NEUROTECHNOLOGICAL STUDY OF THE APPLICATION OF THE ACTIVE LEARNING METHODOLOGY OF ROLE-PLAYING

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Abstract

The aim of this study is to explore and analyse the impact of the active Role-Playing methodology on the learning process in a face-to-face university setting, using neurotechnology. This approach represents an innovation in academic literature, as it employs neuroscience technologies to measure cognitive processing during a specific academic experience within a university master's program. The neurotechnologies used in the study include skin conductance response (GSR), electroencephalography (EEG), and eye tracking. These tools allow for the measurement of different aspects of cognitive processing, such as emotional response (GSR), brain electrical activity (EEG), and gaze patterns (eye tracking). The analysis of brain records focuses on key learning variables, such as attention, interest, stress, and emotional connection (engagement). These aspects are evaluated in the context of a face-to-face educational environment, providing valuable insights into how the active Role-Playing methodology influences these cognitive processes. The results obtained enable the quantification of the value of key learning variables through specific brain signals, offering detailed information on the impact of the active methodology in a face-to-face monitoring format. Additionally, the study identifies key aspects of the Role-Playing methodology for this specific environment, providing valuable information for designing and improving future learning experiences.

Keywords: Neuroeducation, neurotechnology, learning, active methodology, educational innovation, role-playing.

1 INTRODUCTION

In the realm of education, fostering innovation entails modifying the learning process to enhance overall outcomes [1]. A prevailing trend involves incorporating inventive techniques like gamification, role-playing, flipped teaching, and group dynamics to enrich the learning experience [2]. Rather than concentrating solely on student attendance, a comprehensive analysis should spotlight the interactions between teachers and students, as well as among students themselves, emphasizing both the quantity and quality of these interactions. Understanding the principles of brain-based learning becomes a crucial element in propelling educational innovation forward. This underscores the significance of neuroeducation in shaping the development of educational systems [3]. The incorporation of such insights contributes to a more dynamic and effective educational environment, fostering a holistic approach to learning.

Role-playing (RPG) is an activity in which participants assume fictitious roles and act according to the attributes and characteristics of those roles. This concept has been applied in various areas such as theatre, board games, video games, therapy, and education. In professional environments, role-playing is employed to simulate work situations and practice communication, problem-solving, and decision-making skills [4]. Many forms of role-playing involve a certain degree of improvisation, where participants must respond to unexpected situations in a manner consistent with their roles. In the educational context, role-playing is used to teach social skills, explore historical events, or simulate practical situations. Students take on specific roles to better understand concepts, fostering empathy as participants must step into another person's shoes and understand their thoughts, feelings, and perspectives [5]. It is a versatile and powerful tool used in various fields to promote creativity, enhance social skills, provide immersive learning experiences, and explore emotional and psychological aspects of the human experience, with the ability to implement and assess communication skills training [6]. Finally, it is worth noting that role-playing simulations are a promising transdisciplinary method for engaging stakeholders in decision-making processes [7].

2 METHODOLOGY

In this research, neuroscience technology was employed to document brain activity, aiming to capture cognitive processing during an academic experience within a university class (specifically, the Flexible

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Manufacturing Systems course in the Master's program in Engineering, Processing, and Characterization of Polymeric Materials - theoretical class). The study distinguishes between a first group that received a 45-minute lecture on the importance of numerical control machines in manufacturing and a second group that engaged in a 45-minute role-playing activity in the classroom. In this activity, participants assumed roles such as R&D director, quality director, financial director, production director, and human resources director. The R&D director was tasked with proposing the idea of acquiring a CNC machine for manufacturing, and the other departments had to take a position on this proposal. The R&D director had to develop their proposal using a Canvas Model template adapted for decision-making (Fig.1)

