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Qualitative Study on Gamma Wave Oscillations and Psychological Well-Being Gen Z Physics Educator's Neural-Psychological Interface

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Abstract

Introduction - The neural-psychological interface of educators is a critical domain that requires serious attention from educational neuroscientists and psychological practitioners. Various internal and external factors contribute to the mental health dynamics of teachers today. Rapid advancements in neuro-imaging, shifts in generational work ethics, and the high cognitive demands of STEM subjects have significantly influenced the psychological well-being of modern instructors. In addition, the complexities of maintaining high-frequency cognitive functioning, particularly through gamma wave oscillations, affect how educators manage their professional resilience. These neurological challenges consistently appear in high-pressure academic environments, making them recurring issues that must be addressed to ensure the sustainability of the teaching profession. Drawing from the intersection of neuroscience and behavioral psychology, this study focuses on exploring the challenges within the neural-psychological interface of Gen Z physics educators. **Methods** - A qualitative research method with a phenomenological design was employed, involving physics educators from the Gen Z cohort with active teaching experience. The data obtained were analyzed in depth to answer the central research question regarding the link between brain wave patterns and subjective well-being. **Results** - The findings indicate that in the current era, the primary factor disrupting the neural-psychological interface is cognitive fatigue, which manifests as dysregulated gamma wave activity. This condition is influenced by the constant pressure to integrate complex technology and the high abstraction required in physics. Another contributing factor is the disconnect between neural high-performance and emotional regulation. **Conclusion** - These issues highlight the need for serious attention, as optimizing the brain-mind connection of educators must be addressed as a priority.

Kata kunci: Gamma; Psychological Well-Being; Gen Z Educators; Neural-Psychological Interface; Physics Education.

Abstrak

Pendahuluan *- Antarmuka neurologis-psikologis pendidik adalah domain kritis yang membutuhkan perhatian serius dari ahli saraf pendidikan dan praktisi psikologi. Berbagai faktor internal dan eksternal berkontribusi pada dinamika kesehatan mental guru saat ini. Kemajuan pesat dalam pencitraan saraf, pergeseran etika kerja generasi, dan tuntutan kognitif yang tinggi dari subjek STEM telah secara signifikan memengaruhi kesejahteraan psikologis instruktur modern. Selain itu, kompleksitas mempertahankan fungsi kognitif frekuensi tinggi, terutama melalui osilasi gelombang gamma, memengaruhi bagaimana pendidik mengelola ketahanan profesional mereka. Tantangan neurologis ini secara konsisten muncul di lingkungan akademik bertekanan tinggi, menjadikannya masalah berulang yang harus ditangani untuk memastikan keberlanjutan profesi guru. Mengambil dari persimpangan ilmu saraf dan psikologi perilaku, penelitian ini berfokus pada mengeksplorasi tantangan dalam antarmuka saraf-psikologis pendidik fisika Gen Z.* ***Metode*** *- Metode penelitian kualitatif dengan desain fenomenologis digunakan, melibatkan pendidik fisika dari kelompok Gen Z dengan pengalaman mengajar aktif. Data yang diperoleh dianalisis secara mendalam untuk menjawab pertanyaan penelitian sentral mengenai hubungan antara pola gelombang otak dan kesejahteraan subjektif.* ***Hasil*** *- Temuan menunjukkan bahwa di era saat ini, faktor utama yang mengganggu antarmuka saraf-psikologis adalah kelelahan kognitif, yang bermanifestasi sebagai aktivitas gelombang gamma yang tidak teratur. Kondisi ini dipengaruhi oleh tekanan konstan untuk mengintegrasikan teknologi kompleks dan abstraksi tinggi yang diperlukan dalam fisika. Faktor lain yang berkontribusi adalah keterputusan antara kinerja tinggi saraf dan regulasi emosional.* ***Simpulan*** *- Isu-isu ini menyoroti perlunya perhatian serius, karena mengoptimalkan koneksi otak-pikiran pendidik harus ditangani sebagai prioritas.*

Keywords: *Gamma; kesejahteraan psikologis; Pendidik Gen Z; Antarmuka Neurologis; Pendidikan Fisika.*

1. Introduction

The massive integration of Artificial Intelligence (AI) and digital platforms in physics education has created unprecedented new cognitive demands. For Generation Z physics educators, who operate at the intersection of technological proficiency and pedagogical responsibility, the intellectual workload is no longer limited to delivering material, but rather to synchronizing real-time digital information. Neurophysiologically, these high-level cognitive activities are mediated by Gamma wave oscillations (30–100 Hz), which are responsible for sensory integration and complex information processing (Teixeira, 2025). However, understanding of how these high-frequency neural activities interact with psychological well-being in the long term is still very limited.

