Comunicar, n. 76, v. XXXI, 2023 | Media Education Research Journal | ISSN: 1134-3478; e-ISSN: 1988-3478
www.comunicarjournal.com

Analysis of stress, attention, interest, and engagement in onsite and online higher education: A neurotechnological study

Análisis del estrés, atención, interés y conexión emocional en la enseñanza superior presencial y online: Un estudio neurotecnológico

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ABSTRACT
The aim of this work is to register and analyse, using neurotechnology, in onsite onsite and online university educational context, the effect on relevant variables in the learning process. This represents an innovation in the current academic literature in this field. In this study, neuroscience technology has been used to measure the cognitive processing of stimuli designed for an academic experience in a university master's degree class. The neurotechnologies employed were galvanic skin response (GSR), electroencephalography (EEG) and eye tracking. After the analysis of the brain recordings, based on attention, interest, stress and engagement in an onsite educational context and their comparative analysis with the online monitoring, the results indicated that the levels of emotional intensity of the students who followed the class in person were higher than those who attended online. At the same time, the values of positive brain activity (attention, interest and engagement) were higher in the onsite group, and the negative variable stress was also higher, which could be explained by the fact that the online students did not activate the camera. The brain recordings of students who were distance learning show less interest and attention, as well as less emotional intensity, demonstrating that distance (online) learning is less effective than classroom learning, in terms of brain signals, for a theoretical university master's degree class.

RESUMEN
Este trabajo tiene como objetivo registrar y analizar, mediante el uso de neurotecnología, en un contexto formativo universitario presencial y online, el efecto que tiene en variables relevantes en el proceso de aprendizaje, lo cual supone una innovación en la literatura. En este estudio se ha empleado tecnología de neurociencia para medir el procesamiento cognitivo de los estímulos diseñados para una experiencia académica de una clase de máster universitario. Las neurotecnologías empleadas han sido la respuesta galvánica de la piel (GSR), la electroencefalografía (EEG) y el seguimiento ocular. Tras el análisis de los registros cerebrales, basados en la atención, interés, estrés y conexión emocional (engagement), en un contexto educativo presencial y su análisis comparativo con el seguimiento online, los resultados indicaron que los niveles de intensidad emocional de los alumnos que siguieron la clase de forma presencial son más elevados que aquellos que asistieron de forma online. A su vez, los valores de actividad cerebral positiva (atención, interés y engagement) son superiores en el grupo de asistencia presencial, siendo la variable negativa estrés también superior, pudiendo justificarse debido a que los alumnos conectados online no activaban la cámara. Los registros cerebrales de los alumnos que asisten a distancia muestran menor interés y atención, así como una menor intensidad emocional, por lo que el aprendizaje a distancia (online) es menos efectivo, a efectos de señales cerebrales, que la enseñanza en el aula, para una clase teórica de máster universitario.

KEYWORDS | PALABRAS CLAVE
Learning, classroom teaching, online teaching, university, educational innovation, neuroeducation.
Aprendizaje, enseñanza presencial, enseñanza online, universidad, innovación educativa, neuroeducación.

Received: 2022-12-25 | Reviewed: 2023-01-22 | Accepted: 2023-02-23 | OnlineFirst: 2023-05-30 | Published: 2023-07-01
DOI https://doi.org/10.3916/C76-2023-02 | Pages: 21-33

1. Introduction

Innovating in education means making changes in the learning process with the aim of improving the results obtained (Horn et al., 2009). Digital technologies, as part of the innovation process, are being increasingly integrated into education, often used as mediators in the teaching and learning process (da-Silva et al., 2023). There is a trend towards online teaching, which represents the basis for the construction of learning for society in the 21st century, with the COVID-19 pandemic marking the turning point at which the use of online methodologies to achieve online teaching became incredibly widespread (Sanchez-Mendiola et al., 2020). The analysis should not focus on the location of the teacher and the student, but on the interactions between them, both in terms of quantity and quality. Understanding the principles of how the brain functions in learning contributes to the advancement of educational innovation, and thus neuroeducation facilitates the development of educational systems (Hillman, 2011). The purpose of this research is to determine, through neuroscience technologies, the difference in brain activation levels between a group of students with classroom teaching compared with another group of students who follow the class remotely, synchronously (online), in a theoretical class session on consumer behavior, which is part of a master's degree course. In this case, biometrics were used to monitor the intensity or emotional arousal experienced (GSR - galvanic skin response) and brain activity (EEG - electroencephalography), shown through variables of attention, interest, stress and engagement. This study aims to respond, empirically, to aspects related to the difference in efficiency of classroom teaching compared to online teaching. The specific objectives of the research are as follows:

- Analyze the levels of emotional arousal registered depending on the format (classroom teaching or online).
- Analyze the levels of attention, interest, stress and engagement of the participants, depending on the format of the class.
- Determine which monitoring modality is most effective, according to data provided by the biometric measurements carried out.