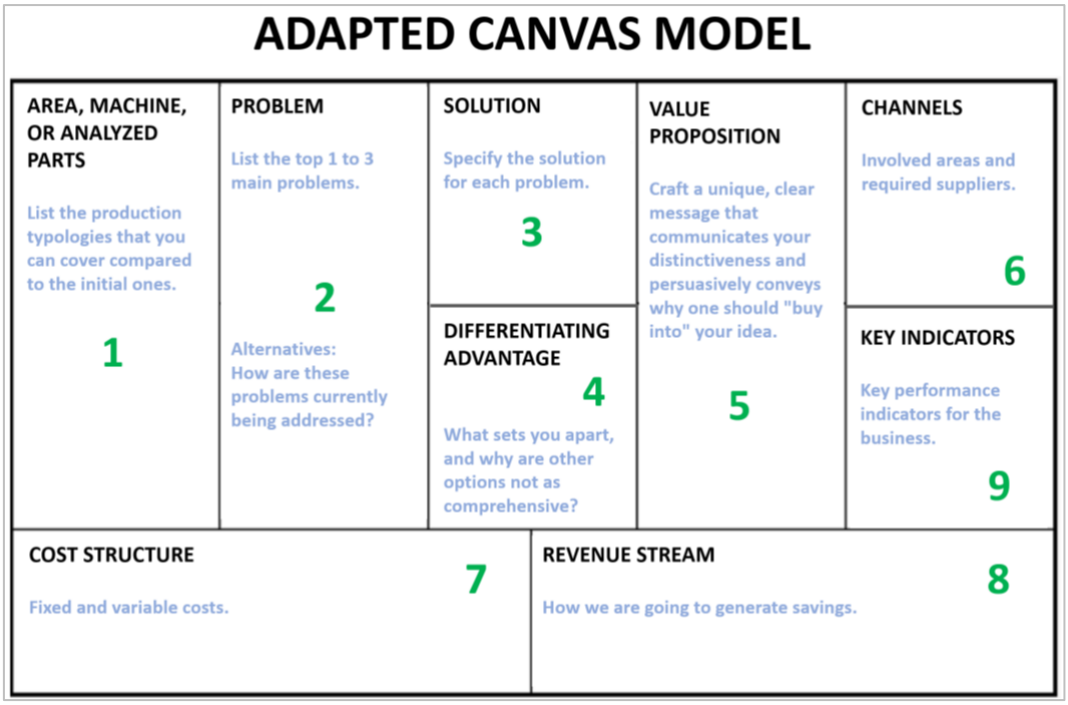

Figure 1. Adapted Canvas Model Template created by the authors. Source: Prepared by the authors.

The utilization of neuroscience technology allows for the assessment of the efficacy of stimuli targeted at users and the psychology of consumer behavior [8], offering more comprehensive insights than conventional research methods, which may be limited by participant behavior or perceptions. This study employs two specific neuroscience techniques: Skin Conductance Response (GSR) and Electroencephalography (EEG). Electrodermal activity (EDA) is measured using GSR, indicating fluctuations in emotional arousal in response to presented stimuli. Brain activity, monitored through brain waves, is documented via EEG [9].

2.1 Sample characteristics

The sample selected for the study consists of undergraduate students aged between 22 and 24 years. The total number of participants was 14 (50% male, 50% female), evenly distributed between the two proposed groups, representing a suitable sample size for a neuroeducation study [10]. 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

The Shimmer3 GSR+ model was utilized in both groups to record electrodermal activity, employing ConsensysPRO software, version 1.6, for data collection. This recording facilitated the assessment of participants' emotional arousal levels throughout the session, providing insights into the extent of sympathetic activation during the emotional experience [11]. For the recording of brain activity, the portable electroencephalography equipment EPOC+ by the manufacturer Emotiv, featuring 14 channels and saline-based electrodes, was employed. Data collection was conducted using EmotivPRO software version 2.0. This technology interprets the most relevant emotions experienced based on the gathered

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information from brain activity. The analyzed brain activations encompassed attention (focused on a specific task), interest (attraction or aversion to the stimulus), long-term emotion (physiological excitement with a positive value, stemming from sympathetic nervous system activation, reflecting enthusiasm), stress (a measure of comfort with the current challenge), relaxation (the ability to recover from intense concentration), and engagement (a combination of attention and concentration, contrasting with boredom). Engagement is defined as the capacity of a brand, product, service, or stimulus to establish a lasting connection between both parties [12].

3 RESULTS

Below are the results obtained from the recording of cerebral emotional activity, separating the overall analysis of the group (lecture group versus role-playing activity group) and the analysis of the groups participating in the role-playing activity.

