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A Neurotechnological Study to Quantify Differences in Brain Activity Using Game-Based Learning:

Gamification vs. Traditional Teaching

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ABSTRACT

This research delves into the comparative analysis of brain activity using gamification in the classroom versus traditional teaching. This study aims to employ neurotechnology to record and analyse the impact of active gamification methodology on relevant variables in the learning process within a traditional university education setting, presenting an innovative contribution to the existing literature. Neuroscience technology has been utilized to gauge cognitive processing of stimuli tailored for an academic experience in a university master's class. By scrutinizing brain recordings related to attention, interest, long term excitement, stress, relaxation, and engagement, the findings provide a quantitative assessment of key learning variables through brain signals. Gamification is the active methodology employed, and the application of neuroscience technologies facilitates an understanding of the variations in levels of brain activation among students, shedding light on the contributions of this active teaching methodology to the learning process.

KEYWORDS

Active Learning, Educational Innovation, Neuroeducation, Gamification, Neurotechnology, Higher Education, Game-Based Learning

INTRODUCTION

Innovation in education involves making changes to the learning process with the aim of improving outcomes (Kottmann et al., 2024). There is a trend towards the adoption of innovative techniques such as gamification, role play, flipped teaching, and group dynamics to enhance learning (Maleko et al., 2018). The analysis should focus on interactions between teachers and students, as well as among students themselves, in terms of both quantity and quality, rather than solely on student attendance. Knowledge of the principles of brain-based learning contributes to the advancement of educational

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innovation, emphasizing the importance of neuroeducation in the development of educational systems (Hillman, 2011).

The objective of this research is to use neuroscience technologies to determine the difference in brain activation levels between a group of students attending a masterclass and another group participating in a gamification activity in the classroom, both belonging to an undergraduate level of study. The research gap lies in the possibility of quantifying, for the first time, the difference in brain activity among students when receiving knowledge through traditional lectures versus through active learning techniques such as gamification, highlighting the novelty in expressing these differences through performance metrics. The initial hypotheses of the study are the enhancement of brain performance metrics when applying gamification techniques in active learning compared to traditional lectures and the improvement of brain performance metrics in gamification by enhancing student participation in the development of gaming strategies.

Biometrics were employed to monitor the intensity of emotional arousal, through galvanic skin response (GSR), and brain activity, through electroencephalography (EEG), as reflected in variables such as attention, interest, long-term excitement, stress, relaxation, and emotional connection (engagement). This research aims to provide empirical answers regarding the comparative efficiency between traditional teaching and gamification-based teaching in the classroom. Consequently, the research has specific objectives like analysing the recorded emotional arousal levels based on the teaching format (masterclass or gamification); analysing levels of attention, interest, long-term excitement, stress, relaxation, and engagement of participants based on the type of teaching delivered in the classroom; and determining which teaching methodology is more effective based on data provided in experimental records.

LITERATURE REVIEW

Traditional Teaching: Masterclass

The masterclass is a traditional form of teaching in which the teacher plays a central role in imparting knowledge and students act as receivers of information. The teacher speaks for the majority of the class while students listen and take notes. The masterclass has several advantages, such as the ability to convey a large amount of information in a relatively short time, allowing the teacher to delve into complex and challenging topics; it can also be a stimulating and inspiring experience for students. This method adds to the availability of information, the teacher's ability to control the learning process, and the objectivity of assessments (Soboleva et al., 2021). However, the masterclass also has some disadvantages, as it can be a passive form of learning, limiting students to listening and note-taking. It may be challenging to maintain students' attention for an extended period and can hinder student participation in the learning process.

The current educational landscape has required the incorporation of active-participatory methodologies into the traditional teaching-learning paradigm (López-Alegría & Fraile, 2023). Strategies that can enhance the masterclass include using visual materials (slides, videos, or experiments to illustrate concepts and make them more engaging for students), encouraging student participation (asking questions, organizing group work, or giving assignments), and promoting reflection (encouraging students to think about the concepts being learned). Consequently, the masterclass is an effective teaching method when used appropriately. Teachers must consider the advantages and disadvantages of this method and employ strategies to enhance its effectiveness (Jelovica & Alajbeg, 2023).

Innovation in Education

The application of innovation in the educational field is known as educational research, which aims to conduct a systematic exploration of a relevant research question (Watts et al., 2023). What typically distinguishes this research from other types of traditional approaches is largely the nature of the problem it addresses. Innovation in services, products, processes, and knowledge drives change in education, contributing to addressing challenges and situations arising from teaching practices and methods. In this context, educational innovation is defined as the introduction of changes aimed at improving learning outcomes through enhancements in training (Bastone et al., 2023; Clark et al., 2016). To achieve this, educational innovation must be adopted inclusively and holistically, involving students, educational providers, communities, businesses, and political organizations in integrating key aspects of innovation at all levels of their hierarchical structure.

Furthermore, it is essential to understand the classification of research approaches. Scholars like Ramirez-Montoya (Ramirez-Montoya et al., 2020) have proposed a comprehensive classification that encompasses educational management (planning, organization, administration, resource management, and evaluation), psycho-pedagogy (teaching and learning), technology applied to education (usage and development, both in-person and distance), and sociocultural management.

Gamification in the Classroom

One of the most significant innovative trends in modern education is gamification, often regarded as a system that employs game components in non-gaming environments (Astashova et al., 2023). Gamification in the classroom is a teaching technique that utilizes game-based elements, such as peer competition, teamwork, or scoring boards, to enhance engagement and facilitate the assimilation of new information among students. Gamification is grounded in the idea that games are an effective way to motivate individuals and stimulate their learning, as games are typically fun, challenging, and rewarding, making them an ideal tool for the classroom. Gamification offers several advantages for students, including increased motivation (promoting learning), better retention, and the development of skills such as problem-solving, teamwork, and creativity, with satisfactory settings for active learning without loss of academic performance (Murillo-Zamorano et al., 2021), allowing the cultivation of skills particularly relevant to 21st-century professionals.

