ANALYSIS OF KEY VARIABLES IN ACTIVE LEARNING USING GAMIFICATION: A NEUROTECHNOLOGICAL STUDY

D. Juárez-Varón, A. Mengual-Recuerda, F. Sempere-Ripoll, M.A. Peydró-Rasero

Universitat Politècnica de València (SPAIN)

Abstract

This study aims to register and analyse, using neurotechnology, the effect of the active gamification methodology on relevant variables in the learning process within a face-to-face university educational context, representing an innovation in the literature. Neuroscience technology has been employed in this study to measure the cognitive processing of stimuli designed for an academic experience in a university master's class. The neurotechnologies used include skin conductance response (GSR), electroencephalography (EEG), and eye tracking. Following the analysis of brain recordings based on attention, interest, stress, and emotional connection (engagement) in a face-to-face educational context, the results allow for quantifying the value of key learning variables through brain signals, specifically in a face-to-face monitoring format and the active gamification methodology employed. The application of neuroscience technologies enables understanding the difference in levels of brain activation among students, analysing the contributions of this active teaching methodology on the brain in the learning process.

Keywords: Learning, educational innovation, neuroeducation, neurotechnology, gamification, active methodology.

1 INTRODUCTION

Innovation in education involves making changes to the learning process with the aim of improving outcomes [1]. There is a trend towards the adoption of innovative techniques such as gamification, role play, flipped teaching, and group dynamics to enhance learning [2]. 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 innovation, emphasizing the importance of neuroeducation in the development of educational systems [3].

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 [4]. 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 [5], 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 [6]. The student of the new era, Generation Z, is different from its predecessors, and therefore, educators need pedagogical interventions to cater to this group of students [7]. 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 [8]. 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 [9]. Literature review suggests three main perspectives on gamification, such as innovation in processes revealing issues (research), stimulating

novel behaviors (induction), or transforming processes (intervention) to enhance effectiveness and engagement [10].

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.

2 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 (Industrial Processes subject, part of the bachelor's degree in industrial design and product development engineering- theoretical class). The study differentiates between a first group 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 gamification activity in the classroom (also 45 minutes), using a board game designed to develop the mentioned skills, titled "The Mind," from the Mercurio publisher (EAN: 8437015001524).

The application of neuroscience technology enables the analysis of the effectiveness of stimuli directed towards users and consumer behavior psychology [11], 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 Electroencephalography (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 [12].

2.1 Sample characteristics

The sample selected for the study consists of undergraduate students aged between 20 and 22 years who are interested in the subject matter of managerial and social skills. 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 [13]. 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).

2.2 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 [14]. Regarding the recording of brain activity, the portable electroencephalography 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 [15].

3 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).

The results obtained from the electrodermal activity (GSR) and electroencephalography (EEG) recordings are presented, in an aggregated manner, in Table 1 and Fig. 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.

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	0,63	0,53	0,58	0,66	0,61	0,55	0,59
Gamification Group	0,36	0,44	0,52	0,49	0,45	0,29	0,64
Gamification vs. masterclass	+76%	+21%	+11%	+34%	+36%	+93%	-7%

Source: Prepared by the authors.

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.

