to guarantee a sample size that allows for the accurate detection of effects. We used the Online Calculator for A-priori Sample Size Calculator for SEM proposed by Soper [58]. This calculator uses formulas proposed by Cohen [57] and Westland [59] to calculate the required sample size to detect effects in a study based on SEM, considering the quantity of observed and latent variables within the model, along with the expected effect size, and the specified probability and levels of statistical power.

To set the correct number of participants for the study, especially, because as far we know, we do not have proper previous literature with similar analyses to use as a base for defining the expected effect size, we used standard values from the literature [57], [59] to define the values, when there are no hypotheses based on previous evidence: *anticipated effect size*: 0.5; *desired statistical power level*: 0.8; and *probability level*: 0.05. In our study, we have 10 latent variables (six Hexad dimensions and four engagement dimensions) and 54 observed variables (*i.e.*, the sum of items from both scales). The result indicated a minimum sample size of 47 participants to detect an effect.

The invitation was released on April 24, 2023, and data collection occurred for 274 days until receiving 107 answers, of which 104 were valid according to our attention-check statement. As we favor a study in a real environment, we chose not to establish other criteria for removing participants. Of these 104 students, 37 identified themselves as female, 65 as male, and 2 preferred not to respond. The average age of the participating students is 31 years old, with a standard deviation of 10.18 and a variance value of 103.68. The respondents participated voluntarily, as we did not offer any remuneration or gifts to them.

Data analysis was carried out using the PLS-SEM technique [60], a method for SEM that allows the estimate of relationships between latent variables [61]. This technique has been widely used in studies in the area as it generates robust results even in complex models and with relatively small samples [62]. In our study, the model tested was composed of six independent variables (*i.e.*, Hexad user types) and four dependent variables (*i.e.*, the four dimensions of engagement).

The data analysis was conducted in the software SmartPLS 4[2], a graphical interface for implementing the PLS-SEM method [62]. The software was used under license Tampere University.

IV. Results

Initially, as PLS-SEM provides a kind of analysis that works in the same way regardless of the distribution of the data, eliminating the need for normality tests [63], we started analyzing the Composite Reliability (CR) to assess the internal consistency of the items used to measure the latent variables. A value of 0.700 or above is generally considered acceptable) [61], [64]. The AVE value of 0.5 or higher is typically considered acceptable, indicating that the indicators adequately measure the latent construct [61], [64], [65]. Table II presents the CR. The results have shown that the internal reliability of the “Free spirits” and “Perceived usability” was below the acceptable threshold, suggesting potentially weaker consistency.

Next, we calculated the Discriminant Validity (DV) [66] to measure whether the concepts that are not supposed to be related are unrelated, thus referring to the ability of a construct to be distinguished from other constructs in the same model. Ideally, the correlation coefficients should be low or non-significant between theoretically unrelated constructs [61], [64], [65]. Since in our study, the intention is not to propose a model but rather to analyze the relationships between variables, this calculation will have a more observational character. Table III presents the DV results.

[2]https://www.smartpls.com/

TABLE II
COMPOSITE RELIABILITY

	α	**RHO A**	**RHO C**	**AVE**
Achiever	0.723	0.810	0.825	0.547
Aesthetic appeal	0.901	0.994	0.923	0.707
Disruptor	0.738	0.406	0.765	0.468
Focused attention	0.918	0.936	0.933	0.667
Free spirit	0.617	0.656	0.774	0.468
Perceived usability	0.668	0.755	0.778	0.343
Philanthropist	0.890	0.932	0.923	0.750
Player	0.759	0.800	0.840	0.567
Reward	0.842	0.914	0.886	0.489
Socialiser	0.821	0.031	0.705	0.437

Key: α: Cronbach’s; RHO A: Jöreskog’s Rho; RHO C: Cronbach’s Rho C; AVE: Average Variance Extracted.