Gamification can be an effective tool for improving learning in the classroom, whereby teachers can help motivate students, enhance their retention, and develop their skills. This methodology can assist educators in developing innovative pedagogical strategies to promote active and experiential learning in controlled environments (Ilbeigi et al., 2023). The students of the new era, Generation Z, are different from their predecessors, and therefore, educators need pedagogical interventions to cater to this group of students (Saxena & Mishra, 2021). The education system needs to be renewed to incorporate tools that meet the needs of students, with gamification being a motivation and engagement tool for Generation Z in higher education levels, creating an engaging and meaningful learning environment. Considering that one of the most relevant problems facing education today is the lack of student motivation, it is tempting to examine whether gamification can positively impact motivation, resulting in increased interest and engagement among students (Giordano & Dias de Souza, 2021). The gamification methodology in education includes systematic, personality-oriented, and activity-based approaches, serving as an innovative teaching method whose components include game elements, mechanisms, dynamics, and characters (Viktoriia et al., 2022). A review of the literature suggests three main perspectives on gamification: innovation in processes revealing issues (research), stimulating novel behaviors (induction), or transforming processes (intervention) to enhance effectiveness and engagement (AlSaad & Durugbo, 2021).

Gamification represents a tool with significant potential in the design and implementation of training actions. The methodology is perceived as particularly relevant for developing written expression, encouraging meaningful learning, promoting feedback, fostering teamwork, or presenting complex content in more engaging formats (Cuevas Monzonis et al., 2021). Gamification is used to engage students in the learning of various disciplines, such as mathematics, engineering, economics, and nutrition, among others (Ilbeigi et al., 2023; Moreno-Guerrero et al., 2021; Pardim et al., 2023), both in face-to-face and e-learning formats (Saleem et al., 2022). In addition, this approach facilitates language learning (Chan et al., 2022), training in musical instruments (Aras & Can, 2023), implementing inclusive practices (Manzano-Leon et al., 2022), promoting student self-realization (Tsurkan et al., 2023), or even in increasing the completion rate of massive open online courses (MOOCs) (Nesterowicz et al., 2022). While gamification likely experiences the novelty effect, it also benefits from the familiarity effect, contributing to an overall positive impact on students (Rodrigues et al., 2022). Design and development of games can teach players important critical thinking skills (de Vero & Barr, 2023); professional development should be designed with a focus on teacher training (Matic et al., 2023), trying to identify the core motivators for engaging students in research (Mukherjee et al., 2019).

Gamification has significant potential to address the drawbacks of other methodologies, such as flipped learning, an increasingly common teaching strategy. Adding game elements to a flipped classroom produces greater motivation, participation, and improved learning performance (Ekici, 2021). Platforms like Moodle and Kahoot are the most preferred, and points, badges, and leaderboards are the most commonly used game elements for gamification. Likewise, technology can help improve the efficiency of gamification, generating various benefits for students, assisting educators, enhancing the educational process, and facilitating the transition to enhanced learning (Lampropoulos et al., 2022). Students demonstrate positive changes in behavior, attitude, and psychology, as well as increased engagement, motivation, active participation, knowledge acquisition, concentration, curiosity, interest, enjoyment, academic performance, and learning outcomes (Magadan-Diaz & Rivas-Garcia, 2022). Finally, teachers also positively value these activities as they enhance learning motivation. It is necessary to develop validation tools, appropriate design techniques, and theories to create collaborative and personalized learning experiences and to promote and improve student quality, with evident cognitive and socio-emotional development.

Learning and the Brain

It is essential to restructure pedagogical practices to connect learning with the functioning of the brain, integrating insights from neuroscience. In this context, neuroeducation emerges as a new discipline whose primary goal is to merge pedagogy, cognitive psychology, and neuroscience. Its purpose is to provide various educational stakeholders with the necessary resources to understand the relationship between the brain and the learning process. Research in neuroscience focuses on the neural foundations of learning, memory, emotions, and various brain functions, offering highly applicable results in the educational field (Howard-Jones, 2014). The development of neuroeducation not only drives educational innovation but also contributes to the progress of educational systems.

There is an ongoing debate about the applicability of knowledge from neuroscience research to educational problems (Bueno & Fores, 2021), and active explorations are taking place worldwide to establish potential connections between neuroscience and education. Various labels, such as neuroeducation, educational neuroscience, and mind, brain, and education, have been used to describe these efforts. However, the transition from neuroscience research to educational practice presents significant challenges. This process is extensive and begins from a foundation of basic science. The complexity of learning in the brain and the current state of scientific knowledge pose the risk of premature application before establishing a solid foundation. This risk is exacerbated by the legitimate desire of policymakers to use scientific evidence to guide their educational decisions (Bittencourt & Willetts, 2018), as well as by educators' enthusiasm to incorporate knowledge about brain function into their teaching. Additionally, the interaction between the disciplines of neuroscience, psychology, and education has sometimes been marked by competition rather than collaboration, and educational researchers still show skepticism towards exaggerations surrounding the educational field.

Neuroeducation

Neuroeducation, as an emerging discipline, facilitates the examination of users, their perceptions, and the overall experience (Borst, 2023). This area of study allows for documenting the existence of potential positive emotional connections between students and the classes they receive, enabling the scientific determination of levels of attention and emotion generated while paying attention to the lessons taught. Additionally, it establishes a clear distinction between traditional teaching and gamification. Research has been conducted on the use of portable electroencephalography technology (PEEGT) in educational research (Juárez-Varón et al., 2023), specifically to analyze levels of attention, interest, engagement, and stress.

Although neuroeducation is in its early stages of development in research, it is generating critical dialogues among teachers, educational authorities, families, and the scientific community. Exploring the conceptual delineation of the term, neuroeducation is classified as an application of cognitive neuroscience, especially when there are no substantial differences in philosophical and methodological orientations between education and cognitive neuroscience (Campbell, 2011). It is a field of educational research grounded in the mechanisms of information processes, theories, and methods of applied cognitive neuroscience. However, unlike these, neuroeducation is not limited to these elements, as it focuses on the individual as its primary object, not just on the physiological and biological mechanisms that form the basis of neuroscience. Given the transdisciplinary focus of neuroscience, neuroeducation has the potential to contribute to the creation of new educational frameworks and research methodologies that serve as a reference in the relationship between learning and the brain.

Despite significant advancements in brainwave analysis in various academic and professional contexts, the application of this analysis in educational settings has been limited. Thanks to technological advances, EEG devices are becoming increasingly portable and compact, facilitating the collection of precise brainwave data with simple preparation. Currently, there are indications that a growing number of researchers choose to use PEEGT as a research tool in their educational studies, suggesting that it could be a relevant tool for enhancing education research. However, this assertion still requires more solid backing through the application of experiences and, above all, through empirical evidence.