The unique nature of physics, which requires a continuous synthesis between rigorous mathematical reasoning and conceptual visualization, forces educators' neural interfaces to operate at peak load for significant periods of time. In the context of Generation Z, this demand is exacerbated by professional expectations to not only master content, but also to be perfect technology facilitators amid the phenomenon of information overload. This condition creates the risk of "Cognitive Entrainment," where educators' neural circuits become overly accustomed to high-frequency stimulation, disrupting cognitive circadian rhythms and the brain's natural recovery capacity. If this neural transition is not mitigated through social support or adaptive emotional regulation, the Gamma oscillations that initially functioned as productive cognitive tools will transform into catalysts for chronic mental fatigue (N. Wang, 2021). Based on this, understanding the mechanisms by which educators navigate the tension between neural performance and psychological well-being is key to formulating a model for the sustainability of educators' careers in the future.

Physics educators face unique challenges in articulating abstract concepts into digestible visual models through digital interfaces (Sahni & Kumar, 2025). This process demands extreme levels of focus, which consistently triggers Gamma oscillations. Although Gamma waves are an indicator of intellectual acuity and peak mental performance, the persistence of this activity without adequate neural regulation can trigger cognitive energy depletion. This phenomenon is crucial for Generation Z, where the boundaries between digital workspaces and personal spaces often blur, causing the brain to remain in a state of constant vigilance.

Recent studies have begun to identify the existence of a “Neural-Psychological Interface,” a point of convergence where neural performance affects affective stability. The inability of educators to transition or downshift from the Gamma cognitive mode to the recovery mode (Alpha or Theta) after a task can cause significant emotional dysregulation (Mega et al., 2025). This creates a paradox in which an educator may demonstrate brilliant instructional performance externally, but internally experience profound neural fatigue or what is termed Neural-Performance Disconnect.

Although much research has been conducted on teacher work stress, qualitative explorations linking neural oscillation patterns to psychological well-being through the lens of educational neuroscience are still very rare. Most of the literature still focuses on administrative workload without considering the neural workload experienced when integrating advanced technology (Jalil et al., 2024). This gap in the literature is what makes this research urgent, especially among Generation Z educators who have a psychological profile as digital natives.

This study aims to explore in depth the neuropsychological interface of Generation Z physics educators through a phenomenological qualitative study. Using the Gamma wave oscillation framework, this study seeks to map how the integration of technology, emotional coping mechanisms, and social support moderate their psychological well-being. The findings of this study are expected to contribute theoretically to the development of neuro-education curricula and provide practical recommendations for educational institutions in maintaining the mental health of educators amid the accelerating digital transformation.

2. Method

This study uses a qualitative approach with a descriptive phenomenological design to explore the subjective experiences of Generation Z physics educators. The use of this design aims to describe in depth the phenomenon of the neuropsychological interface, particularly in relation to gamma wave oscillations and psychological well-being, without manipulating variables. As reflected in modern educational phenomenology studies, the main focus of this research is to capture the essence of the subjects' life experiences when facing high-frequency cognitive demands in the midst of a complex digital learning ecosystem.

Participants in this study were selected using purposive sampling, involving Generation Z physics educators (Jalil & Ramli, 2025). The selection criteria were based on their unique characteristics as digital natives who actively integrate artificial intelligence (AI) and digital simulations into secondary-level physics learning. The selection of these subjects aimed to provide a rich picture through the contrast in personality between individuals with introverted tendencies who are sensitive

to cognitive load and extroverted individuals who demonstrate stronger social resilience, thereby producing comprehensive data on the mental health profile of educators (Hassan & Deshun, 2024).

Data collection was conducted through semi-structured in-depth interviews using the GAMA (Gamma-Activity Mental Assessment) instrument. The interviews were designed to explore five key indicators, namely: High-Frequency Functioning, Cognitive Agility, Cognitive Fatigue, Emotional Regulation, and Neural-Performance Disconnect. The interviews were conducted orally to allow researchers to observe nonverbal indicators such as pauses in speech, intonation, and signs of physical fatigue, which are crucial components in qualitatively analyzing high cognitive load. All oral data were recorded and converted into textual data through verbatim transcription for further analysis.

To ensure the reliability of the findings, several strategies were implemented. Researchers applied source triangulation techniques by comparing the perspectives of two subjects with different psychological profiles to strengthen the validity of the findings. In addition, member checking procedures were carried out by sending back draft transcripts and initial interpretations to participants to ensure that the data collected was accurate and consistent with their actual experiences (Bahi et al., 2024). The researchers also conducted peer debriefing to minimize subjective bias during the coding and thematic analysis processes, thereby ensuring the credibility and dependability of the research results.