TABLE III
DISCRIMINANT VALIDITY (COMPLETE BOOTSTRAPPING, SAMPLE=5000)

	A	**AE**	**D**	**FA**	**F**	**PU**	**P**	**R**	**RW**
AE	0.203								
D	0.429	0.105							
FA	0.132	0.662	0.138						
F	1.001	0.248	0.534	0.350					
PU	0.571	0.337	0.267	0.332	0.591				
P	0.240	0.113	0.213	0.133	0.373	0.273			
R	0.774	0.134	0.421	0.128	0.840	0.304	0.174		
RW	0.229	0.794	0.153	0.851	0.317	0.458	0.122	0.202	
S	0.209	0.121	0.156	0.122	0.469	0.201	0.760	0.208	0.120

Key: A: Achiever; AE: Aesthetic appeal; D: Disruptor; FA: Focused Attention; F: Free Spirit; PU: Perceived Usability; P: Philanthropists; R: Player; RW: Reward; S: Socialiser.

Finally, we conducted analyses to model the effects of ecological gamification on learners’ engagement according to their gamification user types, as well as the internal predictive power (*i.e.*, the ability of a model to predict the observed variables within the model) based on R^2 values. It is not part of our study to investigate the predictive power of the model, therefore, the R^2 values reported are purely descriptive. Table IV presents the path coefficients and Table V present the internal predictive power.

While our study identified both positive and negative relationships between user type and different dimensions of engagement, suggesting that ecological gamification affects gamification user types differently, two statistically significant relationships were identified: **ecological gamification positively affected Disruptors’ sense of perceived usability** (β= 0.288 | p = 0.034), and **positively affected Players’ sense of reward** (β= 0.322 | p = 0.030).

A. Discussion

The objective of this study was to investigate the effects of ecological gamification design on learner engagement based on their gamification user type. The results indicate different positive and negative associations between the independent and dependent variables.

The positive effect on Disruptors’ sense of perceived usability can be attributed to the alignment of ecological

TABLE IV
PATH COEFFICIENTS

	β	M	SD	p	CI (BC) 2.5%	CI (BC) 97.5%
A → AE	-0.262	-0.207	0.148	0.077	-0.577	-0.032
A → FA	-0.188	-0.120	0.162	0.248	-0.579	0.057
A → PU	-0.276	-0.329	0.148	0.063	-0.489	0.155
A → RW	-0.242	-0.167	0.174	0.164	-0.635	0.021
D → AE	-0.042	-0.040	0.156	0.787	-0.329	0.255
D → FA	0.103	0.099	0.157	0.512	-0.250	0.373
D → PU	0.289	0.245	0.136	**0.034**	-0.009	0.476
D → RW	-0.033	-0.006	0.155	0.830	-0.333	0.247
F → AE	-0.063	-0.032	0.300	0.835	-0.459	0.509
F → FA	0.062	0.028	0.387	0.873	-0.546	0.652
F → PU	-0.325	-0.232	0.196	0.097	-0.797	-0.023
F → RW	0.015	0.007	0.339	0.964	-0.526	0.536
F → AE	-0.031	-0.084	0.155	0.844	-0.252	0.378
F → FA	-0.040	-0.165	0.160	0.803	-0.230	0.473
F → PU	0.022	-0.120	0.161	0.891	-0.162	0.447
F → RW	-0.105	-0.140	0.148	0.479	-0.342	0.262
R → AE	0.285	0.224	0.171	0.096	-0.061	0.556
R → FA	0.136	0.102	0.161	0.398	-0.170	0.448
R → PU	0.072	0.026	0.127	0.569	-0.119	0.397
R → RW	0.315	0.263	0.149	**0.034**	0.029	0.543
S → AE	-0.008	0.003	0.170	0.961	-0.331	0.313
S → FA	-0.054	0.065	0.220	0.805	-0.500	0.294
S → PU	-0.087	0.092	0.184	0.637	-0.516	0.127
S → RW	0.082	0.091	0.165	0.618	-0.253	0.393

Key: Bold values are significant associations; β: Regression Coefficient; SD: standard deviation; CI (BC): Confidence interval (bias-corrected); A: Achiever; AE: Aesthetic appeal; D: Disruptor; FA: Focused Attention; F: Free Spirit; PU: Perceived Usability; P: Philanthropists; R: Player; RW: Reward; S: Socialiser.