METHODOLOGY

In this study, neuroscience technology has been employed for recording brain activity with the aim of capturing cognitive processing during an academic experience in a university class, namely a theoretical class titled Human Resources Management that is part of the bachelor's degree in business administration. The study differentiates between a first group of students that received a 45-minute lecture on the importance of teamwork, decision-making, non-verbal communication, and leadership and a second group that engaged in a 45-minute gamification activity in the classroom, using a board game designed to develop the aforementioned skills, titled The Mind," and published by Mercurio (Warsch, 2018).

The application of neuroscience technology enables the analysis of the effectiveness of stimuli directed towards users and consumer behavior psychology (Juárez-Varón et al., 2024), providing more information than other conventional research methods, where limitations may arise from participant behavior or perceptions. In this study, two specific neuroscience techniques are employed: skin conductance response (GSR) and EEG. Electrodermal activity (EDA) is recorded through GSR, reflecting changes in emotional arousal in response to presented stimuli. Brain activity, captured through brain waves, is recorded through EEG (Núñez-Cansado et al., 2024).

The required sample size for a study using neurotechnologies is not based on traditional statistical parameters, as in quantitative research, but on mental patterns; each neurotechnology requires a minimum number of participants, delimited when all of them respond to the same registered pattern. The neurotechnologies used, GSR and EEG, require a minimum of 20 users and nine users, respectively, selecting a minimum sample size according to the larger required sample size (20 users). The sample size is adequate for a neuromarketing study (Cuesta-Cambra et al., 2017). However, a larger sample size has been employed for ease of access to participants.

Sample Characteristics

The sample selected for the study was made up of university students aged between 20 and 22 years old and enrolled in a course titled Human Resources Management; the sample included men and women in a 50/50 distribution. In total, there were 64 students (50% male, 50% female), evenly distributed between the two proposed groups, representing a suitable sample size for a neuroeducation study (Juárez-Varón et al., 2023). The fieldwork was conducted between October and December 2023, and the study took place at the Alcoy Campus of the Universitat Politècnica de València (Alicante, Spain).

Data Collection and Analysis

To record electrodermal activity, the Shimmer3 GSR+ model was used in both groups, employing ConsensysPRO software, v.1.6 for data collection. This recording allowed the determination of the level of emotional arousal experienced by participants throughout the session, indicating the amount of sympathetic activation during the emotional experience (Juarez-Varon et al., 2023). Regarding the recording of brain activity, the portable EEG equipment EPOC+ from the manufacturer Emotiv was used, which has 14 channels and saline-based electrodes. Data collection was carried out using EmotivPRO software v.2.0. This technology is used to interpret the most relevant emotions experienced, based on the collected information from brain activity. Analyzed brain activations included attention (focus on a specific task), interest (attraction or aversion to the stimulus), long-term emotion (physiological excitement with a positive value, derived from sympathetic nervous system activation, reflecting enthusiasm), stress (measure of comfort with the current challenge), relaxation (ability to recover from intense concentration), and engagement (a mix of attention and concentration, contrasting with boredom). Engagement is defined as the ability of a brand, product, service, or stimulus to establish a lasting connection between both parties (Emotiv, 2023).

Statistical analysis of the data was conducted using R software, v.3.6.3. Common stimuli were established for all participants (volunteers), with independent variables being the age and gender of the participants; participants had similar socio-cultural profiles as determined by the main profiles in the degree program. Dependent variables included the level of emotional intensity and levels of attention, interest, long-term emotion, stress, relaxation, and engagement in response to observed stimuli.

For this study, a biometric-focused experiment was conducted to understand the subconscious perceptions of students when observing classes, both in masterclass format and through gamification. The study took place over 8 days, with eight different participants per session (four in masterclass format and four in gamification format). Fifty percent of them attended the class in masterclass format, and the other 50% participated in a gamification session. Additionally, participants in the gamification session were divided into two groups: the first group knew the game rules but couldn't establish a strategy (no talking among themselves before or during the game), and the second group knew the game rules and could speak halfway through the session to establish a possible teamwork strategy. The total duration of the sessions was 45 minutes, during which the brain activity of students was recorded using GSR and EEG technologies. Finally, qualitative data analysis was employed to assess participants' perception of the gamification activity, identifying key relevant aspects.

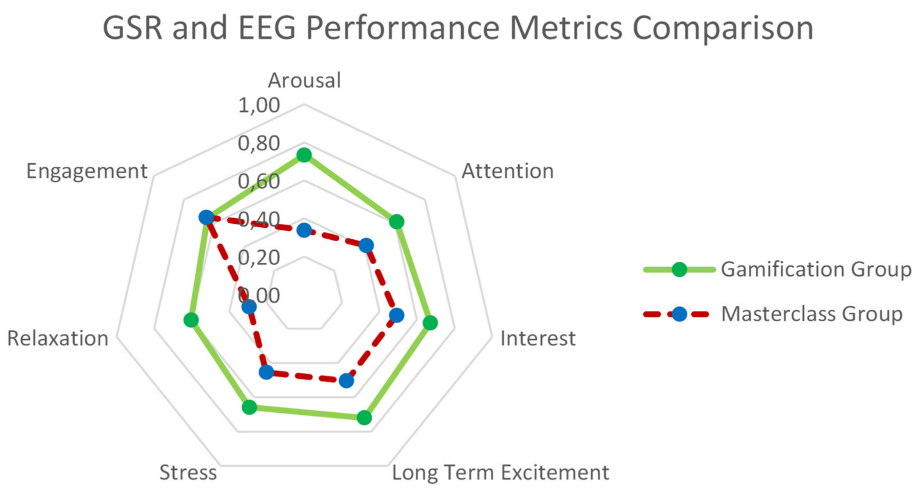
RESULTS

Below are the results obtained from the recording of cerebral emotional activity, separating the overall analysis of the group (lecture group versus gamification activity group) and the analysis of the groups participating in the gamification activity. All results are displayed on a scale from 0 to 1.