2. Theoretical framework

Innovation can be defined as the sequence of stages to conceive new products or services which can be adopted or redesigned for their applications and transformation (Rikkerink et al., 2016), even in an open manner (Ramírez-Montoya & Lugo-Ocando, 2020). Thus, innovation is the result of applying new processes (strategy, methodology, organization, procedure, training, technical development), new services (provision, care, function, benefit, action, dependence, assistance), new products (material, prototype, manufacture, object, technology, application, result), or new knowledge (knowledge, evolution, cognition, talent, model, impact, transformation, patent, system).

The application of innovation to education is called educational research, the objective of which is the systematic inquiry of a research question of interest (Horn et al., 2009). What generally differentiates such research from other traditional types of research is typically the problem on which the work is focused. Innovation in services, products, processes and knowledge generates change in education, where innovation often helps to address problems and situations arising from teaching practices and presentation. In relation to this, innovating in education consists of generating changes that improve learning results, through improvements in training (Clark et al., 2016). To achieve this, educational innovation must be embraced in an inclusive and holistic manner, and so students, educational providers, communities, companies, and political organizations need to integrate the key aspects of innovation throughout their hierarchy of levels.

Similarly, it is important to understand the proposal of research applications stated by academics (Ramírez-Montoya & Lugo-Ocando, 2020). It is a comprehensive classification based on educational management (planning, organization, administration, management and evaluation of resources), psych pedagogy (teaching and learning), technology applied to education (use and development, both onsite and remote) and sociocultural management.

There is great interest within education in using digital technologies as mediators of the teaching and learning process (da-Silva et al., 2023). In the field of education, there is a growing interest in technologies that support teaching and learning activities. When modern technology is systematically applied to an organized educational process, it can be used in three domains: tutoring, teaching tool and learning tool. Today, educators are increasingly familiar with tools that can be used in distance learning, educational games, and simulations; many researchers also pay more attention to the effects that technology can generate (Waxman et al., 2013). Many studies suggest that the use of technology could inspire positive effects among students, such as improving academic performance, increasing students' competitive abilities, and raising learning motivation (Clark et al., 2016; Lai & Bower, 2019). The growth and trends in the field of educational technology deserve attention.

Furthermore, the definition of technology may have numerous ramifications. In some recent studies, educational technology is defined as "tools that help students acquire cognitive knowledge, improve communication skills, and develop problem-solving skills" (Lee et al., 2019). Based on this definition, the emphasis would fall on those related to information technology (Doyle et al., 2019), since not only learning instruments are being revolutionized by technological advances, but also the pedagogies and mentalities of educators.

There is a trend towards distance learning, which represents the foundation for the construction of learning for society in the 21st century, with the COVID-19 pandemic being the turning point. This was a time when onsite education for high school and university students was interrupted in more than one hundred countries (Sánchez-Mendiola et al., 2020). This affected traditional programmed teaching and encouraged the use of online methodologies to be able to continue an education that suddenly had to be at a distance. There are comparative studies between virtual and classroom teaching scenarios, such as the didactic content preferences of university professors in different teaching environments (Sevimli, 2022), the lower grades in virtual environments (Morgan, 2015), the improvement of students' self-learning (Huamán-Romaní et al., 2021), the lack of motivation, contact with classmates or the absence of classroom practices and other aspects that cause disinterest and increase the dropout rate of subjects (Chávez-Miyauchi et al., 2021; Serrano-Díaz et al., 2022).

The key and innovative role of ICT and communication is to encourage interaction between the students themselves and reduce the teacher-student distance. This makes it necessary for the teacher, before starting the course, to correctly organize the work, achieving the same knowledge and skills, regardless of the format of attendance by the students. The lack of personalized contact with the student is one of the main disadvantages of distance learning. Videoconference, for example, is an adequate system to listen to and see the student, and there must always be a commitment from the teacher to respond within a good amount of time. Social interactions are key in the construction of knowledge (Van-Ameringen et al., 2003), however, those students with social anxiety may choose the distance approach as a solution to their mental disorder.