The results obtained from the electrodermal activity (GSR) and electroencephalography (EEG) recordings are presented, in an aggregated manner, in Table 1 and Fig. 2 for both the lecture group and the role-playing 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 role-playing activity.

Table 1. GSR and EEG records for Masterclass Group and Role-playing Group.

Average emotional performance metrics	*Arousal*	*Attention*	*Interest*	*Long term Excitement*	*Stress*	*Relaxation*	*Engagement*
Masterclass Group	0,49	0,65	0,62	0,45	0,58	0,53	0,63
Role-playing Group	0,39	0,38	0,69	0,39	0,44	0,32	0,53
Role-playing vs. masterclass	+25%	+71%	+16%	+31%	+69%	+18%	-10%

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.

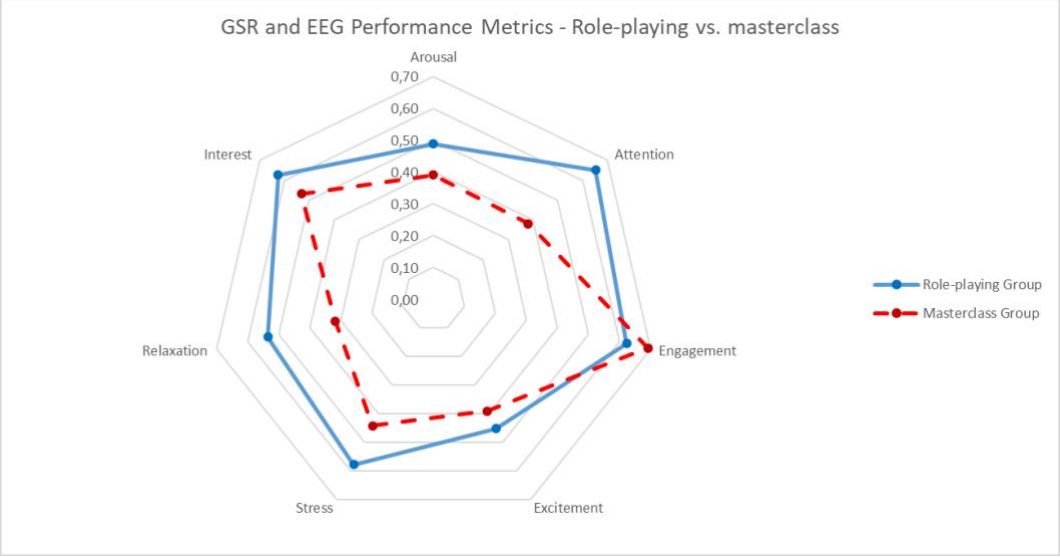

Figure 2. GSR and EEG performance metrics comparison for Role-playing and Masterclass groups. Source: Prepared by the authors.

Fig. 1 allows highlighting the overall increase in variables of brain activity recorded when using role-playing in the classroom. In percentage terms, the emotional intensity of role-playing activity exceeded its masterclass equivalent by 25%. Attention increased by 71%, interest by 16%, long-term excitement by 31%, stress by 69%, relaxation by 18%, and only engagement had a lower value, with a 10% reduction in the case of role-playing.

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Differentiating by the role of each department, the values obtained for the metrics are shown in Table 2 and Fig. 3:

Table 2. GSR and EEG records by department.

Average emotional performance metrics	*Arousal*	*Attention*	*Interest*	*Long term Excitement*	*Stress*	*Relaxation*	*Engagement*
Financial department	0,57	0,67	0,66	0,48	0,70	0,50	0,70
Human resources department	0,33	0,66	0,55	0,31	0,45	0,49	0,53
R&D Department	0,59	0,63	0,67	0,57	0,59	0,62	0,65
Production department	0,50	0,69	0,66	0,49	0,61	0,52	0,67
Quality department	0,45	0,60	0,57	0,42	0,53	0,54	0,57

Source: Prepared by the authors.

The department that has obtained the highest arousal is the R&D department (0.59), which is the department proposing the idea. Attention levels are very similar, with the production department having the highest value (0.69). Regarding interest, with similar values, the R&D department has obtained the highest value (0.67), and the same is true for the long-term excitement variable (0.57). The highest recorded stress corresponds to the financial department, while the highest relaxation is in the R&D department. Finally, the highest engagement corresponds to the financial department.