Table 1. GSR and EEG records for traditional classroom group and gamification activity group

Average emotional response of the group	Arousal	Attention	Interest	Long term excitement	Stress	Relaxation	Engagement
Masterclass Group	0.34	0.41	0.49	0.50	0.45	0.29	0.65
Masterclass Std. Dev.	0.07	0.04	0.06	0.16	0.02	0.03	0.06
Gamification Group	0.73	0.61	0.67	0.72	0.66	0.60	0.64
Gamification Std. Dev.	0.35	0.06	0.03	0.38	0.11	0.10	0.06
Gamification vs. masterclass	+117%	+49%	+37%	+43%	+45%	+106%	-1%

Figure 1. GSR and EEG performance metrics comparison for gamification and masterclass groups



Overall Analysis of the Emotional Response of the Group

The results obtained from the GSR and EEG recordings are presented, in an aggregated manner, in Table 1 and Figure 1 for both the lecture group and the gamification group. Table 1 separates the overall results for the group that attended the lecture and the overall results for the group that participated in the gamification activity.

Below are graphically displayed the results obtained using a radial chart with markers, allowing for a visual comparison of the brain activity records from both methodologies.

Figure 1 allows highlighting the overall increase in variables of brain activity recorded when using gamification in the classroom. In percentage terms, the emotional intensity of gamification activity exceeded its masterclass equivalent by 117%. Attention increased by 49%, interest by 37%, long-term emotion by 43%, stress by 45%, relaxation by 106%. Only engagement had similar values, with a 1% reduction in the case of gamification. In an individual analysis for each recorded variable, the results obtained are detailed below.

Arousal

Emotional arousal, understood as the amount of sympathetic activation experienced during the emotional experience, was higher in the group that participated in the gamification activity, by 117% compared to the masterclass. Figure 2 shows the comparative results.

Figure 2. GSR metrics comparison for the gamification and masterclass groups

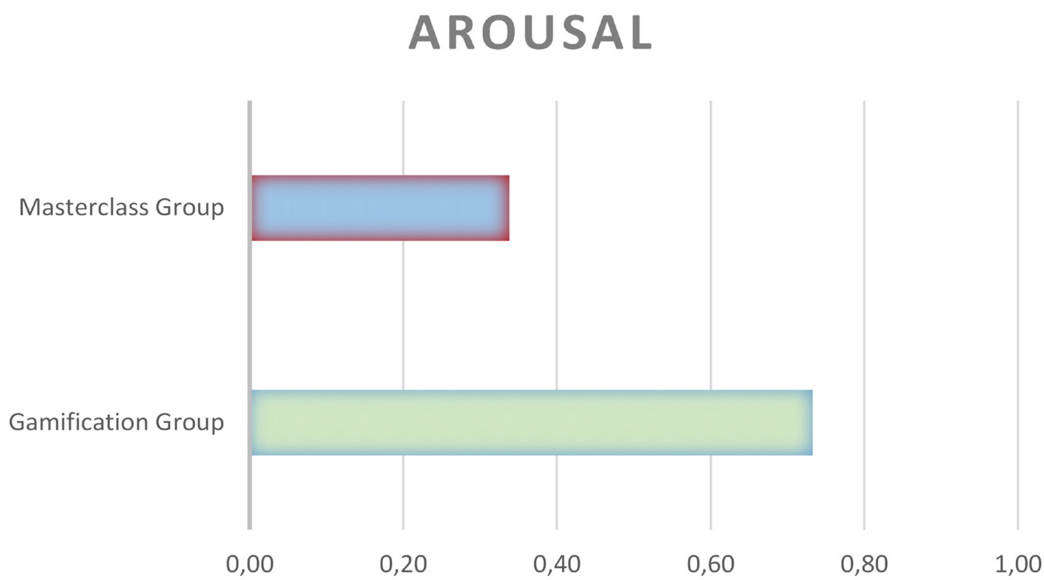


Figure 2 shows an emotional intensity value (Arousal) for the gamification activity more than double that recorded for the group attending the masterclass. Participants expressed, in the subsequent qualitative study, that the activity naturally encouraged participation and that is how they experienced it.

Attention

Attention, understood as the concentration on a specific task during the experience, was higher in the group participating in the gamification activity by 49% compared to the masterclass. Figure 3 shows the comparative results.

Figure 3 shows an attention value for the experience in the gamification activity 49% higher than that recorded for the group attending the masterclass. Participants expressed, in the subsequent qualitative study, that the activity motivated them a lot.

Interest

Interest, understood as the degree of attraction or aversion to the stimulus presented during the experience, was higher in the group participating in the gamification activity by 37% compared to the masterclass. Figure 4 shows the comparative results.

Figure 4 shows an interest value for the experience in the gamification activity 37% higher than that recorded for the group attending the masterclass. Participants expressed, in the subsequent qualitative study, that the activity generated motivation for them to participate.

Long-Term Excitement

Long-term excitement, understood as physiological excitement with a positive value, derived from the activation of the sympathetic nervous system and reflecting enthusiasm during the experience, was higher in the group participating in the gamification activity by 43% compared to the masterclass. Figure 5 shows the comparative results.

Figure 3. EEG attention metric comparison for the gamification and masterclass groups

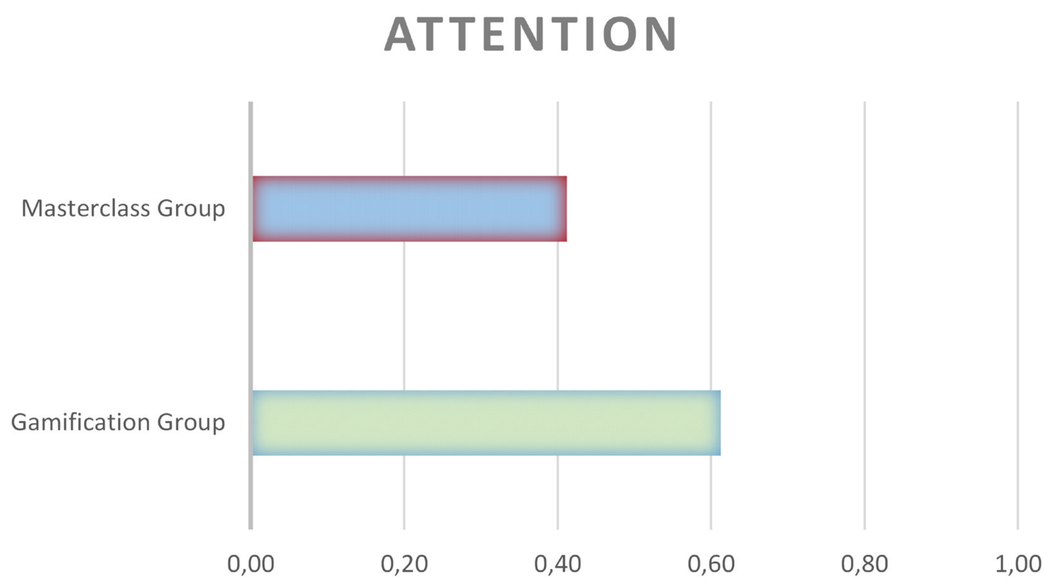


Figure 4. EEG interest metric comparison for the gamification and masterclass groups