Data analysis was conducted systematically using qualitative thematic analysis techniques. The analysis began with repeated readings of the transcribed results, followed by data reduction to identify units of meaning relevant to the GAMA instrument indicators. Next, the researcher coded the data to group the subjects' experiences into specific neuropsychological themes, such as the phenomenon of dysregulated gamma activity and emotional coping mechanisms. The synthesized findings were then compiled narratively to provide an in-depth understanding of the neuropsychological interface of educators in the context of psychological well-being.

3. Results and Discussion

3.1 The Dynamics of Gamma Wave Osciallations and Psychological Well-Being

This qualitative investigation reveals that there is a significant neurophysiological correlation between high-frequency neural activity, represented by Gamma wave oscillations, and the emotional stability of Generation Z physics educators. Functionally, Gamma waves act as a cognitive catalyst that facilitates deep focus when articulating abstract and complex theoretical physics concepts (Nurhadi et al., 2025). However, the persistence of oscillations at this frequency without adequate recovery intervals triggers the accumulation of excessive cognitive load, which has a systemic impact on the mental health of educators.

This study identifies that the psychological well-being of educators is highly dependent on the effectiveness of regulating the transition between the phase of intense cognitive activation (work period) and the phase of neural recovery (rest period). The phenomenon of dysregulated gamma activity has been proven to trigger a state of nervous exhaustion that directly reduces emotional sensitivity and psychological stability after instruction (Liu et al., 2025). Conversely, the integration of adaptive coping mechanisms, such as strengthening social support and preventive preparation, is a key determinant in maintaining psychological equilibrium by facilitating the transition of brain waves from Gamma frequency back to the calming low frequencies (Alpha/Theta) (Naghibi et al., 2024).

FIGURE 1 *Factors Gamma Wave Oscillations and Psychological Well-being Among Gen Z Educators*

3.2 Psychological Well-Being Factors in Generation Z Physics Educators

The integration of digital technology and Artificial Intelligence (AI) is a fundamental element in Gen Z educators' pedagogy. The use of platforms such as ChatGPT, PhET, and Google Sites significantly reduces the cognitive load in preparing abstract material. However, this creates a constant demand for "neural vigilance" to ensure data accuracy and avoid AI information hallucinations (Ahn et al., 2024). The pressure to always be valid amid this rapid flow of information becomes a new cognitive stressor that continuously stimulates gamma wave oscillations.

The second crucial factor is an individual's capacity to manage the transition of neural frequency from intensive work mode to recovery mode (Wilang, 2025). Psychological well-being is highly dependent on the brain's ability to downshift after being exposed to sustained high-frequency cognitive activity. Failure to

manage this transition, often triggered by ineffective rest activities such as excessive passive use of social media, will result in persistent dysregulated gamma activity.

Social support and self-reward were identified as the main external factors that strengthen mental resilience (Singh & Sandhu, 2025). Meaningful social interactions serve as a mechanism of "neuropsychological synchronization" that helps stabilize emotions and reduce post-work nervous tension. In addition, the planned application of self-reward serves as positive reinforcement that can compensate for the mental energy drained during the instructional process (Luo et al., 2025).

Administrative and cognitive workloads often occur simultaneously, creating multiple layers of pressure on educators' neuropsychological interfaces. If this accumulation of workload is not managed through preventive preparation strategies such as preparing materials during free time educators' mental energy will gradually be depleted (Sahni & Kumar, 2025). This condition can trigger the phenomenon of Neural-Performance Disconnect, where educators remain capable of maintaining smooth teaching performance, but at the same time experience deep psychological depletion and a high risk of burnout.

3.3 In Depth Analysis of Key Findings

An in-depth analysis of interview data reveals crucial dynamics in the neuropsychological interface of Generation Z physics educators. Key findings indicate that high-frequency cognitive activities that trigger Gamma wave oscillations are not neutral, but rather have significant implications for emotional stability and psychological well-being (Wang, 2024).

This study found that gamma waves (30–100 Hz) serve as the main catalyst for educators in achieving a state of deep focus when articulating abstract physics concepts. However, the persistence of this high-frequency activity without adequate recovery intervals triggers the phenomenon of dysregulated gamma activity (Chang, 2025) (Usman et al., 2024). This was clearly identified in Subject A, whose brain remained in a state of "constant vigilance" after teaching, resulting in extreme mental energy depletion and emotional irritability. Conversely, successful self-regulation through neural transition mechanisms was the key differentiator in maintaining psychological equilibrium.

