Game On: A Pilot Study of a Gamified Digital Learning Platform and Protocol

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Abstract

Gamification use in educational contexts impacts learning performance, engagement, motivation, cognition, and emotions. However, limited theoretical support, heterogeneous results, and lack of objective measures or validated questionnaires hinder gamification research. Via descriptive statistics and qualitative analysis, this pilot study aimed to assess the usability and functionality of the gamified digital learning platform, validate the study protocol through platform usage, gauge the presence of promising evidence regarding its effectiveness, and gain insights into hypotheses. A digital course was nested within different versions of a gamified digital learning platform with embedded game elements alongside a version without game elements. Eight students completed the course (6 participated in the embedded versions and 2 participated in the version without game elements), watching video lectures and doing exercises, while we measured affective states, motivation, user experience, and feedback through questionnaires. Furthermore, we assessed learning performance by analyzing the exercises and gathered webcam-based eye-tracking and facial emotion recognition data to gauge student attention and emotional states. Participants adeptly executed the established protocol, and the gamified digital learning platform (coupled with both webcam applications for eye-tracking and facial emotion recognition) functioned properly, capturing all requisite data. Due to the small sample size and limited statistical power in this pilot study, the other results across all measurements were further discussed to derive insights, formulate hypotheses, and identify potential enhancements for the forthcoming randomized control trial, which will involve a larger sample size. Our results will allow us to refine the experimental design to further evaluate the influence of gamification in a digital learning setting and thoroughly investigate, via scientific inquiry, how it can significantly enrich the field of education. Moreover, the platform's potential for controlled experimental research augments its usefulness for diverse other studies, delving into the impact of game elements on educational outcomes.

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Keywords

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1 Introduction

Gamification, defined as integrating game elements into non-gaming contexts [6], has been applied to enhance learning and cognition, through attention, emotion, motivation, engagement, and academic performance [11, 12, 18, 36]. In the fields of human-computer interaction (HCI) and user experience (UX), gamification influences the development, evaluation, and experience of interactive systems [8]. However, gamification research encounters challenges, including insufficient theoretical support, diverse combinations of game elements, heterogeneous findings, and a lack of objective metrics and validated questionnaires [14, 15, 27, 29, 31, 35, 38]. To address these gaps, we established a study protocol and designed a gamified digital learning platform for a future randomized control trial (RCT). This RCT builds upon the gamified learning theory, employing isolated game elements to evoke specific psychological and behavioral states [10, 11]. Additionally, it explores the cognitive load theory, examining the impact of extraneous cognitive load on mental resources during digital learning [28]. Also, the study employs objective measurements and validated questionnaires to assess outcomes.

Feasibility and pilot studies are crucial to increase the quality of evidence-based research. Feasibility and pilot studies aid in developing and evaluating implementation strategies by addressing design uncertainties, methodological approaches, and potential impacts

[20]. While smaller in scale, they should adhere to high methodological standards similar to larger trials, wielding considerable influence in guiding future research trajectories, and furnishing essential insights for the planning of subsequent studies [9, 17, 33]. The primary aim of a pilot study is to evaluate viability rather than statistical significance [33]. A meticulously executed pilot study not only optimizes resource utilization but also upholds ethical principles by informing critical methodological choices through data-driven analysis [9]. Consequently, the findings from these studies refine research priorities and assess the viability and acceptability of methodologies for broader implementation in larger-scale investigations [30].

In a previous preliminary feasibility study [4], an initial protocol was evaluated and enhanced, highlighting the necessity for creating a new digital platform. This process led to the development of a novel gamified digital learning platform. Thus, here, we aim to assess an improved intervention protocol and test the developed gamified digital learning platform, which is crucial for the upcoming RCT. Said that the objective of this pilot study is to: 1) assess the usability and functionality of the gamified digital learning platform; 2) validate the incremented study protocol through platform usage; 3) gauge the presence of promising evidence regarding the gamified digital learning platform and protocol effectiveness; and 4) gain insights into the hypothesis for a future RCT study with a statistically robust sample.

2 Material and Methods

We adopted an experimental between-subject pilot RCT design with four different intervention groups (IG) and one control group (CG) to evaluate and improve the practicability of a future RCT protocol. The learning performance, attention, emotions, motivation, and UX were assessed with questionnaires and a webcam to unravel the impact of game elements on these outcomes.

