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Biofeedback games in education: A review with implications for teacher training

Giochi di biofeedback nell'istruzione: una revisione con implicazioni per la formazione degli insegnanti

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ABSTRACT Biofeedback games use physiological feedback such as heart rate variability, electrodermal activity, breathing rate, and EEG data to help individuals improve awareness and control of their emotional responses. These tools have become increasingly recognized for their role in enhancing cognitive development, emotional regulation, and stress management. While biofeedback games have demonstrated substantial benefits in therapeutic contexts, their use in teacher training remains significantly underexplored. This review synthesizes the current research on biofeedback games, highlighting their therapeutic effects and cognitive benefits, followed by a discussion on their potential for application in teacher training settings. Through a critical disability studies lens, we propose the potential of these tools in supporting teachers' emotional well-being and reducing teacher burnout, thereby fostering more inclusive learning environments. The review concludes with the limitations of current research, along with recommendations for future studies to address the research gap and enhance teacher well-being and resilience through biofeedback interventions.

KEYWORDS Biofeedback Games; Teacher Training; Gamification; Inclusive Education; Emotional Regulation.

SOMMARIO I giochi di biofeedback utilizzano feedback fisiologici come la variabilità della frequenza cardiaca, l'attività elettrodermica, la frequenza respiratoria e i dati EEG per aiutare le persone a migliorare la consapevolezza e il controllo delle proprie risposte emotive. Questi strumenti sono diventati sempre più

riconosciuti per il loro ruolo nel migliorare lo sviluppo cognitivo, la regolazione emotiva e la gestione dello stress. Sebbene i giochi di biofeedback abbiano dimostrato benefici sostanziali in contesti terapeutici, il loro utilizzo nella formazione degli insegnanti rimane significativamente sottoesplorato. Questa recensione sintetizza l'attuale ricerca sui giochi di biofeedback, evidenziandone gli effetti terapeutici e i benefici cognitivi, seguita da una discussione sul loro potenziale di applicazione nei contesti di formazione degli insegnanti. Attraverso la lente degli studi critici sulla disabilità, proponiamo il potenziale di questi strumenti nel sostenere il benessere emotivo degli insegnanti e nel ridurre il burnout degli insegnanti, favorendo così ambienti di apprendimento più inclusivi. La revisione si conclude con i limiti della ricerca attuale, insieme a raccomandazioni per studi futuri per colmare il divario della ricerca e migliorare il benessere e la resilienza degli insegnanti attraverso interventi di biofeedback.

PAROLE CHIAVE: Giochi di Biofeedback; Formazione degli Insegnanti; Gamificazione; Educazione Inclusiva; Regolazione Emotiva.

1. Introduction

Significant shifts and demands have come alongside Education 4.0 and the movement into a digital era (Bonfield et al., 2020; Hussin, 2018) which challenges traditional educational methods and approaches. Within this, the integration of gamification into education contexts has gained significant momentum (Lampropoulos & Kinshuk, 2024). Gamification, defined as "the use of game design elements in non-game contexts to motivate and increase user activity and retention" (Deterding et al., 2011, p. 9), stands as a powerful tool in modern educational settings through its ability to engage learners (Smiderle et al., 2020). By fostering motivation (Ratinho & Martins, 2023) and providing more interactive, personalized learning experiences, gamification has become a rapidly growing trend within innovative educational methodologies. A more recent development within this trend is the rise of biofeedback games, which use physiological data like heart rate variability (HRV) and electrodermal activity (EDA), as well as brainwave activity (EEG) in neurofeedback games, to give users real-time feedback on their emotional and physical states. Although biofeedback games have been explored for their use as tools for improving attention (Mercado et al., 2021), emotional regulation (Jerčić & Sundstedt, 2019), cognitive development (Liu et al., 2014), and stress management (Zafar et al., 2020), their use within teacher training remains largely unexplored.