Linking learning and the brain, it is necessary to carry out a restructuring of pedagogical practices so that they can be linked to the contributions of neurosciences. Neuroscience allows us to rethink education and what data this field provides so that pedagogy can continue optimizing the explanations of the teaching and learning processes (Bueno-i-Torrens & Forés-Miravalles, 2021). Learning and memory are closely related in terms of mental processes, and these give rise to adaptive changes in behavior (Morgado-Bernal, 2005). Active learning makes the student go beyond simple memorization and make an effort to understand the concepts and information with which they answer the teacher's questions. This type of learning, based on relating and contrasting a range of information, helps make mental processes more robust and improves memory (Bernal, 2022). In this sense, neuroeducation is emerging as a new science whose main objective is the synergy of pedagogy, cognitive psychology and neuroscience, and with this, to be able to bring the necessary resources to the different educational agents in terms of the binomial brain-learning. Neurosciences are developing research focused on the neural bases of learning, memory, emotions and different functions of the brain, the results of which have high applicability in the field of learning (Bowers, 2016; Howard-Jones, 2014). The development of neuroeducation contributes to the advancement of educational innovation, as well as to the development of educational systems.

Over the past two decades, research in cognitive neuroscience has provided significant insights into how the brain functions and into the neural mechanisms of learning. It is important to know how the brain is formed and learns (Bueno-Torrens & Forés-Miravalles, 2018), since one of the keys is the amygdaloid body, traditionally associated with the emotional system of the brain and is involved in emotional learning (Torras et al., 2001). Educational neuroscience is an interdisciplinary field of research that seeks to translate research findings on the neural mechanisms of learning into educational practice and policy. This field is also a basic science that studies how education changes the brain and the mechanisms that lead to behavioral changes (or lack thereof) through education. The relevance of neurobiology in relation to education was recognized throughout the 20th century, but it was not until the 1990s and the "Decade of the Brain" that technological advances in live imaging of brain function led to the theoretical advances that made educational neuroscience viable as a field (Varma et al., 2008).

Despite ongoing criticism and debate about the merits of applying knowledge from neuroscientific research to educational problems (Bowers, 2016), potential connections between neuroscience and education are being actively explored around the world. Different labels have been used to describe such efforts. These include neuroeducation, educational neuroscience, and mind, brain, and education. However, translating neuroscience research into education is difficult. This process is extensive and starts with a basic science foundation. The complexity of learning in the brain and the state of current scientific knowledge means that there is a risk of premature translation before the foundation is established. This risk is compounded by the legitimate desire of policymakers to use scientific evidence to inform their educational policies (Bittencourt & Willetts, 2018) and the enthusiasm that educators have to inform their teaching with insights into how the brain works. Furthermore, the interplay of the disciplines of neuroscience, psychology and education has sometimes been characterized by competition rather than collaboration, and educational researchers remain wary of the hype surrounding education.

Neuroeducation is a new discipline that is under development, thanks to the contributions of neuroscience, cognitive psychology, and educational sciences, to generate a better understanding of how to learn and how this information can be used to create teaching methods, curricula and educational policies (Carew & Magsamen, 2010). Despite the fact that neuroeducation is just beginning in the field of research, it is giving rise to new critical dialogue between teachers, those responsible for educational administrations, families and the scientific field.

Entering into the conceptual delimitation of the term, neuroeducation is classified as applied cognitive neuroscience, especially if there are no substantial differences in the philosophical orientations and methodologies found between education and cognitive neuroscience (Campbell, 2011). It is an area of educational research that is based on the mechanisms of information processes, theories and methods of applied cognitive neuroscience, but unlike these, it is not limited to these elements, since neuroeducation has the person as its principal object, and not only the physiological and biological mechanisms on which neurosciences are based. Considering the transdisciplinary approach of neurosciences, neuroeducation can contribute to the construction of new educational frameworks and new research methodologies that serve as a reference framework in the learning-brain binomial, including the learning of social values in favor of prosocial behavior that move towards an inclusive and sustainable society (Villardón-Gallego et al., 2018).

Regarding the centers of interest of the neurosciences with respect to neuroeducation, neuroscientific research addresses the pathologies of learning difficulties (Ferrari, 2011); consequently, the objective from educational research should be to understand the broader context of learning and personal development that complements the contributions of neuroscience and avoids the labelling of atypical students which often leads to possible stigmatization. It is this juncture of increased interdisciplinary collaboration between neurosciences and education that has made possible the emergence of this new disciplinary field, known as neuroeducation, which will not only inform educational approaches, but also advance scientific understanding of the relationship of neural processes with complex behaviors observed in the classroom.

3. Methodology

In this study, neuroscience technology has been used to record brain activity, with the aim of recording cognitive processing in an academic experience of a master's degree class (Consumer Behavior subject - theoretical class), through stimuli designed so that the session is followed in person and online synchronously (without connection of cameras by the students). It is experimental research, and the results are limited to the conditions of the registered experience, not assuming a generalization of results for any experiment.