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

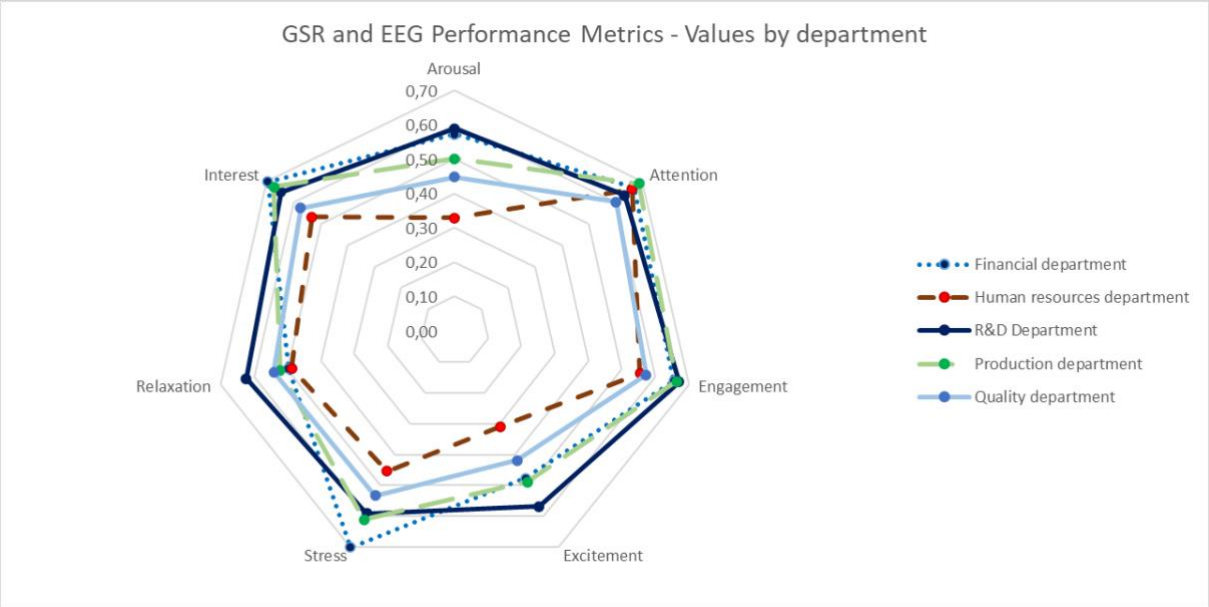

Figure 3. GSR and EEG performance metrics comparison by department.
Source: Prepared by the authors.

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 role-playing activity, by 25% compared to the masterclass. Figure 2 shows the comparative results.

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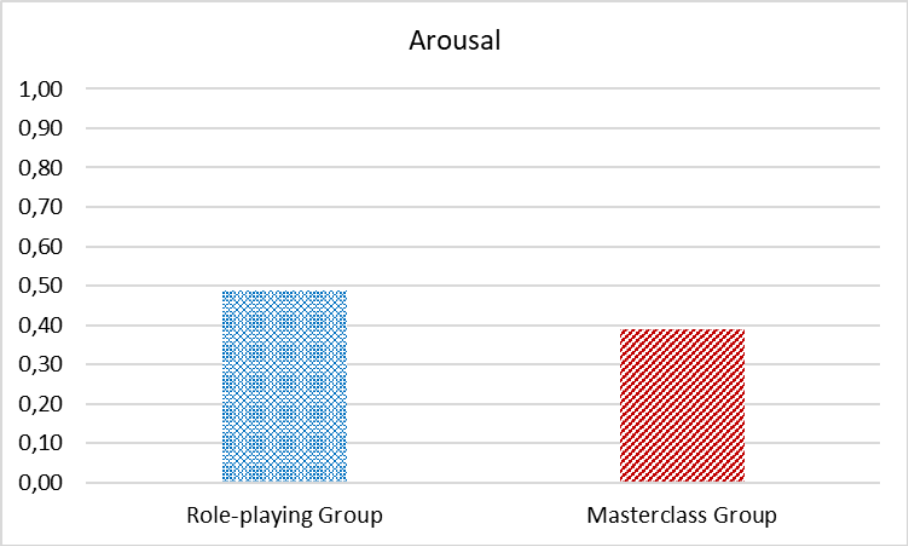

Figure 2. GSR metrics comparison for the Role-playing and Masterclass groups. Source: Prepared by the authors.