We set up a digital course about autism spectrum disorder (ASD) within a gamified digital learning platform, which was adapted to four different versions containing different embedded game elements representing the IG (IGPoints: "points," IGChallenges: "challenges," IGBadges: "badges," and IGAll: "points + challenges + badges") and one version without embedded game elements, representing the CG. These game elements ("points", "challenges" and "badges") were chosen because they are both the most used and the most controversial in the literature concerning learning processes, since, together with other elements, they present positive, mixed, and negative results [15]. Thus, we aimed to examine the impact of individual game elements on outcomes by comparing them to a group where all elements were present together and a group with no game elements.

2.1 Research Questions

This pilot study aims to: 1) assess the usability and functionality of the gamified digital learning platform; 2) validate the incremented study protocol through platform usage; 3) gauge the presence of promising evidence regarding the gamified digital learning platform and protocol effectiveness; and 4) gain insights into the hypothesis for a future RCT study with a statistically robust sample.

2.2 Sample

We recruited eight students (one man and seven women) from health-related post-graduate courses at the local University. The participants' ages ranged from 26 to 44 years old (mean=32.6; SD=6.6). The participants were randomly divided by drawing lots into five groups (IGPoints n=2; IGChallenges n=1; IGBadges n=1; IGAll n=2; CG n=2). We used a convenience sample, and the students participated voluntarily in this experiment. To prevent bias, the participants were not informed about their group allocations. This study received approval from the local Ethics Committee, and all the participants signed an informed consent form before the study.

2.3 Instruments

2.3.1 Learning (Pre- and Post-test). Learning performance (LP) was measured with one assessment test with five multiple-choice questions concerning the content exposed (a 16-minute video lecture about ASD) before and after the course (pre- and post-test). Feedback about the correct answers was given only during the post-test to avoid bias.

2.3.2 Cognition and Attention (Eye-tracking). We chose to measure attention using eye-tracking technology. By measuring visual attention on interfaces, we aim to verify the allocation of attentional focus on different parts of the screen [1]. We used the Webgazer (v 3.1.2) eye-tracking system [19] during the video lecture and the learning performance post-test.

2.3.3 Emotions (Pre- and Post-test and Facial Emotion Recognition). We used the Self-Assessment Manikin (SAM) test [32] as a subjective measure of arousal and valence and the facial emotion recognition software Morphcast, which measures emotions of anger, disgust, fear, happiness, sadness, surprise, and neutral [7]. We aimed to compare both measurements. The SAM was used pre- and post-test (10-point Likert scale) and the Morphcast was used during the video lecture and the learning performance post-test.

2.3.4 Motivation (Pre- and Post-test). We chose to measure motivation through a questionnaire based on the Self-Determination Theory (SDT) [26] and validated for the Portuguese population, the Post-Experimental Intrinsic Motivation Inventory (PEIMI) questionnaire [16], consisting of six subscales (10-point Likert scale each). The questionnaire was used in pre- and post-tests.

2.3.5 User Experience and Human-Computer Interaction (Post-test). To collect data about the course experience and the system interfaces and usability, we used the User Experience Questionnaire (UEQ) (7-point Likert scale), validated for the Portuguese population [5]. In addition, we used two open questions at the end of the questionnaire to gather the participants' feedback concerning their thoughts on the course and the gamified digital learning platform.

2.4 Research Protocol

Participants answered a sociodemographic questionnaire (SQ) and the pre-tests previously described, i.e., five multiple-choice questions about the course subject (LP), the SAM test, and the PEIMI questionnaire. Then, they watched a 16-minute video lecture and answered the post-test LP, containing the same five multiple-choice