The use of neuroscience technology makes it possible to analyze the effectiveness of the stimuli projected onto users and the psychology of consumer behavior (Plassmann et al., 2012), providing more information than other conventional research methods, where the behavior or perceptions of participants may limit the study.

Eye tracking, galvanic skin response (GSR) and electroencephalography (EEG) are the three specific neuroscience techniques used in this work. The visual attention of the students is captured from the ocular movement (Duchowski, 2007). Electrodermal activity (EDA) is recorded through GSR, reflecting changes in emotional arousal due to projected stimuli. Finally, brain activity (brain waves format) is recorded by EEG (Yadava et al., 2017). The attention of the students is recorded by the eye tracker, starting the affective and cognitive process (partially recorded by GSR and EEG). When subjects focus their attention on a stimulus, it is recorded by the eye tracking system and initiates cognitive and affective processing (recorded by GSR and EEG) (Ramele et al., 2012). The variables measured with these biometrics focus on stress, attention, interest, and engagement (Juarez et al., 2020). Stress measures how comfortable an individual is with a task. Elevated stress can result from the inability to complete a difficult task or fearing negative consequences for not meeting the task's requirements. In general, a low to moderate level of stress can improve productivity, while a higher level tends to be destructive and can have long-term consequences for health and well-being. Attention is a measure of concentration on a specific task. This variable records the depth of attention, as well as the frequency with which attention switches between tasks. A high level of task switching is an indication of inattention and distraction. Interest measures the degree of attraction towards the stimuli, the environment or the current activity. Low interest scores indicate a strong dislike of the task, high interest indicates a strong affinity for the task, while mid-range scores indicate that individuals neither like nor dislike the activity. Finally, emotional connection is experienced as alertness and the conscious direction of attention toward task-relevant stimuli. It measures the level of immersion in the moment and is a mixture of attention and concentration, and contrasts with boredom.

The first task is to find out how the neural bases of the brain predispose us to act in one way or another in relation to autonomy and happiness, establishing a series of conclusions about how the neural bases of the brain influence and how they contribute to learning. In this context, neuroeducation is a new-born discipline which facilitates the study of users, their perceptions, and the global experience (Bercík et al., 2016). Neuroeducation, therefore, makes it possible to register the existence of a possible positive emotional connection between students and the classes that are taken, allowing us to determine in a scientific way the levels of attention and emotion that are generated by paying attention to the classes taught, making a clear distinction between online and onsite.

There are studies on the use of portable EEG technology (PEEGT) in educational research (Xu & Zhong, 2018). These tools have been used mainly to assess the attention and meditation of the participants. PEGT has been used primarily in seven research topics: reading context, patterns of presentation of learning materials, interactive behavior, edutainment, e-learning, motor skill acquisition, and promoting learning performance with PEEGT.

Although brain wave analysis is now quite advanced in a variety of academic and professional contexts, such as healthcare, few studies have put brainwave analysis in the classroom setting. In the past, brainwave experiments required a lot of preparation, and also required the use of gel to affix electrodes to the experimental subject's head. For these reasons, it was challenging to administer brainwave experiments in the classroom. However, with advances in technology, EEG equipment is becoming more and more portable, so it is now possible to obtain accurate brainwave data with just a simple miniature setup.

Regarding portable EEG technology (PEEGT), most offer a painless, low-cost, ergonomic, wireless EEG monitoring solution for researchers and everyday users who are interested in monitoring neural correlations associated with various behaviors and mental processes. Nowadays, there are indications that more and more researchers like to use PEEGT as a research tool in their educational research, which suggests that PEEGT is becoming an increasingly relevant tool in educational research. However, this statement needs to be further supported through the application of experiments and, above all, through empirical evidence.

Wang & Hsu (Wang & Hsu, 2014) used the PEEGT Neurosky equipment Mindset to measure students' attention levels during computer-based instructional learning, in which participants completed three lessons of easy, medium, and hard levels. Ghergulescu and Hava-Muntean (2016) used the neuroheadset Emotiv EPOC to measure student engagement during game-based e-learning. Other work (Lin & Hsieh, 2016) also used the NeuroSky headset MindWave to recognize student attention levels during e-learning. Most of the published works used PEEGT to assess the attention (and meditation) of the participants, with a few studies using it to detect the motivation of the participants (and commitment) and emotions.

Most of the EEG experiments (Wang & Hsu, 2014) lasted less than 60 minutes. The sample sizes of the EEG experiments were small, the largest research group was university students, and the portable EEG devices used in the educational research were primarily developed by NeuroSky Inc. and Emotiv Inc.