Teaching is widely recognized as a highly demanding position, with educators increasingly leaving the profession (Madigan & Kim, 2021b) due to issues such as burnout (Brackett et al., 2010) and stress (Turner & Garvis, 2023). These issues not only have a direct impact on teachers' own socio-emotional well-being (Dreer, 2024) but also on student outcomes (Madigan & Kim, 2021a), making stress management and emotional regulation critical for effective teaching. Despite the importance of teacher well-being, there has been limited discussion on how elements of gamification with biofeedback could benefit teachers. Biofeedback games that focus on stress management and anxiety reduction could offer teachers valuable strategies by promoting emotional awareness and stress regulation. These benefits are also particularly relevant during the early stages of their careers when training is typically accompanied by heightened anxiety (Bilali, 2012; Morton et al., 1997; Paker, 2011). Incorporating these games

into teacher training programs could help equip educators with lifelong practical strategies to manage stress and create more emotionally safe and supportive learning environments.

This review aims to address the existing gap in the literature by exploring the current state of research on biofeedback games in therapeutic and cognitive-enhancing contexts, along with a discussion on the important implications and potential uses of biofeedback games in teacher training and professional development programmes. Through a comprehensive search of the literature, this review will explore the potential benefits of incorporating biofeedback games into teacher professional development programs, especially in fostering emotional regulation and stress management strategies. While biofeedback games have demonstrated theoretical promise in teacher training, the current body of literature is limited by a lack of direct empirical studies showcasing their effects in naturalistic educational settings. This review synthesizes existing research, but pilot studies or case studies from diverse contexts are necessary to provide concrete evidence for their efficacy in real-world applications. Grounded in the theoretical framework of Critical Disability Studies (CDS), this review will explore how integrating biofeedback games for teachers, rather than only for students, aligns with more inclusive educational approaches. CDS challenges conventional understandings of disability by advocating for educational systems that accommodate the diverse needs of learners, rather than requiring students to conform to standardized norms. This perspective will inform the implications for teacher training, recognizing that emotionally regulated teachers play a crucial role in creating responsive, safe learning environments. By adopting a holistic view of the inclusive classroom, this approach emphasizes the meaningful use of technology, not just for students, but for teachers as well, acknowledging them as central figures for defining classroom dynamics.

2. Background

2.1. Gamification

Gamification involves integrating game mechanics into non-game environments such as education, business, or healthcare (Wood & Reiners, 2015) to enhance user motivation and engagement, which in turn improve the relevant learning or health outcomes (Manzano-León et al., 2021, Rivera & Garden, 2021). Gamification in education involves key elements such as engaging challenges, interactivity, and continuous feedback (Díaz & Troyano, 2013; Kapp, 2012; Zichermann & Cunningham, 2011). Mechanics like levels and badges reward achievement, while appealing aesthetics enhance user experience. Games can involve problem-solving to assist users in acquiring new skills through gameplay. Different player types are considered to ensure motivation, and learning is promoted through points and corrective feedback. Rewards include point systems, level progression, badges, tangible rewards, leaderboards, and challenges, all designed to motivate students and track their progress (Rodríguez-García & Gómez-García, 2020). Also, gamification promotes collaboration among users, stimulating cooperation and teamwork, and making the learning process more social (Floris et al., 2024).

2.2. Biofeedback games

Biofeedback is a technique that helps individuals learn to control physiological processes that are typically involuntary (Tosti et al., 2024). Biofeedback works by converting

physiological signals into visual and auditory cues that are then, in real-time, shown back to the user (Frank et al., 2010), creating a feedback loop to encourage better self-awareness and control over these physiological reactions and arousal states. Biofeedback, as a therapeutic approach, provides users with real-time information about their physiological processes that help them develop increased understanding and improved self-regulation. The idea is that when combined with emotional or behavioural interventions, this awareness can assist in a change in the physiological process, with the aim that newfound control can be maintained further down the line without the equipment (Kondo et al., 2019; Peper, 1979). This process has been used for a wide variety of different conditions (Giggins et al., 2013; Kondo et al., 2019; Schoenberg & David, 2014).

Although biofeedback is a valuable tool for enhancing self-awareness and emotional regulation, its physiological conceptions and the mechanisms behind it could be challenging for many individuals to understand intuitively. Parnandi & Gutierrez-Osuna (2021) explain that gamified biofeedback is "a form of instrumental conditioning in which reinforcements (i.e., rewards or penalties in the game) are used to modify voluntary behaviours (e.g., increase or decrease breathing rate)" (Parnandi & Gutierrez-Osuna, 2021, p. 141). The sensors track the player's emotional states during gameplay, allowing the game to adjust and provide rewards for actions that encourage relaxation (Parnandi et al., 2014; Parnandi & Gutierrez-Osuna, 2021). Thus, serious games serve as an effective bridge (Jerčić & Sundstedt, 2019; Parnandi & Gutierrez-Osuna, 2015; Stapleton, 2004), and in this context provide interactive environments that contextualize bio- and neurofeedback data (Lüddecke & Felnhofer, 2022; Vinod & Thomas, 2018) to facilitate the real-time perception of emotional responses reflected in physiological changes. By transforming the concepts of biofeedback into engaging gameplay, these serious games help users better recognize and manage their internal physiological states and emotions, in a more streamlined way.