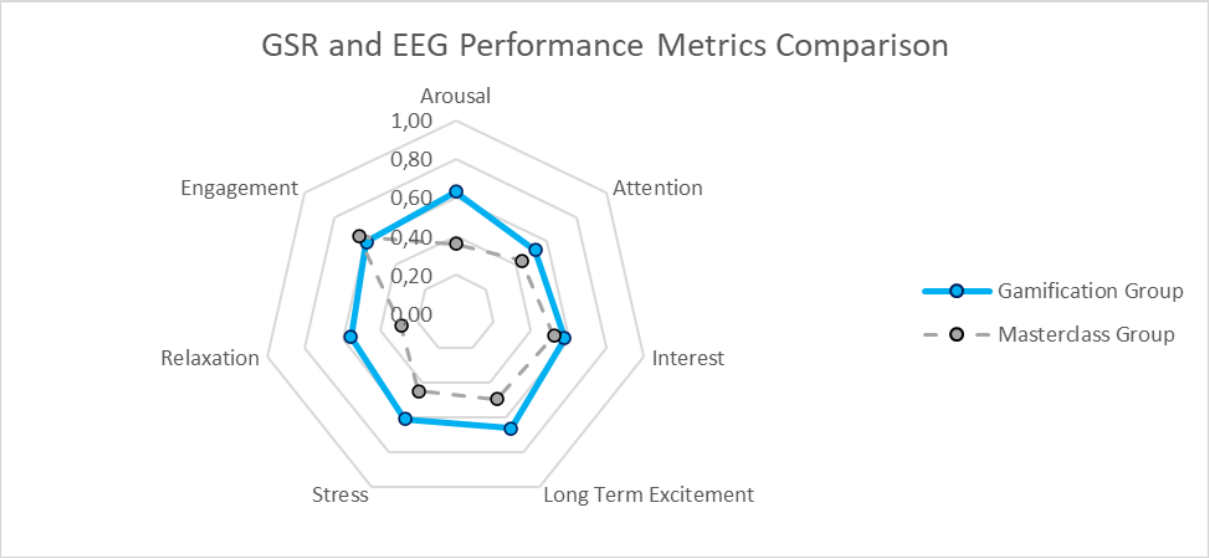

Figure 1. GSR and EEG performance metrics comparison for Gamification and Masterclass groups. Source: Prepared by the authors.

Fig. 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 76%. Attention increased by 21%, interest by 11%, long-term excitement by 34%, stress by 36%, relaxation by 93%, and only engagement had a lower value, with a 7% reduction in the case of gamification.

In an individual analysis for each recorded variable, the results obtained are detailed below:

3.1 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 76% compared to the masterclass. Figure 2 shows the comparative results.

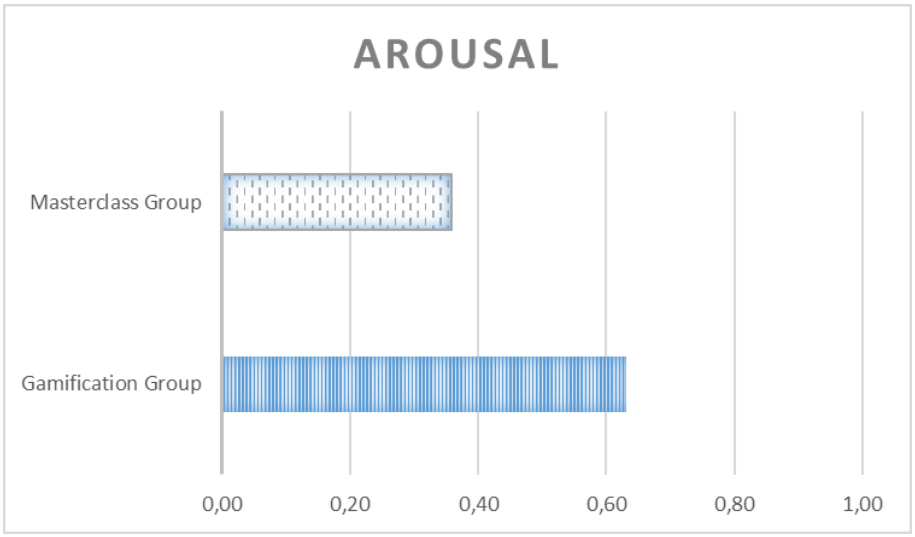

Figure 2. GSR metrics comparison for the Gamification and Masterclass groups.

Source: Prepared by the authors.

Fig. 2 shows an emotional intensity value (Arousal) for the gamification activity 76% higher than that recorded for the group attending the masterclass. Participants expressed, in the subsequent qualitative study, that the activity naturally encouraged participation and that's how they experienced it.