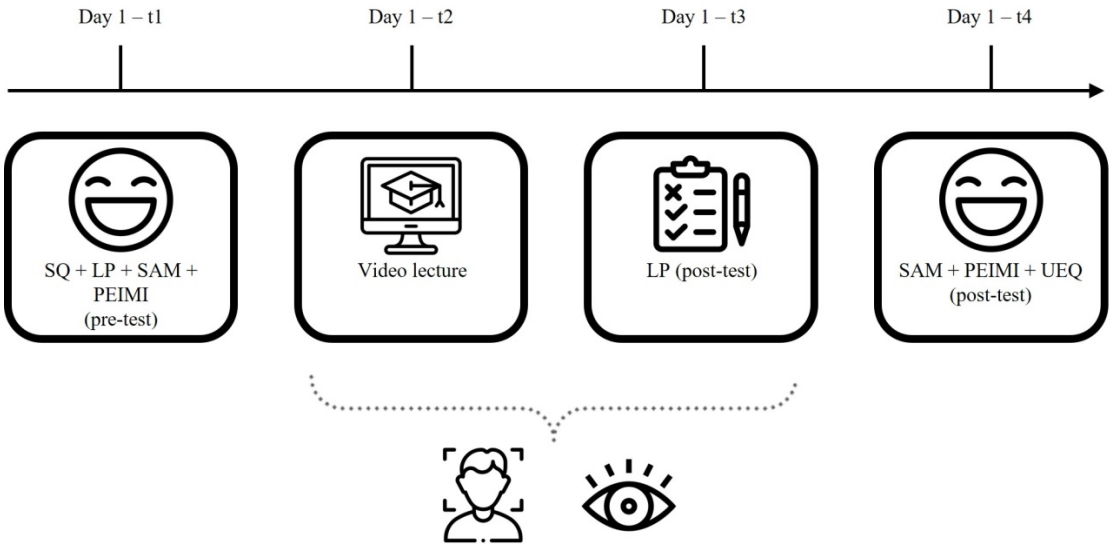

Figure 1: Research protocol

questions, but embedded in the gamified digital learning platform. The viewing of the course occurred in a dimly lit computer lab with few distractors, at the local University. All participants viewed the course in tandem, but on different individual computers, interacting with distinct versions of the gamified digital learning platform. During the interaction with the gamified digital learning platform, i.e., course viewing and questions, the eye-tracking and facial emotion recognition applications collected data via webcam. Finally, the participants answered all the other previously described post-tests, i.e., the SAM test, the PEIMI questionnaire, and the UEQ with two open questions. Figure 1 illustrates the protocol.

2.4.1 Gamified Digital Learning Platform. We developed a gamified digital learning platform primarily rooted in the gamified learning theory [10, 11], YUP Academy, to run our experiment embedded in a controlled environment. The platform was created to establish an adaptable educational system integrating gamification. Its development aimed to meticulously assess the impact of different game elements on cognition, emotion, motivation, and learning. By exerting precise control over variables, triggers, game elements, and outcomes the platform facilitated a scientifically rigorous conduction of the experiment. Developed with Unity engine, WebGL, and C#, along with React application and Javascript for the front-end, and Aspnet Core for the back end, the platform ensured comprehensive functionality and robust performance. PostgreSQL served as the database infrastructure. Additionally, to gather objective metrics of attention and emotion, the eye-tracking (Webgazer 3.1.2) [19] and facial emotion recognition (Mphtools 1.0 and Morphcast 1.16 v1.3) [7] applications were plugged into the platform.

For this study, we developed five varied versions of the gamified digital learning platform, each featuring the course content, including video lectures and exercises. For the "points" and "badges" versions, an interface with some visual components displayed the accrued points or badges. For the "challenges" version, there were several additional visual components, allowing users to view completed challenges and details about upcoming ones. In the version incorporating all game elements, users had access to all available interfaces. In the version devoid of any game elements, the platform solely presented the course itself.

The gamification design process involved controlling variables through a digital system to stimulate the participants to present more desirable behavior [3], e.g., to exert effort in providing a correct answer to an exercise rather than guessing, as mistakes resulted in fewer or no rewards. Thus, the behaviors that were stimulated and received feedback within the system (points, badges, or completion of challenges) included: 1) starting the course; 2) watching the lecture video; 3) correctly answering the proposed exercises with the fewest possible attempts; and 4) completing the course.

2.5 Data Analysis

We used descriptive statistics and qualitative analyses to interpret data. As IGPoints, IGAll, and CG had two people per group, we considered the mean for the data analysis. IGChallenges and IGBadges had one person each. Therefore, the data from the latter represents data from a single participant. Larger samples will afford to test the significance of our findings. This pilot study aims to validate the protocol, raise insights, and evaluate if there is promising evidence regarding its effectiveness.