Biofeedback games combine the biofeedback techniques with interactive game elements, providing a dynamic way to learn self-regulation. Gamification plays a critical role here by increasing motivation and engagement, which can be particularly valuable in educational and therapeutic settings. In contrast to biofeedback as a standalone technique, gamified biofeedback incorporates fun, interactive elements to increase motivation to practice self-regulation techniques, with research demonstrating its promise in aiding skill acquisition and transfer (Parnandi & Gutierrez-Osuna, 2017).

3. Theoretical framework

The theoretical framework and approach we adopt for the conception of this paper is grounded in Critical Disability Studies (CDS) which redefines how we perceive and address disability. Instead of focusing on individual impairments, critical disability theory emphasizes the social, cultural, and institutional factors that contribute to the lived experience of disability (Campbell, 2010; Goodley, 2013; Meekosha & Shuttleworth, 2009). This perspective is critical within educational and therapeutic contexts, and when assessing the potential role and benefits of biofeedback games. As assistive technologies, the use of these biofeedback games can either challenge or reinforce existing power dynamics and accessibility issues, depending on how they are implemented. An inclusive education system, as Hoogerwerf describes, "supports all of its students to access, participate in, and benefit from an appropriate education" (Hoogerwerf et al., 2021, p. 1). This means that systems must adapt to meet the diverse needs of all learners, rather than problematising or "othering" (Barnes, 1992; Manchanda, 2024; Reutlinger, 2015;

Saltaga, 2017) disabled students and placing the onus on them to conform to rigid norms. Truly inclusive integrations of assistive technologies, such as biofeedback games, lie in their thoughtful, meaningful use (Connor & Beard, 2015), and the principle of designing these technologies "with and for" (Motti, 2019) users is essential. When implemented in this way, biofeedback games have the potential to create adaptive, responsive environments that benefit all users, especially those with diverse needs.

Moreover, the role of teachers in the meaningful implementation of these technologies cannot be overlooked. Pérez (2014) stresses that teachers are key figures in ensuring that assistive technologies are effectively integrated into the classroom. However, not only must teachers be equipped with sufficient knowledge and skill in using such innovative tools, but teachers must also be emotionally regulated to maintain an inclusive and emotionally safe environment. This is particularly pertinent for neurodiverse students who rely more on others for emotional regulation (Cibralic et al., 2019), thus require emotionally safe and predictable adults. However, practising effective emotional regulation is something that can be difficult within systems that are increasingly requiring more emotional labour and leading to burnout (Kariou et al., 2021). A CDS framework also stresses systemic and structural factors that influence teacher well-being, rather than placing stress management solely as an individual responsibility. This aligns with the review's aim to propose the potential of bio- and neurofeedback games as necessary in stressful teaching environments. By acknowledging the broader institutional pressures and expectations that contribute to teacher stress and burnout, these tools can support the creation of inclusive educational practices.

Regulated adults are fundamental to creating an inclusive classroom, as they help shape an emotionally safe environment in which students can thrive emotionally (Frenzel et al., 2021) and academically (Pi et al., 2022). Thus, this review proposes that biofeedback games should not only be used to support students but also to encourage emotionally regulated teachers. In doing so, it is more possible to ensure that the integration of such technologies is both meaningful and aligned with the principles of truly inclusive education and critical disability studies, which advocate for systemic change rather than superficial fixes.