3.2 Attention

Attention, understood as the concentration on a specific task during the experience, was higher in the group participating in the gamification activity by 21% compared to the masterclass. Fig. 3 shows the comparative results:

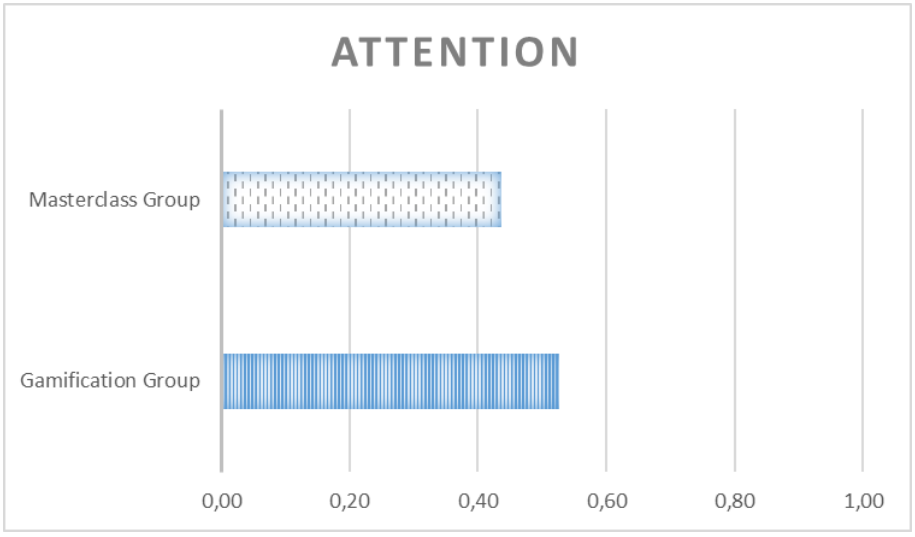

Figure 3. EEG Attention metric comparison for the Gamification and Masterclass groups.
Source: Prepared by the authors.

Fig. 3 shows an attention value for the experience in the gamification activity 21% higher than that recorded for the group attending the masterclass. Participants expressed, in the subsequent qualitative study, that the activity motivated them a lot.

3.3 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 11% compared to the masterclass. Fig. 4 shows the comparative results:

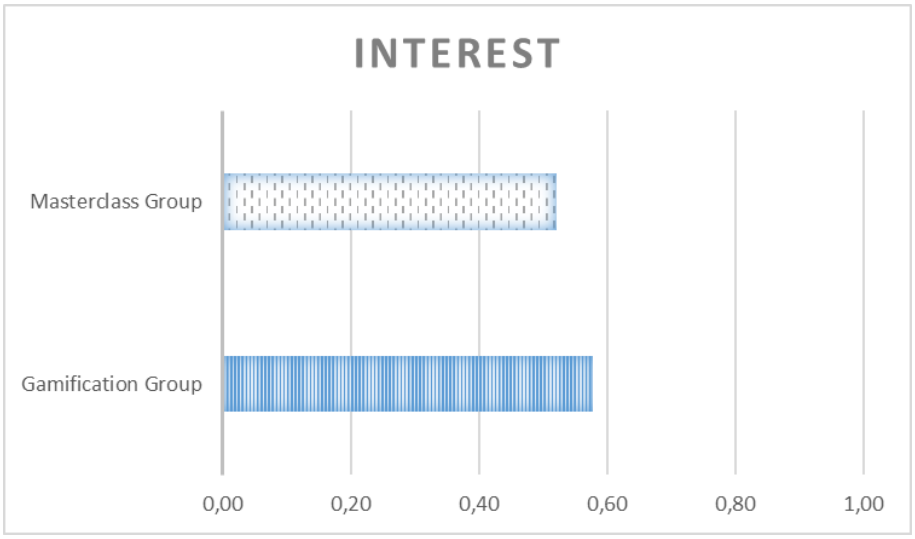

Figure 4. EEG Interest metric comparison for the Gamification and Masterclass groups. Source: Prepared by the authors.