3 Results

Below we can find the results related to the Gamified Digital Learning Platform, and Protocol Adequacy, together with Learning, Cognition and Attention, Emotions, and Motivation (illustrated in Table 1), and User Experience (shown in Table 2). Because of the limited

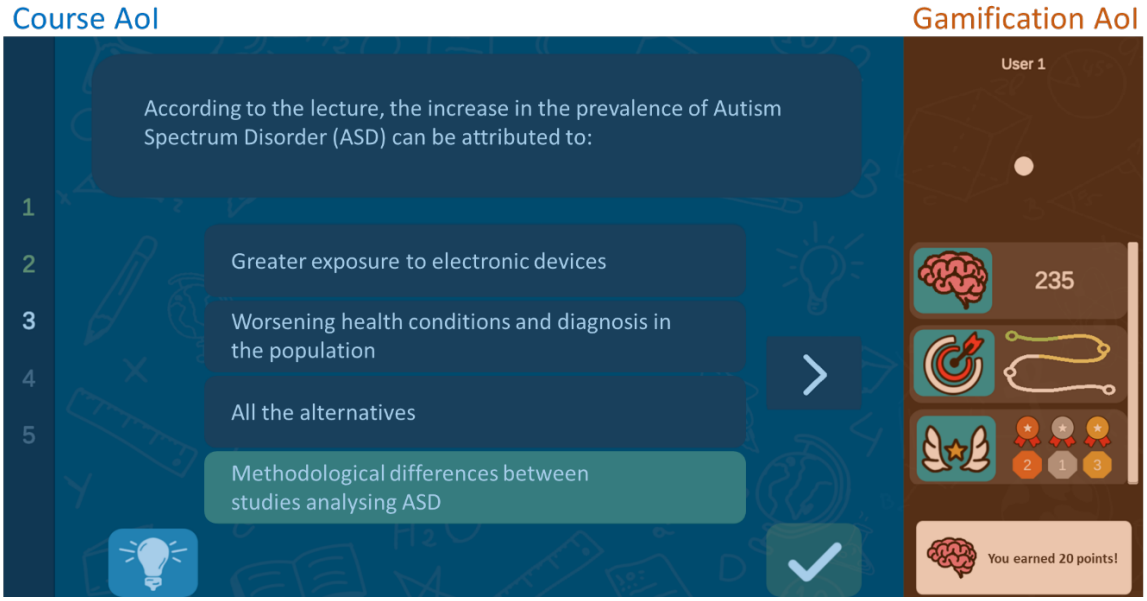

Figure 2: Multiple-choice questions interface and AoI divisions

sample size, all the data was subjected to descriptive statistical analysis, but not inferential.

3.1 Gamified Digital Learning Platform, and Protocol Adequacy

All participants provided informed consent, completed the SQ and pretest, engaged with the course content, answered the exercises, and responded to the posttest within an hour. The gamified digital learning platform, along with both webcam applications (eye-tracking and facial emotion recognition), functioned properly, capturing all necessary data accurately.

3.2 Learning (Pre- and Post-test)

As shown in Table 1, the variation from pre- to post-test showed a greater amplitude for the CG (3.5), followed by IGPoints (3).

3.3 Cognition and Attention (Eye-tracking)

We considered the number of gaze points from the Webgazer, i.e., how many times it captured the participants paying attention to one of two different areas of the screen during the course. Screens were divided into two Areas of Interest (AoI): the course AoI, and the gamification AoI (Figure 2). As shown in Table 1, the total gaze points were higher for IGBadges (39671), followed by IGPoints (37540).

We also calculated an index (gamification gaze points/course screen gaze points) to assess the ratio between them. A higher index reflects more visual attention directed to the gamification AoI than to the course AoI. Table 1 shows that the index value was higher for IGChallenges (32.13%).

3.4 Emotions (Pre- and Post-test and Facial Emotion Recognition)

As shown in Table 1, the arousal value increased the most for the IGAll (1.5). The CG was the only group that showed a decrease in arousal (-2.5). Regarding valence value, it became more positive for CG (2.5), followed by IGAll (1.5).

Table 1 reveals that IGChallenges showed diverse emotional responses, with the highest percentages in anger (19.4%), fear (10.2%), and happiness (9.7%). IGBadges had peak values in neutral (47%) and sadness (36.1%). IGPoint exhibited the highest values in disgust (9.8%). Conversely, CG had the highest surprise (14.6%) but the lowest sadness (7.4%).

3.5 Motivation (Pre- and Post-test)

Table 1 illustrates that IGBadges alone diminished Interest/Enjoyment (-0.14). However, CG excelled in Perceived Competence (1.42) and Value/Utility (1.07). It is worth noting that IGChallenges exerted the most positive influence on Interest/Enjoyment (1.86) and Perceived Choice (2.14), while IGAll reduced all PEIMI scales, barring Interest/Enjoyment (0.21).

3.6 User Experience and Human-Computer Interaction (Post-test)

As shown in Table 2, the UEQ final mean of the scales was higher for IGChallenge (4.19), followed by IGAll (4.13), CG (4.06), IGPoints (3.96), and IGBadges (3.92).