It is important to understand the relationship between the EEG data and the different cognitive aspects, as well as the pedagogical implications highlighted in these cognitive aspects:

Attention and Meditation: Attention is the behavioral and cognitive process of selectively concentrating on a discrete aspect of information, whether considered subjective or objective, while ignoring other perceptible information (Talmi et al., 2008). Unlike mindfulness, meditation is an intentional, self-regulated focus of attention to relax and calm the mind (Anand et al., 2014). Meditation does not represent the physical state of an individual, but their mental state, and refers to a reduction of the brain's active mental processes. That is, higher relaxation values indicate that an individual is more relaxed and less stressed. PEGT detects human brainwaves according to selected α, β, δ and θ wave characteristics. The variation of the β wave in the EEG is strongly correlated with attention, and the α wave is strongly correlated with meditation. Higher levels of meditation can increase students' ability to pay attention and, as a result, can help them better absorb and retain information. If the levels of attention and meditation are high, the students will be in the optimal state to learn.

Motivation and commitment: Student motivation is one of the main aspects that must be addressed for a successful learning process. Consequently, the assessment and measurement of learner motivation have attracted a great deal of research interest in the area of e-learning in general and in game-based learning in particular. There are studies that show that commitment is a main indicator of motivation (Saeed & Zyngier, 2012), and other studies have confirmed that the $\beta/(\alpha+\theta)$ index obtained from EEG data better reflects commitment (Prinzel et al., 2009).

Emotion (frustration and excitement): According to the broaden-and-build theory, positive emotions broaden the span of attention, cognition, and action, and these then broaden the range of perceptions, thoughts, and actions existing in the mind at that moment. Isen and Reeve (2005) found evidence that students with more positive emotions had better memory recall and were therefore able to remember things more easily. Furthermore, it has been recognized that learning with positive emotions improves learning motivation, problem-solving ability, and cognitive behavioral ability more than when learning with negative emotions.

At present, only the neuroheadset Emotiv EPOC provides a standard development kit (SDK) that can extract frustration and emotion intensities from brain signals in real time. The emotional state is represented by the frustration and arousal values obtained from the SDK.

3.1. Sample

The sample selected in the study is made up of master's degree students between the ages of 22 and 25, interested in the subject taught (Consumer Behavior), who volunteered to participate and signed a consent agreement. A total of 20 students (50% men, 50% women) were monitored (with more non-monitored classmates), making the sample size adequate for a neuroeducation study (Cuesta-Cambra et al., 2017). The field work was carried out between March and April 2022 and the location of the study was in the city of Valencia (Spain).

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3.2. Data collection and analysis

The research phase, with the stimuli exposed, was performed using eye tracking models «Pupil Core» (from Pupil Labs manufacturer, with a sampling frequency of 200 Hz) for classroom learning, and «Gazepoint» (from the manufacturer Gazepoint, with a sampling frequency of 60 Hz) for online learning. For data collection and analysis, the Pupil Capture software, v.1.23 (classroom learning) and the Gazepoint software Analysis UX Edition v.5.3.0 (online learning) were used. To record the electrodermal activity, the Shimmer3 GSR+ model was used in both follow-up models, using the ConsensysPRO software, v.1.6, for data collection. The data gathered showed the emotional arousal that the participants felt throughout the class.

Finally, to record brain activity, the portable EPOC+ electroencephalography equipment was used, with 14 channels and saline-based electrodes from the manufacturer Emotiv. For data collection, the EmotivPRO v.2.0 software was used. This technology is used to interpret the most relevant emotions felt, derived from the information collected from brain activity. The brain activations that were analyzed were attention, interest, stress, and engagement, with engagement being the ability of a brand, product, service, or stimulus to create a lasting bond between both parties (Van-Doorn et al., 2010).

The statistical analysis of the data was performed with the R software, v.3.6.3. Common elements (stimuli) were defined for all consumers (volunteers). The independent variables were the age and gender of the participants, with a similar sociocultural profile and determined by the main profile of the master's degree program. The dependent variables were the level of emotional intensity and the levels of attention, interest, stress, and engagement, in response to the observed stimuli.

To carry out this study, an experiment was carried out with a biometric approach. The objective is to know the subconscious perceptions of the students when observing the classes, both in their classroom format and online. There were 20 students per session, but only the volunteers were monitored (a total of 4 per session). The study was carried out over 5 days with 4 different participants, repeating the same session on Friday afternoon at 4:00 p.m., which was the first hour of class that day. The students could participate in a set of closed concepts. The technology was installed and calibrated by experts in neuroscience, obtaining values within tolerance. A total of 50% of them followed the class in person and the other 50% at a distance, synchronously. The total duration of the class was 45 minutes, during which the brain activity of the students was recorded with the Eye Tracking, GSR and EEG technologies. During the calibration process and because they are wireless technologies and almost imperceptible, students and teachers do not perceive them.