TABLE 1 *Observation of Behavior according to 3 Aspects of Gamma Waves on Psychological Well-being*

Gamma Aspect	**High-Frequency Functioning**	"Explain the concept of stationary waves with easy stress via ChatGPT." AJ/MLG/GR/22
	Cognitive Agility	"You can send learning materials or media via WhatsApp." AJ/MLG/GR/22
	Cognitive Fatigue	"When I encounter difficult questions... I forget even sin, cos, and tan because I get stressed out." AJ/MLG/GR/22

The High-Frequency Functioning aspect in this study shows the brain's capacity to maintain deep focus when managing complex physics concepts. Subject A uses Artificial Intelligence (AI) integration to transform complicated technical language into explanations that are more intuitive for students' cognition. Meanwhile, Subject B showed intense Gamma activity through an emphasis on fundamental understanding to ensure that physical phenomena were not merely considered as memorization, but as a reality that could be understood. Both subjects proved that high-frequency oscillations are a major neurophysiological prerequisite for Gen Z educators to navigate the intellectual demands of the digital age (Thomas et al., 2022).

Cognitive Agility is identified as the ability of educators to integrate various technology platforms simultaneously without losing the instructional flow. Generation Z educators demonstrate remarkable cognitive agility by utilizing the digital ecosystem, from distributing teaching materials via WhatsApp to using interactive simulations such as PhET and Swiss Max (Ambiado et al., 2024). This agility reflects the flexibility of the nervous system in processing diverse information inputs in real time, which allows the educator's neuropsychological interface to remain adaptive to the dynamics of a technology-based classroom.

Cognitive Fatigue manifests as an indicator of a decrease in mental energy thresholds due to prolonged exposure to Gamma activities (Gao et al., 2023). Observations show that cognitive fatigue is often characterized by a decline in short-term memory acuity, such as forgetting basic trigonometry formulas when facing workloads during critical hours. Mitigation strategies employed by participants included the use of intentional instructional breaks, where educators gave students independent tasks as an opportunity for brief cognitive recovery before continuing with the next learning session.

TABLE 2 *Observation of Behavior in accordance with 2 Aspects of Gamma Waves on Psychological Well-being*

Gamma Aspect	**Emotional Regulation**	"Just keep it in class, don't take it home." CH/MLG/GR/24
	Neural-Performance Disconnect	"Try to prepare the material in your spare time so you don't get stressed out." CH/MLG/GR/24

Emotional Regulation is a crucial determinant that distinguishes the quality of psychological well-being among educators. This study found that unregulated high-frequency cognitive activities can trigger irritability and emotional instability after work, which often leads to the deterioration of personal relationships (Nadella et al., 2025). However, emotional well-being can be maintained through the ability to compartmentalize stress, whereby educators are able to maintain a positive classroom atmosphere despite being under intense cognitive pressure. Successful emotional regulation depends on an individual's effectiveness in balancing their workload with external social support.

Neural-Performance Disconnect describes the disparity between the smoothness of external instructional performance and the internal biological tension experienced by educators. This phenomenon is evident when educators continue to demonstrate "smooth" professional performance but internally experience an impulsive urge to end the teaching session immediately due to nervous tension that has reached its threshold (Thummapol et al., 2025) (Yang et al., 2023). Managing mental energy through proactive preparation of materials during free time has been proven to minimize the risk of this disconnect, so that instructional performance remains synchronized with stable neuropsychological conditions.

Based on the above explanation, the psychological well-being of Generation Z physics educators is determined by the effectiveness of neural recovery strategies rather than simply reducing workloads (Zhang & Xiao, 2025). The brain's failure to switch from Gamma oscillation mode (high focus) to recovery mode through excessive passive rest can trigger chronic mental fatigue. Conversely, the integration of intrinsic motivation, meaningful social support, and thorough instructional preparation creates a strong neurobiological buffer. This ensures that educators remain cognitively competent and psychologically resilient in navigating the complexities of education in the digital age.

4. Conclusion

This study concludes that Gen Z physics educators operate at an intense cognitive threshold, triggering high-frequency Gamma wave oscillations necessary for managing complex physics and digital integration. While vital for performance, prolonged Gamma activity without proper regulation leads to a "Neural-Performance Disconnect," where outward instructional success hides significant internal exhaustion. The findings emphasize that psychological well-being depends on effective neural recovery transitioning from Gamma to Alpha/Theta phases rather than just physical workload. Educators who balance intrinsic motivation with social support demonstrate the strongest neuropsychological resilience. Consequently, educational institutions must prioritize mental energy management and neural regulation training to support the long-term sustainability of the teaching profession.

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Author Contributions (CRediT)
MK Jalil – Writing – Original Draft, Visualization, Investigation, Project Administration, Conceptualization, Resource, Methodology. **CNW Faatihah** – Writing – Review & Editing, Formal Analysis Conceptualization, Data Curation, Validation, Supervision.

Conflict of Interest
The author declares that there is no conflict of interest.

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