Fig. 2 shows an emotional intensity value (Arousal) for the role-playing activity 25% 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 role-playing activity by 71% compared to the masterclass. Fig. 3 shows the comparative results:

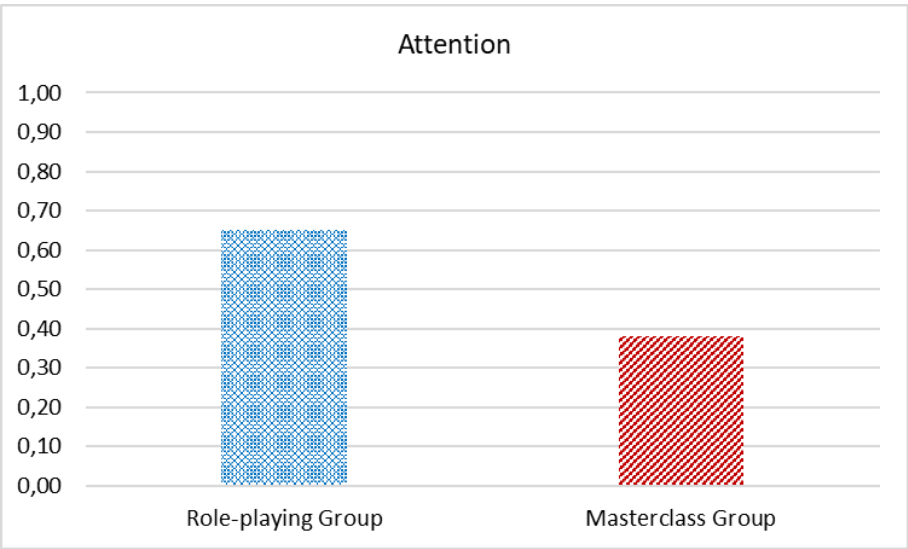

Figure 3. EEG Attention metric comparison for the Role-playing and Masterclass groups. Source: Prepared by the authors.

Fig. 3 shows an attention value for the experience in the role-playing activity 71% higher than that recorded for the group attending the masterclass. Participants expressed, in the subsequent qualitative study, that the activity motivated them a lot.

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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 role-playing activity by 16% compared to the masterclass. Fig. 4 shows the comparative results:

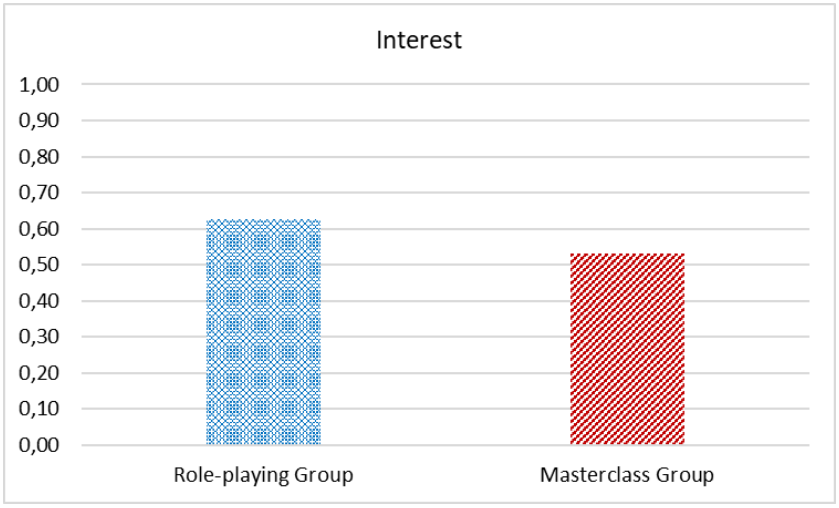

Figure 4. EEG Interest metric comparison for the Role-playing and Masterclass groups. Source: Prepared by the authors.

Fig. 4 shows an interest value for the experience in the role-playing activity 16% 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 role-playing activity by 31% compared to the masterclass. Fig. 5 shows the comparative results:

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

Fig. 5 shows a long-term excitement value for the experience in the role-playing activity 31% 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.