TABLE V
INTERNAL PREDICTIVE POWER (FOR ENGAGEMENT)

	R^2	Adjusted R^2
Aesthetic appeal	0.078	0.021
Focused attention	0.051	-0.008
Perceived usability	0.321	0.279
Reward	0.074	0.016

gamification elements with Disruptors' intrinsic motivations. Disruptors, according to the Hexad user type framework, are motivated by the desire for novelty, exploration, and the breakdown of norms within a system [29], [31]. Ecological gamification, with its emphasis on elements such as rarity, chance, and imposed choice, inherently introduces variability and unpredictability into the learning environment [39]. This aligns well with Disruptors' preference for dynamic and non-linear experiences, thus enhancing their perception of usability. When Disruptors encounter a gamified system that continuously presents new challenges and unexpected outcomes, their engagement and sense of control over the learning environment can be heightened, leading to an improved usability perception.

At the same time, the positive influence of ecological gamification on Disruptors' sense of perceived usability may be directly related to the fact that Disruptors are individuals motivated by a desire for novelty and unpredictability in their gaming experiences [16], [29], [67]. Thus, the incorporation of elements like rarity and chance aligns with the Disruptors' preferences and may enhance their engagement and perception of usability.

The positive impact on Players' sense of reward can be linked to the structured nature of ecological gamification. Players, another category within the Hexad framework, are motivated by rewards, achievements, and the opportunity to gain tangible benefits from their interactions [16], [29], [67]. Ecological gamification incorporates elements like economy and time pressure, which can create a structured pathway for players to earn rewards through strategic decisions and efficient resource management. The sense of achievement derived from successfully navigating these elements and receiving immediate feedback can align with Players' need for tangible recognition, thus enhancing their overall sense of reward.

Furthermore, the positive impact on Players' sense of reward is a significant outcome, indicating that the ecological gamification elements employed in our study effectively contributed to a more rewarding learning experience. The sense of reward is a crucial factor in sustaining learner motivation and participation [7], [65]. Incorporating economy-related elements within ecological gamification, such as managing resources efficiently or making strategic choices under imposed constraints, may have contributed to this positive outcome. These findings suggest that tailoring gamification designs to user types can indeed yield positive outcomes, supporting the argument for personalized approaches in educational technologies.

Moreover, the design of ecological gamification inherently involves strategic challenges and goal-oriented tasks, which are crucial components in fostering a sense of reward among Players. The economic elements and imposed choices create a scenario where learners must plan, make decisions, and anticipate outcomes, providing a clear structure for accomplishment and reward. This aligns with psychological theories of motivation, such as self-determination theory [68], which posits that competence and achievement are fundamental to intrinsic motivation and satisfaction.

The mixed results in the broader gamification literature may be attributed to a lack of personalization in previous approaches, mainly focusing on classic gamification designs like points, badges, and leaderboards. Our study, by exploring the impact of ecological gamification tailored to individual user types, contributes valuable insights to the field of personalized gamification.

Finally, by understanding the user types within the Hexad framework and aligning gamification strategies accordingly, educators can enhance both perceived usability and the sense of reward for learners. Additionally, the incorporation of ecological gamification elements can provide a more holistic and engaging learning environment, especially for disruptors and players.

B. Threats to validity and limitations

Our quasi-experimental study encountered threats of validity and limitations inherent to characteristics of the study that should be considered in the interpretation of the findings. Initially, since this is a quasi-experimental study, participants were not randomly assigned to groups, which could lead to selection bias. The characteristics of those who opted into the study might systematically differ from those who did not participate. This can affect the generalizability of the findings and make it difficult to attribute observed effects solely to the ecological gamification intervention.

While the p-value indicated a significant result in one of the results (*i.e.*, ecological gamification positively affected Disruptors' sense of perceived usability), the confidence interval includes zero, indicating that zero is a plausible value for the parameter, suggesting that there might be no effect. Therefore, this result needs to be interpreted with caution. Even using a scale that had its psychometric properties previously analyzed, participants' self-reported data can be influenced by social desirability bias or misinterpretation of scale items. At the same time, some dimensions did not reach a higher internal reliability, thus, imitating the results interpretation. Also, the study was conducted within a specific educational context focused on logical reasoning. Consequently, the external validity of the findings may be limited when generalizing to diverse educational domains or settings.

Considering that there was no control over where and for how long each user used the system, the actual effects of the gamification design used in the study and participant engagement may have been impacted by these factors. Also, participants' responses might change over the course of the study due to factors unrelated to the intervention, such as fatigue or increased familiarity with the platform. These changes can confound the results, making it harder to isolate the effects of ecological gamification.