Fig. 4 shows an interest value for the experience in the gamification activity 11% 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.

3.4 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 34% compared to the masterclass. Fig. 5 shows the comparative results:

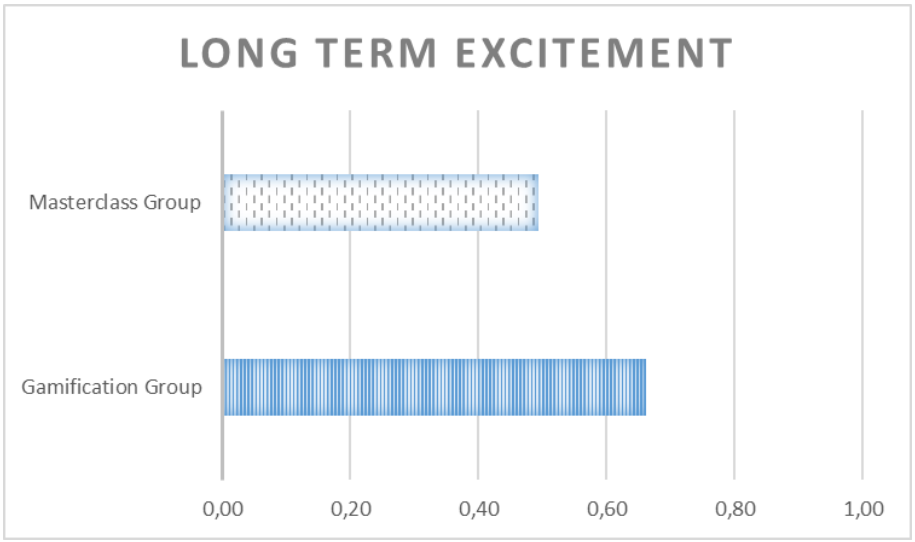

Figure 5. EEG Long Term Excitement metric comparison for the Gamification and Masterclass groups. Source: Prepared by the authors.

Fig. 5 shows a long-term excitement value for the experience in the gamification activity 34% 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.

3.5 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 36% compared to the masterclass. Fig. 6 shows the comparative results:

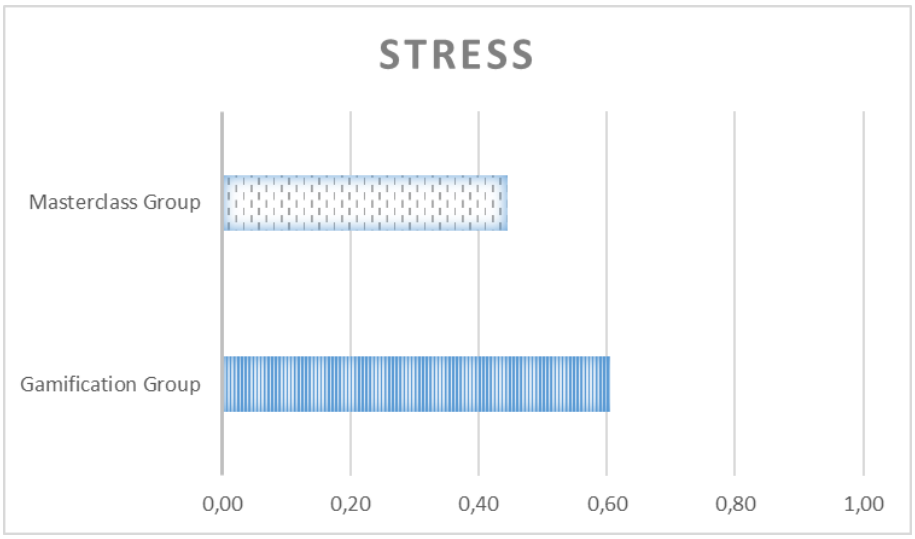

Figure 6. EEG Stress metric comparison for the Gamification and Masterclass groups. Source: Prepared by the authors.