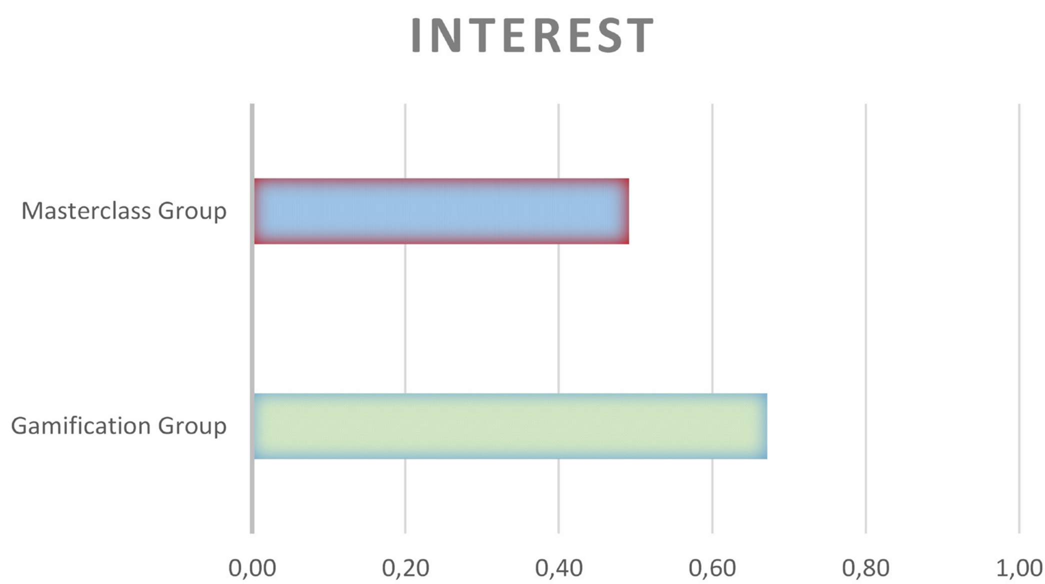


Figure 5 shows a long-term excitement value for the experience in the gamification activity 43% higher than that recorded for the group attending the masterclass. Participants expressed, in the subsequent qualitative study, that the activity had encouraged their participation, and the game had motivated them a lot.

Figure 5. EEG long term excitement metric comparison for the gamification and masterclass groups

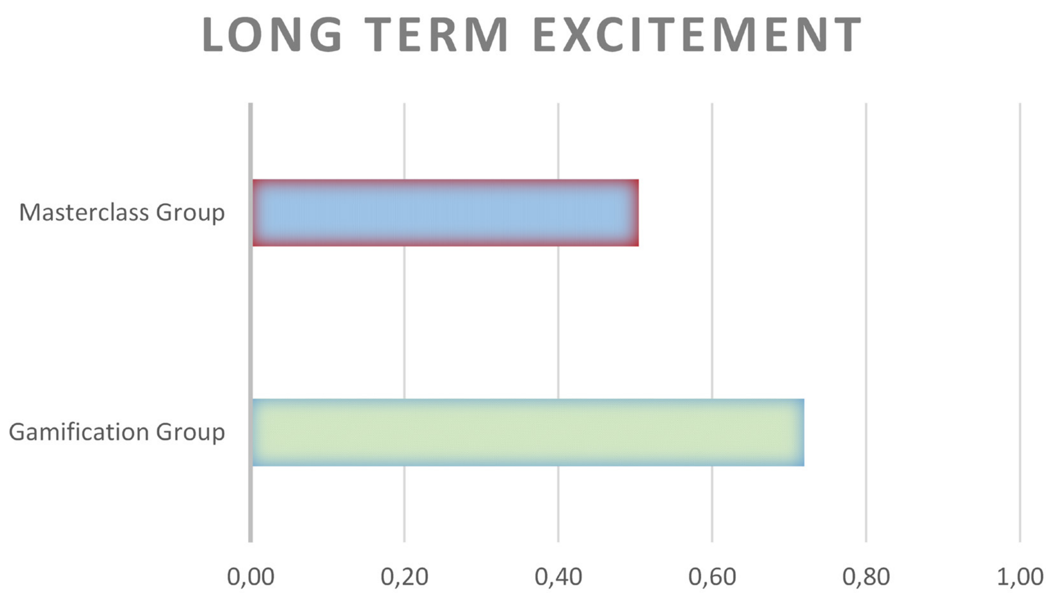
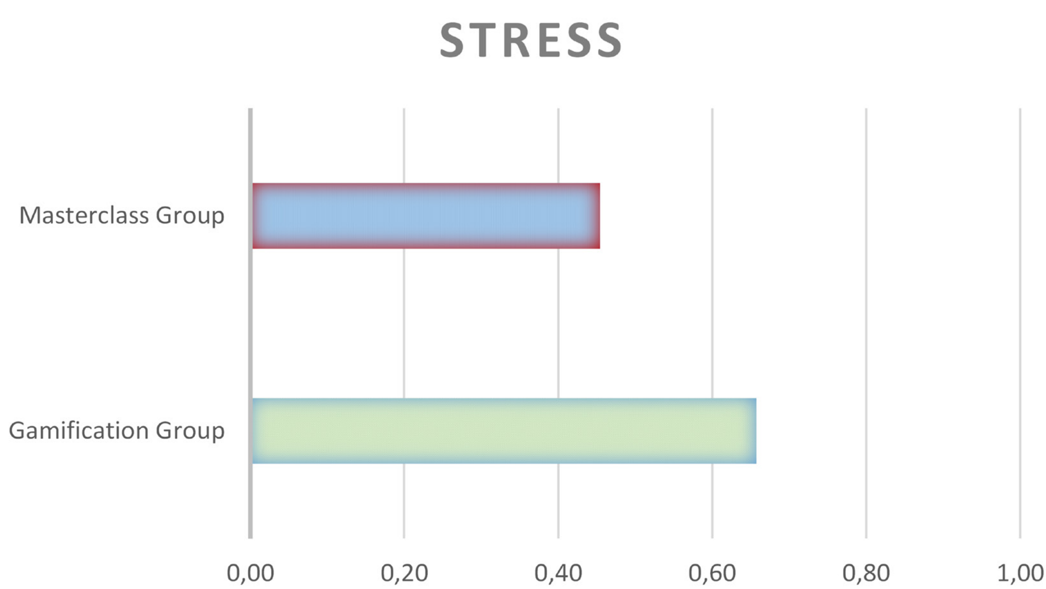