4. Analysis and results

In order to record and analyze the emotional arousal of the students throughout the 45 minutes, the data was divided into three parts:

- First part: 0-15 minutes.
- Second part: 15-30 minutes.
- Third part: 30-45 minutes.

Table 1 shows a summary of the average data collected for the 2 groups (classroom and online). The recorded values are shown in parts per unit, with 0 a null value and 1 the maximum achievable value for each measured variable. The overall average of the experiment refers to the average of each of the average values of the three-time ranges (the 3 parts).

Table 1. Average brain activity data for the classroom group and the online group

	Classroom				Distance/Online			
Part of the class (minutes)	**0-15**	**15-30**	**30-45**		**0-15**	**15-30**	**30-45**	
Registered emotion (average – percent)				**Average experience**				**Average experience**
Average Emotional Intensity	0.73	0.49	0.46	0.56	0.23	0.19	0.21	0.21
Average Attention	0.41	0.44	0.46	0.44	0.42	0.42	0.46	0.43
Average Interest	0.74	0.59	0.63	0.65	0.56	0.62	0.66	0.61
Average Stress	0.45	0.50	0.52	0.49	0.36	0.43	0.47	0.42
Average Engagement	0.74	0.59	0.63	0.65	0.56	0.62	0.66	0.61

4.1. Emotional arousal analysis – GSR

The following figure (Figure 1) shows the average emotional level in each part, for classroom and online formats, measured through the galvanic skin response (GSR).

Figure 1. Results of the GSR analysis

The levels of emotional arousal (intensity) of the students who followed the class in person are higher than those who attended online/at a distance. The level of emotional arousal of the classroom group reached the following values:

- First part (minutes 0-15): 0.73 (73%).
- Second part (minutes 15-30): 0.49 (49%).
- Third part (minutes 30-45): 0.46 (46%).

On average, in the entire class, the classroom students showed a 56% level of emotional intensity. On the other hand, the online students reached the following levels of emotional arousal throughout the 3 parts of the class:

- First part: 0.23 (23%).
- Second part: 0.19 (19%).
- Third part: 0.21 (21%).

On average, in the entire class, online students showed a 21% level of emotional intensity. It should be noted that the emotional intensity values are higher in the classroom group during the first third of the class, decreasing as the class progresses. However, in the online group the values are lower and more stable.

4.2. Analysis of brain activity - EEG (electroencephalography)

We analyzed and compared the levels of attention, interest, stress and engagement (emotional connection), accompanied by the level of emotional arousal (intensity), differentiating between the group that followed the classes in the classroom and distance/online formats.

Figure 2 shows the average level of emotional arousal and the average level of attention, for classroom and distance/online formats, for each part measured through portable electroencephalography (PEEGT).

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Figure 2. Results of the analysis of attention measured with PEEGT

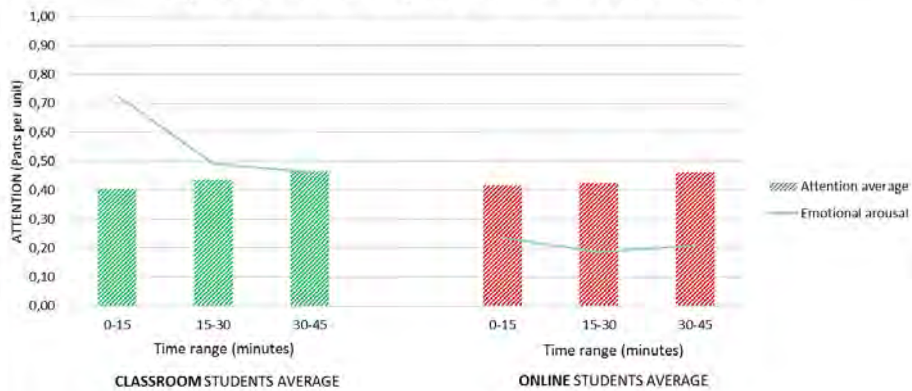
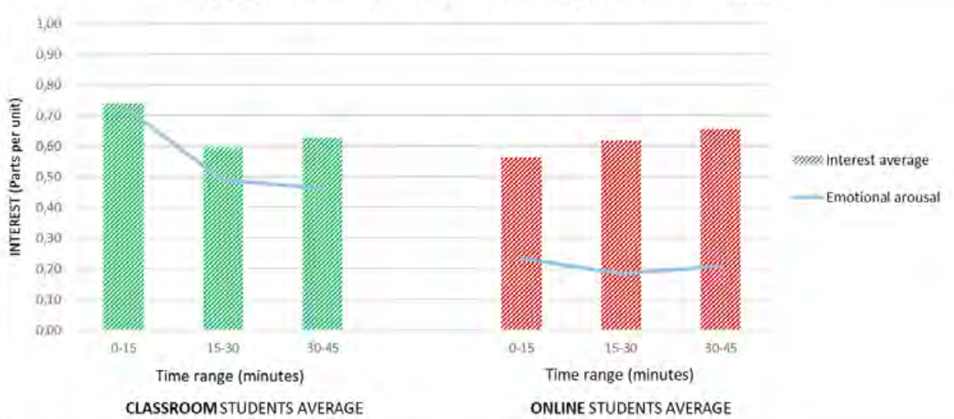