4. Methodology

4.1. Search strategy

This review employed a comprehensive search strategy to identify relevant research on biofeedback games in education, utilizing two major databases: Web of Science and Scopus. Search queries included combinations of terms such as 'biofeedback games,' 'neurofeedback games,' with 'education,' 'learning outcomes,' 'student engagement,' and 'teacher training.' Additionally, the review incorporated terms related to stress, anxiety, and emotion regulation, such as 'relaxation,' 'stress management,' and 'anxiety'. The decision to include these additional terms was made to understand the uses of biofeedback games not only for traditional educational outcomes but also for supporting emotional well-being. Emotional regulation and the management of stress and anxiety impact learning and engagement for both students and teachers. Emotion regulation is key in creating inclusive, supportive classroom environments, making it an essential area to include in this review. The decision not to restrict the search to specific clinical or non-clinical populations was based on the intent to provide a comprehensive understanding of the application of biofeedback games across diverse contexts, followed by a discussion on how such applications and the findings have implications for teacher training

contexts. No date limits were set to gain a complete and thorough overview of biofeedback games and their use in education. Language filters were applied to include only English and Italian publications.

4.2. Search results

Initially, the Web of Science[1] and Scopus[2] database searches yielded a combined total of 116 results. A detailed screening of titles and abstracts was conducted to identify titles and abstracts that included terms that were focused on the theme of biofeedback games within educational and therapeutic contexts. This screening reduced the number of relevant articles to 78. Following importation into reference managing software Zotero, 30 duplicate or non-accessible results were removed which left the remaining 48 articles ready for full-text review. The full-text review involved identifying articles that were relevant to the review's objective, using the inclusion criteria. The inclusion criteria are outlined as follows: articles must involve bio- or neurofeedback games and explicitly discuss their application within therapeutic outcomes, cognitive-attentional interventions, or educational and learning contexts. Articles not meeting these themes were excluded. Additionally, articles that focused solely on bio- or neurofeedback without a gamification element were excluded, for example, articles that were regarding neurofeedback but not relevant to gamification, were not included in the review. Full-text screening resulted in a further 17 articles being excluded, leaving 31 articles to be synthesised. Publications covering broader clinical populations were included to explore their relevance to the therapeutic outcomes, such as stress management or cognitive improvements, which may also hold implications for teacher training. This decision was aimed at bridging the gap between existing evidence in clinical contexts and potential applications in educational settings, which is explored in more detail in the discussion. The review process involved an evaluation of the studies' methodologies, findings, and relevance.

4.3. Data synthesis

Regarding the data synthesis process, information pertaining to the methodologies, key findings, implications and conclusions were extracted. These findings were then synthesised into the 4 key themes:

Biofeedback games for stress management

1 Full Web of Science search query: "biofeedback games" OR "neurofeedback games" OR "biofeedback game" OR "neurofeedback game" OR "biofeedback educational game" (Topic) and "emotion regulation" OR "stress management" OR stress OR anxiety OR depression OR emotion* OR "emotional regulation" OR Education OR Learning OR Teaching OR Pedagogy OR Instruction OR Curriculum OR "Educational technology" OR Classroom OR "Educational tools" OR "Learning outcomes" OR "Educational strategies" OR "Teacher training" OR "Educational policy" OR "Education reform" OR "Distance learning" OR "Blended learning" OR "Online learning" OR E-learning OR "Learning environments" OR "Formal education" OR "Non-formal education" OR "Informal education" OR "Learning styles" OR "Experiential learning" OR "Constructivist learning" OR "Collaborative learning" OR "Active learning" OR "Critical thinking" OR "Problem-solving" OR Creativity OR "Metacognition" OR Motivation OR "Student engagement" OR "Self-directed learning" OR "Personalized learning" OR "serious games" (Topic)

2 Full Scopus search query: (TITLE-ABS-KEY("biofeedback games" OR "neurofeedback games" OR "biofeedback game" OR "neurofeedback game" OR "biofeedback educational game") AND TITLE-ABS-KEY("emotion regulation" OR "stress management" OR stress OR anxiety OR depression OR emotion* OR "emotional regulation" OR Education OR Learning OR Teaching OR Pedagogy OR Instruction OR Curriculum OR "Educational technology" OR Classroom OR "Educational tools" OR "Learning outcomes" OR "Educational strategies" OR "Teacher training" OR "Educational policy" OR "Education reform" OR "Distance learning" OR "Blended learning" OR "Online learning" OR E-learning OR "Learning environments" OR "Formal education" OR "Non-formal education" OR "Informal education" OR "Learning styles" OR "Experiential learning" OR "Constructivist learning" OR "Collaborative learning" OR "Active learning" OR "Critical thinking" OR "Problem-solving" OR Creativity OR "Metacognition" OR Motivation OR "Student engagement" OR "Self-directed learning" OR "Personalized learning" OR "serious games"))