Figure 6. EEG stress metric comparison for the gamification and masterclass groups

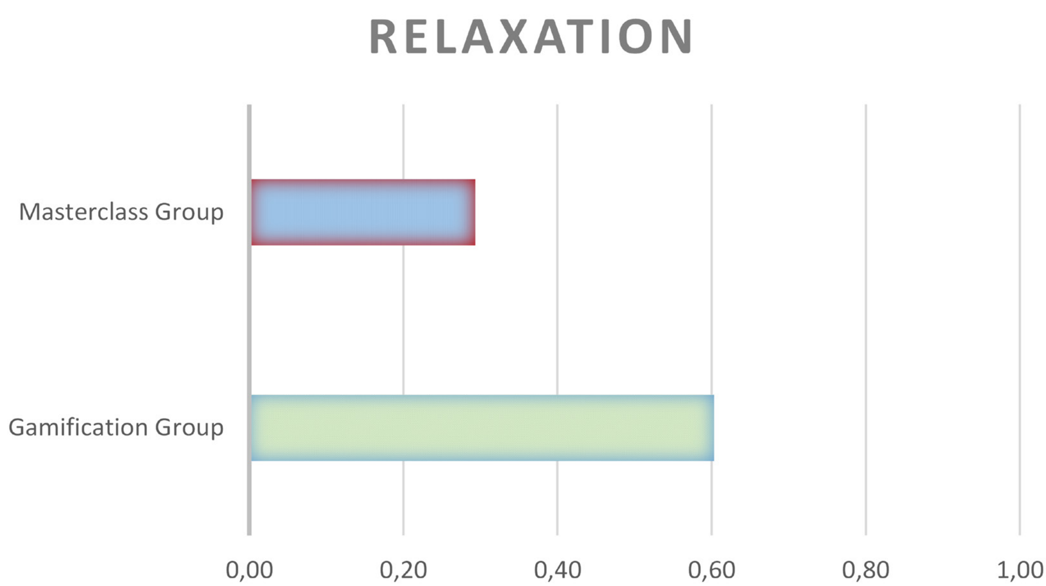


Stress

Stress, understood as the measure of comfort with a challenge (in this case, the gaming experience), was higher in the group participating in the gamification activity by 45% compared to the masterclass. Figure 6 shows the comparative results.

Figure 6 shows a stress value for the experience in the gamification activity 45% higher than that recorded for the group attending the masterclass. Participants expressed, in the subsequent

Figure 7. EEG relaxation metric comparison for the gamification and masterclass groups



qualitative study, that the activity presented them with a challenge to overcome, and the game had motivated them a lot.

Relaxation

Relaxation, understood as the ability to recover from intense concentration, was higher in the group participating in the gamification activity by 106% compared to the masterclass. Figure 7 shows the comparative results.

Figure 7 shows a relaxation value for the experience in the gamification activity 106% higher than that recorded for the group attending the masterclass. Participants expressed, in the subsequent qualitative study, that they lived intensely through each round until it ended, and then they started from scratch in all aspects.

Engagement

Engagement, understood as the combination of attention and concentration, in contrast to boredom, and being the ability of a brand, product, service, or stimulus to create a lasting connection, was lower in the group participating in the gamification activity by 1% compared to the masterclass. Figure 8 shows the comparative results.

Figure 8 shows an engagement value for the experience lived in the gamification activity that is 1% lower than that recorded for the group that attended the master class. The participants in the master lesson expressed, in the subsequent qualitative study, that the teacher transmitted clearly and with easy-to-understand examples.

Analysis of the Emotional Response of Gamification Groups

Participants in the gamification activity were further divided into two groups. The first group participated in the activity without allowing members to talk among themselves. The second group participated in the activity, allowing them to talk and establish game strategies halfway through the activity.

Figure 8. EEG engagement metric comparison for the gamification and masterclass groups

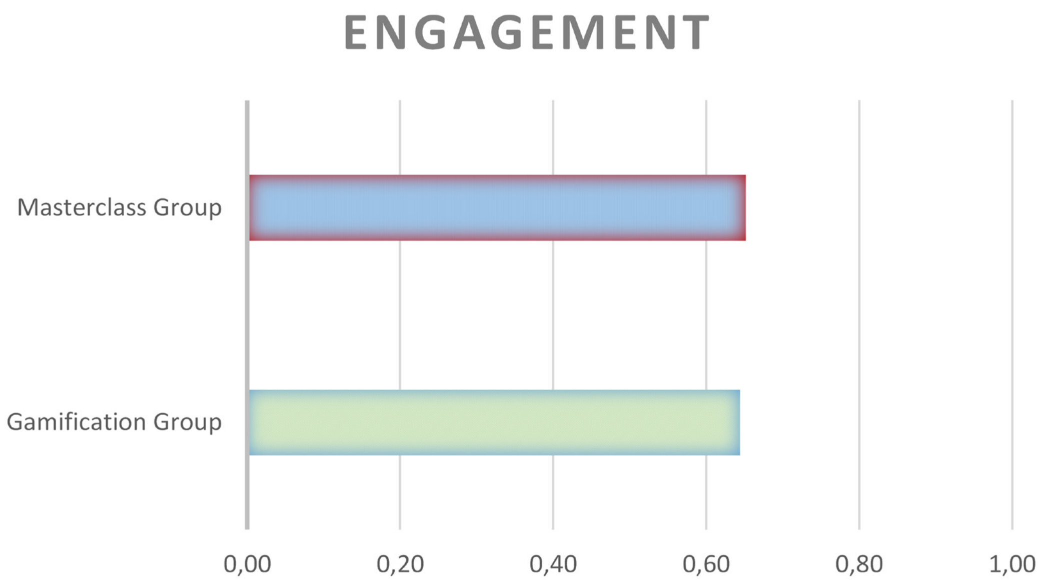


Table 2. GSR and EEG records for gamification activity groups

Average emotional response of the group	Arousal	Attention	Interest	Excitement	Stress	Relaxation	Engagement
Group without strategy	0.49	0.65	0.63	0.45	0.58	0.53	0.62
Group with strategy	0.98	0.57	0.72	0.99	0.74	0.67	0.66
Without vs with strategy	+100%	-12%	+15%	+118%	+28%	+26%	+6%

The results obtained from the GSR and EEG records are presented, in aggregate, in Table 2 and Figure 9, both for the gamification group and the gamification-allowed-to-talk group. Table 1 separates the overall results for the group attending the lecture and the overall results for the gamification activity group.