Regarding the open questions, participants from all groups expressed satisfaction with the system, emphasizing its efficiency, interest, quality, objectivity, simplicity, user-friendliness, and thoughtful design.

Table 1: Results for Learning, Cognition and Attention, Emotions and Motivation

		CG	IGPoints	IGChallenges	IGBadges	IGAll
Learning	Performance	3.5	3	2	1	2.5
Cognition and Attention (eye-tracking)	Course Screen Gaze Points	35660	34253	19050	38588	29347
	Gamification Screen Gaze Points	968	3287	6121	1083	1285
	Total Screen Gaze Points	36628	37540	25171	39671	30632
	Index	2.71%	9.59%	32.13%	2.81%	4.38%
Emotions (SAM)	Arousal	-2.5	0	0	0	1.5
	Valence	2.5	0.5	0	0	1.5
Emotions (facial emotion recognition)	Anger	19.2%	13.0%	19.4%	6.3%	17.5%
	Disgust	6.9%	9.8%	9.6%	1.3%	8.4%
	Fear	6.3%	7.4%	10.2%	1.5%	9.3%
	Happiness	8.6%	5.2%	9.7%	2.9%	7.5%
	Neutral	36.9%	37.1%	22.8%	47.0%	28.0%
	Sadness	7.4%	21.5%	19.3%	36.1%	20.0%
	Surprise	14.6%	5.9%	9.1%	4.9%	9.4%
Motivation (IMI)	Interest/Enjoyment	1.21	0.57	1.86	-0.14	0.21
	Perceived Competence	1.42	1.33	1.00	1.33	-0.33
	Effort/Importance	-0.60	-0.30	-1.80	-0.80	-1.10
	Pressure/Tension	-1.40	-0.20	-2.40	-1.20	-0.10
	Perceived Choice	0.07	0.21	2.14	0.29	-0.64
	Value/Utility	1.07	0.29	0.43	0.43	-0.29

4 Discussion

This pioneering RCT protocol investigates gamification's impact on cognitive, emotional, motivational, and learning outcomes based on the gamified learning theory [10, 11]. The pilot study successfully achieved its primary goal, wherein participants adeptly executed the established protocol, and demonstrated the functionality of the gamified digital learning platform with eye-tracking and facial emotion recognition applications. The protocol is feasible, and the gamified digital learning platform exhibits promise for conducting experimental research on gamification in educational settings under controlled conditions. However, due to the small sample size in the pilot study, the gathered data lacked statistical power. The insights and hypotheses presented below, derived from this pilot study, will direct a subsequent RCT with a statistically robust sample.

First, learning outcomes were high for the CG, contradicting literature proposing improved outcomes with gamified digital learning [2]. However, the course duration was brief, and for short gamified sessions, information retention is comparable between gamified and non-gamified interventions, as information remains fresh in the memory of both groups after the activity [38]. Yet, as suggested by the authors, for longer sessions, gamified interventions may exhibit a more pronounced impact. Considering the importance of program length, our hypothesis for a future RCT with an extended course and robust sample posits that all IGs will surpass CG learning outcomes.

Concerning visual attention, it was high for IGBadges and IGPoints and low for IGAll and IGChallenges, compared to CG. Fewer visual components were used for "points" and "badges" compared to "challenge" in the gamified digital learning platform, suggesting higher user attractiveness for game elements with fewer components (IGPoints and IGBadges) than those with more (IGChallenges and IGAll). This user preference may be linked to cognitive load, where excessive visual components can diminish cognitive resources [28]. Accordingly, our hypothesis for the future RCT posits that game elements with more visual components will elevate cognitive load, detrimentally affecting visual attention.

Only the CG showed reduced arousal yet increased positive valence pre- to post-test, suggesting that gamification elevated excitement without necessarily enhancing positive emotions. Notably, facial emotion recognition revealed the CG's lowest sadness score and highest surprise score. These results suggest that gamification may be linked to heightened excitement and arousal but not necessarily positive affects, aligning with literature on gamification evoking both positive and negative emotions [18]. In the future RCT, we hypothesize heightened arousal across all IGs, though not necessarily a greater positive valence or positive emotional response. Also, the literature suggests varied emotion patterns in learning moments, with positive emotions scoring before and negative emotions during the activity [37]. Therefore, we hypothesize differing emotional variations between groups at the course's start and end.