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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 role-playing activity by 69% compared to the masterclass. Fig. 6 shows the comparative results:

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

Fig. 6 shows a stress value for the experience in the role-playing activity 69% 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 motivated them.

3.6 Relaxation

Relaxation, understood as the ability to recover from intense concentration, was higher in the group participating in the role-playing activity by 18% compared to the masterclass. Fig. 7 shows the comparative results:

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

Fig. 7 shows a relaxation value for the experience in the role-playing activity 18% 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.

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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 role-playing activity by 10% compared to the masterclass. Fig. 8 shows the comparative results:

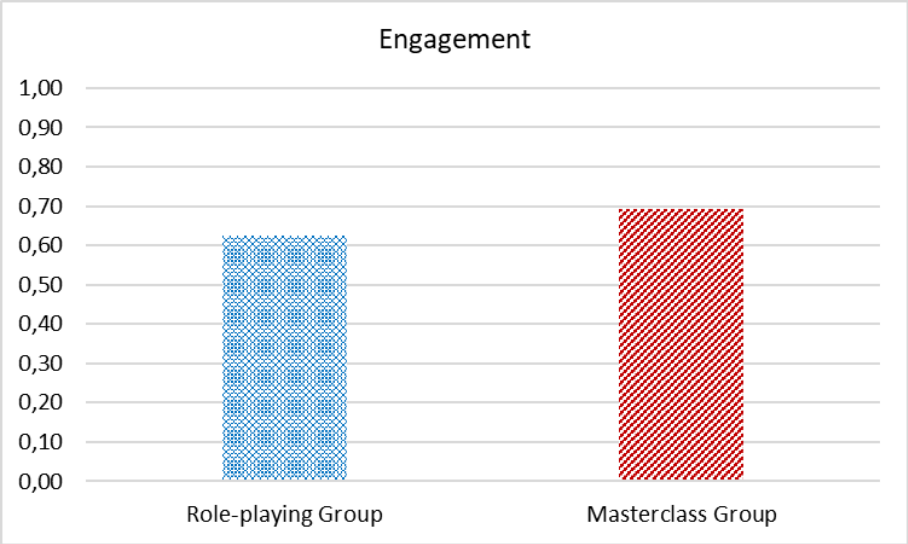

Figure 8. EEG Engagement metric comparison for the Role-playing and Masterclass groups. Source: Prepared by the authors.

Fig. 8 shows an engagement value for the experience lived in the role-playing activity that is 10% lower than that recorded for the group that attended the master class. In the subsequent qualitative investigation, participants in the master lesson conveyed that the instructor effectively communicated concepts, employing clear explanations and illustrating ideas with easily comprehensible examples. The qualitative study delved into the participants' perspectives, shedding light on the instructor's ability to articulate complex ideas in a manner that resonated well with the learners.

4 CONCLUSIONS

The primary objective of this study has been to establish that learning through role-playing activities proves more effective, as indicated by brain signals, than traditional classroom instruction for a theoretical course designed for university-level students. The findings from the conducted experiment demonstrate heightened emotional intensity levels among students engaged in role-playing activities compared to those following the masterclass format. Examining the recorded brain activity of students through portable electroencephalography (PEEG) biometrics, values generally trend higher in the role-playing activity group. Five out of six variables recorded (attention, interest, long-term excitement, stress, and relaxation) show higher levels in the role-playing group. However, the sixth variable, engagement, exhibits similarity (with a 10% decrease for the role-playing group), potentially attributed to the emotional connection traditional classroom students may foster with the instructor. This suggests a nuanced interplay between instructional methods and emotional engagement in the learning process.

Students successfully demonstrated a variety of important competencies through this experience, perceiving it as challenging and highly beneficial for their personal life and professional development [4]. Role-playing games simulate real-life scenarios, enabling students to apply their skills and knowledge in real-time practice, bridging the gap between theoretical concepts and practical application [13]. The implementation of this active learning methodology can equip students with the skills, strategic vision, and professional competencies necessary for innovative practices in the industry. Simulated learning environments, including assessment rubrics and connected instructional methods, can be implemented and further developed for similar educational endeavors [14]. Finally, it is worth noting that the methodological and practical knowledge acquired can be transferred to other subjects in different fields.

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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".

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