Fig. 6 shows a stress value for the experience in the gamification activity 36% higher than that recorded for the group attending the masterclass. Participants expressed, in the subsequent qualitative study, that the activity presented them with a challenge to overcome, and the game had motivated them a lot.

3.6 Relaxation

Relaxation, understood as the ability to recover from intense concentration, was higher in the group participating in the gamification activity by 93% compared to the masterclass. Fig. 7 shows the comparative results:

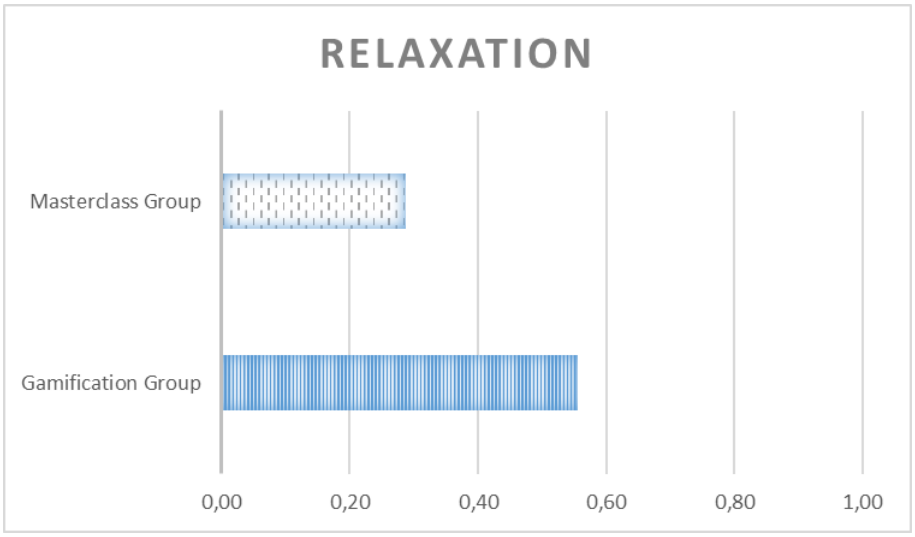

Figure 7. EEG Stress metric comparison for the Gamification and Masterclass groups. Source: Prepared by the authors.

Fig. 7 shows a relaxation value for the experience in the gamification activity 93% 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.

3.7 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 7% compared to the masterclass. Fig. 8 shows the comparative results:

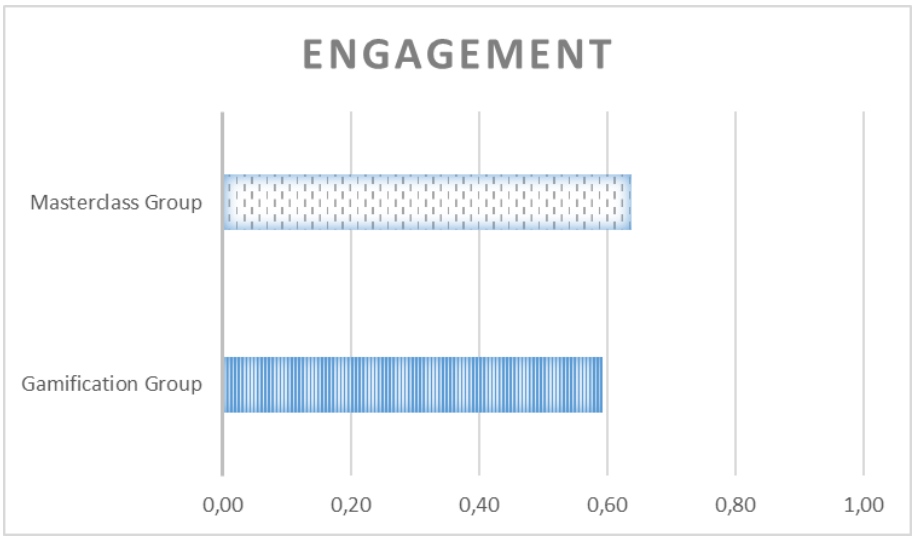

Figure 8. EEG Engagement metric comparison for the Gamification and Masterclass groups. Source: Prepared by the authors.