Figure 2 shows that the levels of attention are similar, although slightly higher for students who attend class online in the first part (minutes 0-15). Later, the levels of attention increase for the classroom students, and it is maintained in the online group (part 3), ending with an equal level in part 3 of the class. In the experiment, the classroom students reached an average level of attention equal to 44%, while the online attendees reached 43% (the figure shows the results in parts per unit). There is a minimum difference of 1% in level of attention in the percentage scale in which the values are recorded.

The level of attention of the online students is more constant than that of the classroom group, while the classroom students start the first part with a lower level of attention but end with a higher level in the third part.

Figure 3 shows, for each part, the level of average emotional intensity and the average level of interest, for classroom and distance/online formats, measured through portable electroencephalography (PEEGT).

Figure 3. Results of the analysis of interest measured with PEEGT

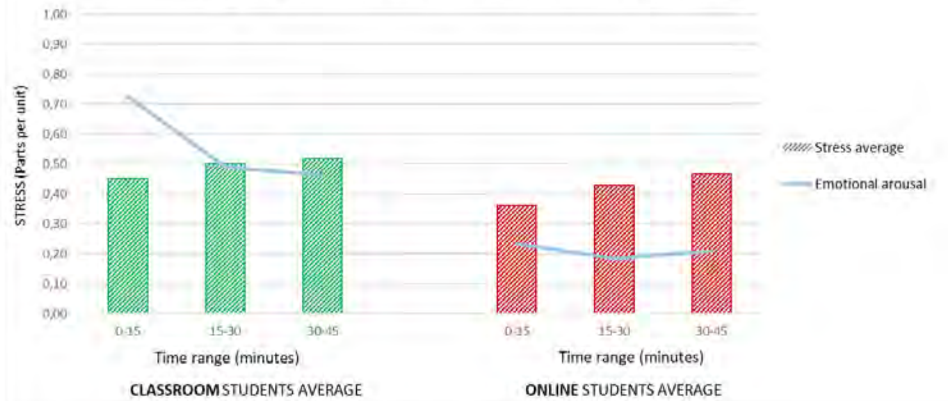


The levels of interest are higher, in general terms, for the classroom group, with average values of 65%, compared to 61% for the distance group. In the first part (first 15 minutes of class), interest levels are higher for students who attend in person. Afterwards, the level of interest for the classroom group decreases and increases for the online group, ending with an increase in interest for the online group, above the classroom group (part 3).

The online students are more constant in their level of attention, and this grows as the class progresses, while the classroom students begin with a higher level of interest in the first part of the class and decrease as the class develops, slightly changing the trend in the third part.

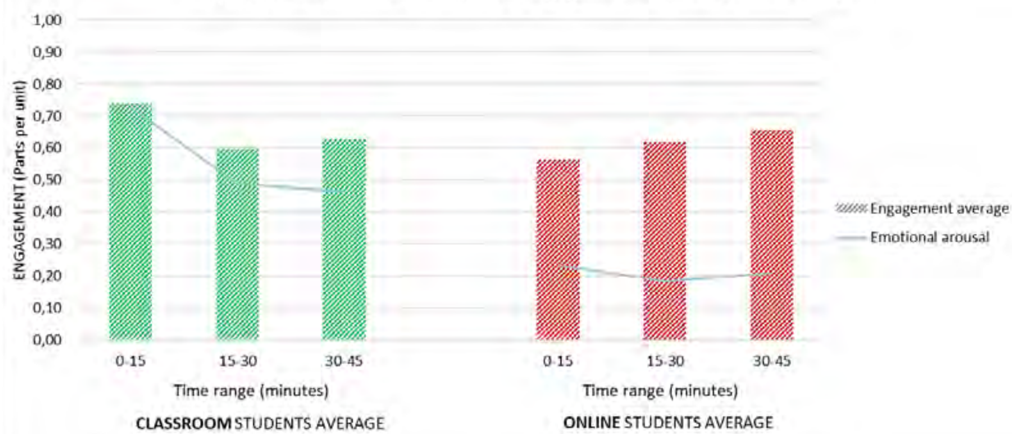
Figure 4 shows, for each part, the level of average emotional intensity and the average level of stress, for classroom and distance/online formats, measured through portable electroencephalography (PEEGT).