Regarding motivation, IGBadges decreased Interest/Enjoyment, while CG excelled in Perceived Competence and Value/Utility. The

Table 2: User Experience results

	CG	IGPoints	IGChallenges	IGBadges	IGAll
Pleasant	6	7	7	5	6.5
Understandable	7	7	7	6	6.5
Creative	5	2	7	4	2
Easy to learn	1	1	1	1	1
Valuable	1.5	1	1	2	2.5
Exciting	5.5	6.5	7	5	5
Interesting	6.5	7	7	6	6
Predictable	6	5	4	7	4
Fast	2	1.5	1	1	4
Original	5	3	4	6	3
Conductor	6	6.5	7	6	6
Good	1.5	1	1	2	1.5
Easy	7	7	7	6	7
Attractive	6.5	7	7	5	6
Original	3	6	7	2	6.5
Convenient	7	7	7	6	7
Safe	1	1	1	1	1.5
Motivating	1.5	1	1	3	2
It meets expectations	2	2	1	2	3
Efficient	6.5	7	7	6	6
Evident	1	1	1	1	2.5
Practical	7	7	7	7	6
Organized	1	1	1	1	2
Attractive	2.5	2	3	4	2
Sympathetic	1.5	1	1	2	1.5
Innovative	5	4.5	4	5	6.5
Final Mean	4.06	3.96	4.19	3.92	4.13

IGChallenges had the highest positive impact on Interest/Enjoyment and Perceived Choice, and IGAll decreased PEIMI scales, except Interest/Enjoyment. These mixed motivational outcomes may be influenced by individual traits, as personal and contextual factors may impact motivation [25]. Literature suggests gamification's influence varies with moderating factors like gender, age, gaming habits, and player traits [21, 22, 24, 34]. Thus, we hypothesize that in the future RCT, interventions' impact on motivation may be moderated by gender, age, gaming habits, and player traits.

In assessing UX, groups with more visual elements (IGChallenges and IGAll) had the highest final means (4.19 and 4.13), while CG fell in the middle (4.06). Conversely, groups with fewer visual components (IGPoints and IGBadges) recorded lower final means (3.96 and 3.92). Thus, it seems like richer gamified interfaces are more effective for a compelling user experience [23]. Despite varied visuals, the system universally satisfied all groups in open-ended responses. In a future RCT, we hypothesize that the combined presence of all game elements and "challenges" will result in a higher overall UX rating. "Points" and "badges" might yield similar scores to the CG, potentially having a less significant impact on UX due to fewer visual components.

5 Limitations and suggestions for future research

Primarily, it is important to emphasize that this pilot study was limited by its small sample size, which restricted the inferential analyses. Nevertheless, as previously addressed in the discussion section, these results were used as data to formulate hypotheses for the future RCT, which will contemplate a larger sample for statistical analysis, and to generate insights to increment the protocol and the gamified digital learning platform. Hence, in alignment with the previously outlined hypotheses, the enhancements to the protocol or the gamified digital learning platform for the future RCT are delineated below, serving as recommendations for forthcoming research.

Based on the learning discussion, we propose extending the educational program with more content and assessments. Concerning visual attention, we suggest adding the cognitive load scale as an additional measurement instrument [13, 39]. Regarding emotions, we plan to segment emotional data throughout the course, assessing fluctuations at the start and end. Regarding motivation, the protocol will include the Player Traits questionnaire [34] as a moderating factor for categorizing the sample and analyzing outcomes, along with other sociodemographic and behavioral individual data. Regarding UX, there are no planned changes, as the system was effective, and data collection was successful.

6 Conclusion

The main objective of a pilot study is to assess feasibility rather than statistical significance [33]. In this regard, this pilot study concluded that the protocol is feasible, the gamified digital learning platform with the eye-tracking and facial emotion recognition applications works, and there is promising evidence of the effectiveness of the interventions, although the current sample size does not allow for statistical inferences. The experimental protocol and the gamified digital learning platform will be incremented based on these results, and we will implement the RCT with a robust sample to verify the impact of different game elements on cognitive, emotional, motivational, and learning outcomes, through inferential statistics. Furthermore, the gamified digital learning platform, which was primarily rooted in the gamified learning theory [10, 11], demonstrates the potential for conducting experimental research within a controlled environment, incorporating webcam eye-tracking and facial emotion recognition features. Hence, it contributes to the educational scientific community by bolstering scientific rigor in forthcoming studies necessitating a gamified digital learning platform to examine the effects of gamification on cognitive, emotional, motivational, and learning outcomes, such as our upcoming RCT.

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