Below, the results obtained are graphically presented using a radial chart with markers, allowing for a visual comparison of the brain activity records of both groups.

Figure 9 highlights an increase in recorded brain activity variables of arousal, interest, excitement, stress, relaxation, and engagement. Only the attention variable experiences a reduction. In percentage terms, the emotional intensity of the gamification activity with a strategy surpassed its counterpart without a strategy by 100%. Attention decreased by 12%, interest increased by 15%, long-term excitement increased by 118%, stress increased by 28%, relaxation increased by 26%, and engagement saw a 6% increment.

In the qualitative study, students who had established a game strategy expressed that participation was more complete, identifying a leader in the group, integrating into the group more effectively, and reaching a consensus when participating.

Furthermore, if this group is analyzed before and after the break to talk and establish a game strategy, the results obtained from the GSR and EEG records are presented, in aggregate, in Table 3 and Figure 10, for both the gamification group and the gamification-allowed-to-talk group. Table 1 separates the overall results for the group attending the lecture and the overall results for the gamification activity group.

Figure 9. GSR and EEG performance metrics comparison for the gamification groups

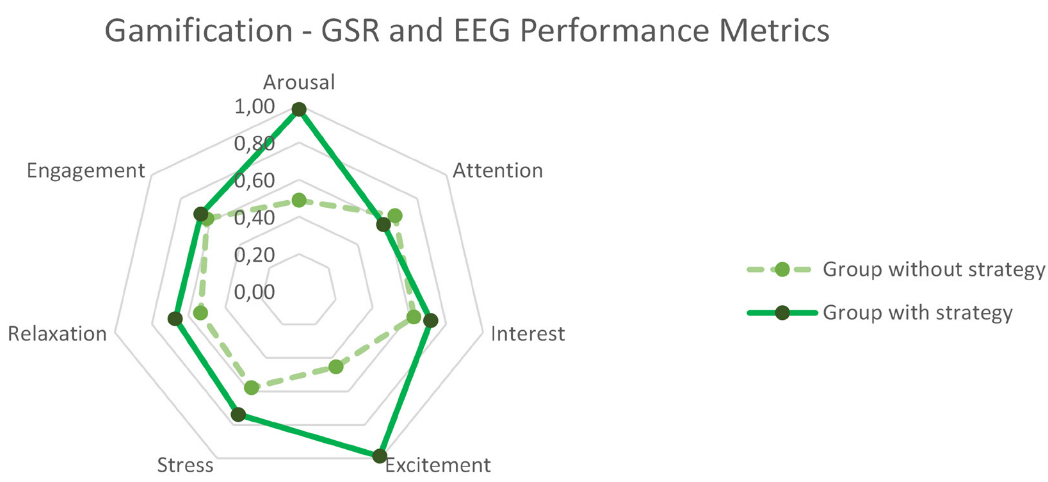
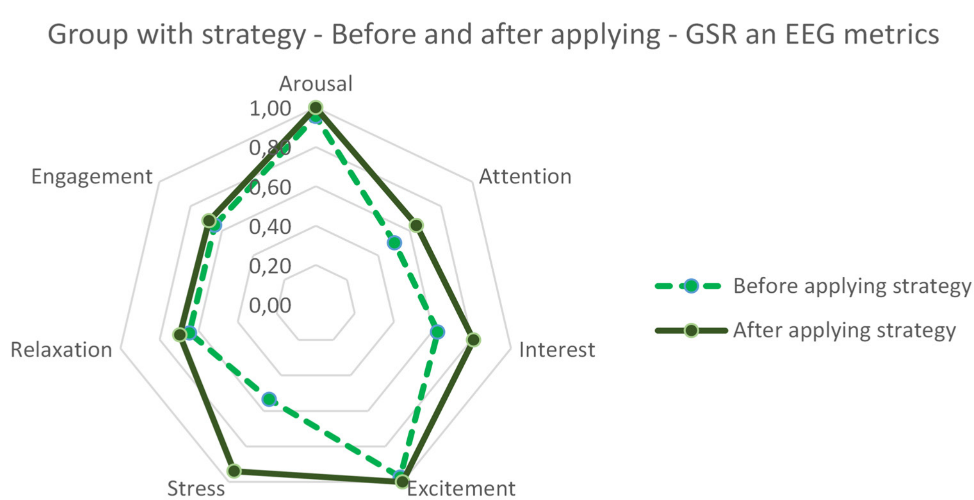


Table 3. GSR and EEG records for gamification activity groups

Group with strategy	Arousal	Attention	Interest	Excitement	Stress	Relaxation	Engagement
Gamification Average	0.98	0.57	0.72	0.99	0.74	0.67	0.66
Before applying strategy	0.96	0.50	0.63	0.97	0.54	0.65	0.65
After applying strategy	1.00	0.64	0.81	1.00	0.94	0.70	0.68
Difference	5%	28%	29%	3%	76%	8%	6%

Figure 10. GSR and EEG performance metrics comparison for the gamification groups



Below, the results are graphically presented using a radial chart with markers, allowing for a visual comparison of the brain activity records of both groups.

Figure 10 highlights, for the group that established a strategy, a general increase in all recorded brain activity variables: arousal, attention, interest, excitement, stress, relaxation, and engagement. In percentage terms, the emotional intensity of the gamification activity for the strategy group exceeded the experience before establishing the strategy by 5%. Attention increased by 28%, interest increased by 29%, long-term excitement increased by 3%, stress increased by 76%, relaxation increased by 8%, and engagement saw a 6% increment.

In the qualitative study, students from this group, who had established a strategy after the midpoint of the experience, expressed that collaboration among team members increased after establishing the strategy. It became easier to make decisions, leadership helped carry out the activity more efficiently, and non-verbal communication improved.