Figure 4. Results of the stress analysis measured with PEEGT



Stress levels are higher, in general terms, for the classroom group, with average values of 49%, compared to 42% for the remote group. In the 3 parts of the class, stress levels are higher for students who attend in person. In both groups the level of stress grows as the class progresses, always with lower values for the online students (note that they do not connect the camera). Figure 5 shows, for each part, the level of average emotional intensity and the average level of engagement, for classroom and distance/online formats, measured through portable electroencephalography (PEEGT).

Figure 5. Results of the analysis of engagement measured with PEEGT



Engagement levels are higher, in general terms, for the classroom assistance group, with average values of 65%, compared to 61% for the remote group. The first part of the class generates a higher level of engagement for the classroom students, falling in the second part and slightly changing the trend in the third part. However, the level of engagement has a growing trend for distance/online students, finishing a third of the class ahead of face-to-face students.

5. Discussion and conclusions

The current globalization is forcing educational centers to adapt, in a constantly evolving teaching context, where new forms of learning must be continually designed. Online learning facilitates accessibility, regardless of the location of the student and the teacher. However, the quality and quantity of interactions between teacher and student is the key, leaving the location of both in a secondary level (Hillman, 2011). The final result (knowledge and skills) should be the same, both for onsite students and for online students. Educational innovation is favored with the integration of digital technologies, where designs converge when working with mixed methods, in a holistic way and improving the focus of researchers (Klingner & Boardman, 2011). In a study conducted with classroom and online students (Price et al., 2007), the experiences of those taking the same course through distance learning were compared, when tutorial support was delivered conventionally (using limited classroom sessions with some contact by phone and email) or online (using a combination of computer-mediated conferencing and email). Students who received online teaching reported worse experiences than those who received classroom teaching. For online students, tutoring was seen not only as an academic activity but also as a highly valued pastoral activity. For online teaching to be successful, both tutors and students need training on how to communicate online in the absence of paralinguistic signals. The examples used in the teaching-learning process have a crucial role in fostering conceptual understanding, and some variables may affect instructors' use of graded examples (Sevimli, 2022).

Educational neuroscience seeks to translate research findings on the neural mechanisms of learning into educational practice and policy and to understand the effects of education on the brain (Thomas et al., 2019). Neuroscience and education can interact with each other directly, by virtue of considering the brain as a biological organ that needs to be in optimal conditions to learn (' brain health '); or indirectly, as neuroscience shapes psychological theory and psychology influences education.

The main objective of this work has been to demonstrate that online learning is less effective, in terms of brain signals, than classroom teaching for a theoretical class intended for master's level university students. The results of this experiment indicate that the levels of emotional intensity of the students who followed the class in person are higher than those who attended online/at a distance and can be justified by the presence of the teacher, colleagues and participation. However, the level of emotional intensity experienced by the group that followed the class remotely is more stable, the justification of which may be due to the lack of visual control, both by the teacher and by the classmates, by not connecting the camera.

Regarding the recording of brain activity by the students, recorded by portable electroencephalography (PEEG) biometry, the values are higher in the classroom attendance group, in general terms. Three of the four registered variables are positive, having higher values in classroom training (attention, interest and engagement). This may be due to a different and more motivational attitude from being in the classroom. However, the fourth variable, stress, is also higher in the classroom group, which can be justified because the students connected online did not activate the camera. The sensations perceived by the students suggest that the classes are more productive in person. The sensations and emotions provoked in the students who attend at a distance show that they have less interest and pay less attention, as well as showing lower emotional intensity.

Finally, regarding future lines of research using neurotechnologies in the classroom, it is very interesting to analyze how the different didactic methodologies (group dynamics, reverse teaching, etc.) bring the levels of brain arousal closer or further apart between classroom and online groups, allowing a basis for the proposal of actions to enhance and improve the results of the groups that follow distance teaching. Similarly, we aim to complement the techniques used with the use of quantitative surveys focused on recording perceptions and possible improvements for each proposed methodology.

Authors' Contribution

Idea, D.J.V., I.B.G; Literature review (state of the art), D.J.V., I.B.G., B.B.G; Methodology, D.J.V., B.B.G; Data analysis, D.J.V., I.B.G., B.B.G; Results, D.J.V., I.B.G., B.B.G; Discussion and conclusions, D.J.V; Writing (original draft), D.J.V., I.B.G; Final reviews, D.J.V., B.B.G; Project design and sponsorships, D.J.V., B.B.G.

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