Biofeedback games for supporting neurodiversity
Biofeedback games for cognitive development
Biofeedback games for anxiety and other mental health conditions

The data synthesis process included a thematic analysis to identify recurring patterns across the diverse studies and contexts of this relatively niche topic with limited data. This allowed for the integration of findings from both clinical and non-clinical populations into broader categories relevant to the present teacher training contexts. This review conducts a thorough analysis and critical evaluation of the included studies through the lens of CDS. These findings preceded a wider discussion on their implication in teacher training, and how the results from implementations of biofeedback games within the contexts of the research could also be integrated into teacher training programmes. This approach seeks to address existing gaps in the literature and contribute to the development of more inclusive and adaptive practices, as well as to identify the potential benefits and challenges of integrating them into training programs for the promotion of stress management techniques and the prevention of teacher burnout.

5. Results

5.1. Overview of included studies

A total of 31 studies were reviewed, focusing on the application of biofeedback games across socio-emotional, cognitive, and therapeutic contexts. The studies ranged from 1998 to 2024, but due to being a relatively novel concept, most of the research has emerged in the last 8 to 10 years. Sample sizes were typically small, although some confirmatory, slightly more higher-powered studies involved samples of up to 100 participants. Participants across the studies varied widely in age, including children with special educational needs, adolescents, young adults, as well as healthy adults. Any conditions addressed included anxiety, depression, ADHD, autism, and other neurodiverse conditions. The reviewed studies used various biofeedback or neurofeedback systems of differing physiological aspects. Many studies demonstrated promising outcomes, such as improved emotional regulation, enhanced cognitive skills, and reduced anxiety, with some showing positive carry-over effects on subsequent stressful or cognitively demanding tasks. Further research is recommended to validate these findings with larger and more diverse populations.

5.2. Biofeedback games for stress management

The review revealed that biofeedback games have shown significant potential for promoting stress regulation and relaxation by providing real-time feedback on physiological data. The feedback loops in these games usually reward relaxing behaviours and penalize states of high arousal, reinforcing stress-management techniques. For example, Parnandi et al., (2014) assessed an adaptive biofeedback game that tracked breathing rate, HRV, and electrodermal activity (EDA), using a positive feedback loop which encouraged users to maintain relaxed states. They found that the biofeedback game lowered arousal during a subsequent stress-inducing task. Similarly, Condron et al. (2009) used two bio-electric sources: GSR and EEG to promote relaxation, with the results demonstrating the utility of biofeedback for stress reduction in a sample of 14 people aged between 20 and 40 years.

Several studies also demonstrate the carry-over effect of these results, where relaxation skills developed during engagement with biofeedback games are successfully transferred to subsequent, cognitively stressful tasks. Zafar et al. (2017, 2020) in studies of samples of 42 and 100 participants, respectively, found that biofeedback games that focused on breathing control not only improved performance during gameplay but also helped users regulate their breathing and manage stress in post-game stress-inducing tasks. In their studies, participants who played biofeedback-enhanced games exhibited better cognitive performance and lower stress arousal during these follow-up tasks, compared to those who played non-biofeedback versions. As well as this, in comparison to the control group, the biofeedback enhancement also improved attentional-cognitive performance in the following task. This suggests that biofeedback games do more than just reduce stress temporarily, they help users acquire longer-term skills in both stress management and cognitive performance, in an engaging and motivating way through the use of game elements. However, it is worth noting that the participants in both studies were exclusively male, which limits the generalisability of the results. This carry-over effect was further supported by Wollmann et al. (2016), who explored how gamified HRV biofeedback enhanced user engagement with breathing exercises, improving motivation and adherence. Together, these studies illustrate the broad applicability of biofeedback games in helping users manage stress not just in real-time, but in the long-term too.