While our study explores user orientations using the Hexad framework, it is crucial to acknowledge that gamification can manifest in various forms beyond the identified Hexad categories. Engagement was measured immediately after exposure to the gamified system, the effects observed may be transient and not indicative of sustained engagement over time. Finally, causal claims are weakened, and alternative explanations for observed associations cannot be fully ruled out.

C. Practical implications

Our study contributes to the growing body of literature on gamification and user engagement by exploring the differential effects of ecological gamification on distinct user types. The identification of significant relationships underscores the relevance of tailoring gamification strategies to align with users' diverse preferences and characteristics. Practically, these findings may inform the design and implementation of gamified systems aimed at promoting engagement and user satisfaction.

The beneficial impact of ecological gamification on Disruptors' perception of usability suggests that designing gamified systems tailored to specific user profiles can enhance their user experience. At the same time, the finding that ecological gamification enhances Players' feelings of being rewarded indicates the importance of well-designed reward mechanisms in educational platforms. Thus, educators and developers can incorporate specific gamification elements that resonate more with Disruptors to improve their perception of usability and Players' to improve their sense of reward.

By understanding how different gamification profiles respond to ecological gamification, educators and designers can develop more effective engagement strategies. Thus, based on our results, educators and designers can create different pathways or options within the same platform that cater to various profiles (*e.g.*, Disruptors, Players), thereby providing a more personalized learning experience.

The positive impact on Disruptors' usability perceptions suggests that ecological gamification elements may make platforms more intuitive and user-friendly for certain types of users. This insight can guide the design of interfaces and interactions that reduce friction and enhance the user experience for those who thrive on innovation and change. Thus, educational institutions and platform developers can allocate resources more strategically by focusing on gamification elements that yield the most significant engagement benefits for their target user profiles.

In summary, our study contributes valuable insights into the nuanced dynamics between ecological gamification and user engagement across different user types. By shedding light on the differential effects of gamification strategies, we pave the way for more targeted and effective approaches to enhancing user engagement in various contexts.

D. Recommendations for future studies

Based on the results obtained in our study, as well as the threats to the validity and limitations of our study, it is possible to propose new studies in the field of personalized gamification. Initially, our study focused on the effects of ecological gamification on learners' engagement. Thus, we believe that **future studies should be conducted with different gamified designs (*e.g.*, social gamification)**.

Also, in our study, we chose to conduct a quasi-experimental study, thus favoring the study in an environment that is closest to reality. Therefore, **we recommend that future studies replicate our analyses in a controlled environment**, also **including new dependent variables in addition to engagement**.

In our study, we specifically analyzed a single gamification design (among a range of designs that can be used). Thus, we recommend conducting future studies comparing ecological gamification with other gamification strategies to determine its relative effectiveness. This can help identify which strategies work best for different user profiles and educational settings.

Our study, while ensuring data collection in a real environment, was conducted in a short space of time. Thus, **we recommend future research to conduct longitudinal studies to examine the long-term effects of ecological gamification on user engagement and usability**. This can help determine whether the observed benefits are sustained over time or if they diminish with prolonged use.

Additionally, we recommend **expanding the scope of dependent variables beyond engagement** to capture a broader range of outcomes, such as learning performance, motivation, and satisfaction. By doing so, future studies can provide a more comprehensive understanding of the impact of personalized gamification on learners' experiences and outcomes.

V. Concluding Remarks

In this study, we investigated the effects of ecological gamification on learners' engagement according to their gamification user types. The results significantly contribute to understanding how ecological gamification can be used to personalize gamification. The outcomes of these investigations may enhance gamified educational frameworks, systems, and guidelines, effectively benefiting classrooms and gamified digital environments. In future studies, we aim to extend this research through experimental studies to investigate the effects of different gamification types on learners' experiences and to provide practical recommendations to personalize gamified education.

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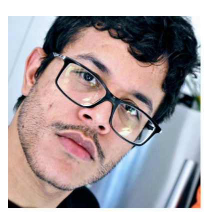

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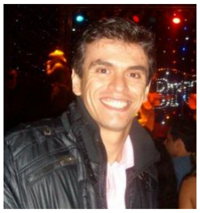

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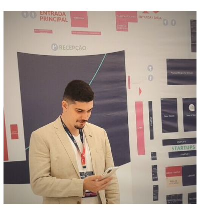

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