Qualitative Research

The qualitative study revealed that participants in the gamification activity felt highly motivated, appreciating collaboration with other participants in work perceived as a team effort. They could make decisions and see the consequences. Overall, they considered non-verbal communication important and had improved it as a skill. Regarding emotional intensity, participants stated that the activity naturally promoted participation, leading to a greater emotional intensity as an experience. Concerning attention, they were aware that it improved compared to a masterclass because the game motivated them and generated much interest when participating. They also mentioned that the activity presented them with a challenge to overcome, and they lived intensely through each round until it ended, starting from scratch in all aspects.

Finally, members of the gamification group who were able to devise a strategy indicated that leadership helped them progress. It became easier to make decisions after outlining the game strategy, making them more efficient and achieving consensus when participating.

DISCUSSION AND CONCLUSIONS

The continuous improvement of educational systems, coupled with a growing demand from students to move away from traditional lectures and enhance stimulation in the classroom, compels educational institutions to adapt in an ever-evolving teaching context. Here, there is a constant need to design new forms of learning. In lecture-based training, the teacher plays a central role in instruction, with students acting as information recipients. While lectures can effectively convey a large amount of information in a relatively short time, providing a stimulating and inspiring experience for students, they also have drawbacks. Lectures represent a passive form of learning and can make it challenging to maintain students' attention over an extended period. Gamification in the classroom is an educational strategy that incorporates game elements and mechanics to motivate, engage, and enhance the learning experience for students. By integrating playful elements into the educational environment, the aim is to make the learning process more interactive, enjoyable, and meaningful. It is crucial to tailor gamification strategies to the specific needs of students and curriculum objectives, balancing fun with educational effectiveness to ensure that gamification enhances the learning experience. The examples used in the teaching-learning process play a crucial role in fostering conceptual understanding, and certain variables can influence the use of qualified examples by instructors (Sevimli, 2022).

Gamified learning can take a leading role in specialist training by employing innovative practices, stimulating motivation, regulating behavior, and implementing ideas of friendly competition and creative cooperation in diverse educational contexts (Astashova et al., 2023). In recent years, many studies have emphasized the need to adapt the design properties of gamification to align with students' needs, characteristics, and preferences (Oliveira et al., 2023). Previous studies on the application of gamification in engineering at the university level confirm a significant contribution of the pedagogical strategy and different categories of motivation, with clear evidence of the significance between collaboration and motivation (Zabala-Vargas et al., 2021). The strategy can provide preliminary evidence of reducing school dropout rates, suggesting the potential use of gamification to strengthen educational processes at the university level. Educational neuroscience seeks to translate findings from research on the neural mechanisms of learning into practical educational policies and practices and to understand the effects of education on the brain (Thomas et al., 2019). Neuroscience and education can directly interact by considering the brain as a biological organ that needs to be in optimal condition for learning (brain health). Alternatively, they can interact indirectly, as neuroscience shapes psychological theory, and psychology influences education.

The main goal of this study has been to demonstrate that learning based on gamification activities is more effective, in terms of brain signals, than traditional classroom teaching for a theoretical class aimed at university-level students. The results of the experiment conducted in this study indicate that the emotional intensity levels of students who followed the class through gamification activities are higher than those who followed the masterclass format. Regarding the recording of students' brain activity, measured through portable EEG biometrics, the values are generally higher in the gamification activity group. Five out of six recorded variables are higher (attention, interest, long-term excitement, stress, and relaxation). However, the sixth variable, engagement, was very similar (1% lower for the gamification group), which could be justified by the emotional connection traditional classroom students may have with the teacher. These marginal differences to be a progressive improvement of traditional teaching, which must be combined with other active learning techniques.

The perceived sensations by students suggest that classes employing gamification activities are more participative, allowing them to be creative, more motivated, and better integrated into the group. The feelings and emotions provoked in students attending a lecture show less interest, less attention, and lower emotional intensity. Only engagement is equivalent (slightly higher) to gamification activities due to emotional connection with the teacher. The study demonstrates that gamification is effective for acquiring and developing specific and cross-cutting competencies related to the subject, with a focus on communication and social skills, teamwork, and time management (Agustin, 2023). The conclusions indicate that a gamified experience is an example of awareness in education, respecting students' learning rhythms, promoting metacognition, and encouraging their involvement in constructing their own knowledge. The qualitative study revealed that intriguing, competency-based activities with high intrinsic interest resulted in tangible achievements that motivated students, giving them a sense of play. Furthermore, implementations supporting learning were found to be collaborative activities that mobilized students to active participation (Erumit & Yilmaz, 2022). Students reported enjoying the activities and lessons, discovering that competitive implementations incorporating social games into lesson topics increased their motivation.

The novelty effect associated with gamification only appears when the game is new or addictive. If the game only represents a novelty on the first occasion, a hedonic adaptation will occur, so the teacher should work to introduce other equivalent games. In any case, gamification is a complementary methodology to traditional teaching, which allows the brain to activate in a different way, generating better performance metrics. Both methodologies are complementary, and gamification does not represent a replacement for traditional teaching. Finally, regarding future lines of research using neurotechnologies in the classroom, it is intriguing to analyze how different teaching methodologies (group dynamics, flipped learning, etc.) bring students' levels of brain activation closer or further apart, providing a basis for proposing actions to enhance and improve group outcomes. Additionally, complementing the techniques used with quantitative surveys focused on recording perceptions and potential improvements for each proposed methodology would be beneficial.

Limitations of the Study

The study was conducted with university students enrolled in the theoretical course Human Resource Management, which is part of the bachelor's degree program in business administration, using the game *The Mind* (Warsch, 2018) for gamification. There may be variability in user experience due to individual differences in preferences. However, the neuromarketing study is based on mental patterns, identifying such patterns in the study from a minimal number of users.

Future Lines of Research

Future lines of work, aimed at reducing the limitations of the study, are focused on expanding the subjects and topics of study, as well as the university degrees from which the sample has been drawn. These practices can be considered a new trend and are part of an integrated work of active methodologies that must be validated individually and jointly.

DECLARATIONS

Availability of Data and Material

Data and materials are available for consulting.

Ethics Statement

This study (involving human participants) followed the declarations of Helsinki. All participants gave their written informed consent, in accordance with the national legislation and the institutional requirements. Subjects were informed of their voluntary participation and anonymous contribution, as well as the possibility of withdrawing from the study at any time without reason.

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Competing Interest Statement

The authors declare no conflict of interest.

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