Fig. 8 shows an engagement value for the experience lived in the gamification activity that is 7% 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.

4 CONCLUSIONS

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 electroencephalography (PEEG) 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.

ACKNOWLEDGEMENTS

This research is part of the action line "Call for Educational Innovation and Improvement Projects" at the Universitat Politècnica de València, under the educational innovation call "Learning + Teaching (L+T)," in the category "Educational Innovation and Improvement Project in Consolidated Teams," within the PIME/23-24/399 project "Neurotechnological study of active methodologies and monitoring formats for learning improvement".

REFERENCES

[1] Kottmann, A., K. Schildkamp, and B. van der Meulen, Determinants of the Innovation Behaviour of Teachers in Higher Education. Innovative Higher Education, 2024.

[2] Maleko, E.V., et al., Applying Innovative Teaching Techniques and Methods, When Teaching Cultural Studies in Higher Education Institutions. Modern Journal of Language Teaching Methods, 2018. 8(11): p. 17-29.

[3] Hillman, T., The inscription, translation and re-inscription of technology for mathematical learning. Technology, Knowledge and Learning, 2011. 16(2): p. 103-124.

[4] Astashova, N.A., S.K. Bondyreva, and O.S. Popova, GAMIFICATION RESOURCES IN EDUCATION: A THEORETİCAL APPROACH. Obrazovanie I Nauka-Education and Science, 2023. 25(1): p. 15-49.

[5] Murillo-Zamorano, L.R., et al., Gamification and active learning in higher education: is it possible to match digital society, academia and students' interests? International Journal of Educational Technology in Higher Education, 2021. 18(1).

[6] Ilbeigi, M., D. Bairaktarova, and A. Morteza, Gamification in Construction Engineering Education: A Scoping Review. Journal of Civil Engineering Education, 2023. 149(2).

[7] Saxena, M. and D.K. Mishra, Gamification and Gen Z in Higher Education: A Systematic Review of Literature. International Journal of Information and Communication Technology Education, 2021. 17(4).

[8] Giordano, C.V. and L.T. Dias de Souza, Gamification and student motivation: considerations about techniques effectively applied in professional education. Revista Eniac Pesquisa, 2021. 10(1): p. 26-38.

[9] Viktoriia, P., et al., Gamification of education: innovative forms of teaching and education in culture and art. Eduweb-Revista De Tecnologia De Informacion Y Comunicacion En Educacion, 2022. 16(2): p. 119-133.

[10] AlSaad, F.M. and C.M. Durugbo, Gamification-as-Innovation: A Review. International Journal of Innovation and Technology Management, 2021. 18(05).

[11] Juárez-Varón, D., et al., Neurotechnologies Applied to Society's Perception of Cyber-Physical Systems (CPS) in Smart Cities. International Journal on Semantic Web and Information Systems (IJSWIS), 2024. 20(1): p. 1-32.

[12] Núñez-Cansado, M., G. Carrascosa Méndez, and D. Juárez-Varón, Analysis of the residual effect using neuromarketing technology in audiovisual content entrepreneurship. Sustainable Technology and Entrepreneurship, 2024. 3(3): p. 100069.

[13] Juárez-Varón, D., I. Bellido-García, and B.B. Gupta, Analysis of stress, attention, interest, and engagement in onsite and online higher education: A neurotechnological study. Comunicar, 2023. 31(76): p. 21-34.

[14] Juarez-Varon, D., et al., Footwear consumer behavior: The influence of stimuli on emotions and decision making. Journal of Business Research, 2023. 164.

[15] Emotiv. Performance Metrics. 2023 [cited 2023 Nov-2023]; Available from: https://www.emotiv.com/knowledge-base/performance-metrics/.