Biofeedback game relaxation-based benefits have also been highlighted within therapeutic contexts. Leahy et al. (1998) applied biofeedback games to teach relaxation techniques to irritable bowel syndrome (IBS) patients, showing significant improvements in stress management. More recently, Burkhart et al. (2018) applied biofeedback games in combination with psychoeducation on the effect of stress, diaphragmatic breathing, and progressive muscle relaxation in younger populations within an adolescent medicine clinic. At post-intervention, they reported a clinically significant decrease in subjective distress, providing important implications for the use of biofeedback games to enhance traditional interventions. This showcases the benefits of game-based intervention as opposed to standard interventions. These results align with findings from Dillon et al. (2016), who within 50 participants aged between 18-35 found that skin-conductance biofeedback combined with gaming-style smartphone applications significantly improved stress and heart rate levels in comparison to the control group.

Mobile biofeedback apps also present a promising, accessible approach to stress management, especially as app-based gaming offers increased accessibility and familiarity for a large portion of users. For instance, Almeqbaali et al. (2022) reported the effectiveness and ease of use of a mobile biofeedback app designed by mental health professionals to help young adults with anxiety. Moreover, Chand & Khosla (2022) showed how affordable, open-source systems like the Nintendo Entertainment System (NES) could gamify biofeedback, enhancing engagement and mental relaxation through higher HRV, indicating lower stress. This demonstrates how biofeedback games can meet the demands of a variety of populations and users through accessibility and affordability.

5.3. Biofeedback games for supporting neurodiversity

Several studies included in the review demonstrated how biofeedback games also show promise for supporting neurodivergent populations, particularly in attention regulation and social support. For individuals with attention deficit hyperactivity disorder (ADHD), a neurofeedback game shows promise in enhancing focus and attention, as shown in a study of adults with ADHD by Ochi et al. (2017), though it is worth noting the study was a pilot.

Further, gamified neurofeedback for increasing adherence to treatment due to the collaborative and engaging nature of these games has also been proposed for children with ADHD (Arrambide et al., 2019). For autistic children, neurofeedback games have been proposed to support social and attentional capabilities, Yang et al. (2021) conducted a neurofeedback training (NFT) game using EEG-based neurofeedback in special education centres. The researchers highlighted the importance of involving both the children and their caregivers and parents to gain deeper insight into the experience of the children given the individual differences and challenges of communication (p.8, Yang et al., 2021).

5.4. Biofeedback games for cognitive development

A further key application of biofeedback games was found to be in enhancing cognitive skills and promoting emotional competence. Echoing the improved attentional-cognitive performance findings from Zafar et al. (2017; 2020), Suhail & Vinod (2024) explored how neurofeedback games could improve attention and working memory in healthy individuals, finding an improvement as a result of the non-violent neurofeedback game sessions. Repeating the sentiments of Chand & Khosla (2022), the authors also highlighted the low cost of the wireless EEG system, suggesting its comfort and convenience as factors for smooth dissemination into non-laboratory contexts (p.490, Suhail & Vinod, 2024). Looking towards cognitive enhancement within a language learning context, Chang et al. (2020) focused on auditory discrimination using an event-related potential game, where participants significantly improved in differentiating speech sounds in a foreign language.

5.5. Biofeedback games for anxiety and other mental health conditions

Several studies support the efficacy of biofeedback games in managing anxiety, depression, and other mental health conditions. Weerdmeester et al. (2021) used a VR biofeedback game called DEEP, which significantly reduced anxiety levels in a group of undergraduates. This game increased participants' self-efficacy, and its effects on anxiety persisted over three months. Biofeedback games have also been employed to address depression. Cai et al. (2017) explored a VR neurofeedback game for individuals with depression, finding that it enhanced their motivation to engage in therapy. Similarly, Rockstroh et al. (2021) showed how biofeedback training for diaphragmatic breathing in a VR environment helped decrease burnout symptoms and boost relaxation-related self-efficacy in participants. Furthermore, biofeedback games were shown to support emotional regulation in a variety of different settings. Haneveld et al. (2023) investigated the use of VR biofeedback for diaphragmatic breathing in forensic psychiatric patients, showing its potential to help individuals manage negative emotions. The results demonstrated how DEEP offered innovative methods to support users, though the inability to personalize the game hindered long-term engagement, which is an important consideration for future implementations.

6. Discussion: implications for teacher training

The goal of this review was to use the findings of a review of applications of biofeedback games in diverse settings to showcase the increasing potential of biofeedback and neurofeedback games as tools for emotional regulation, cognitive development, and stress

management in teacher training contexts. As mentioned, the present state of the literature surrounding the topic is limited, thus in the following discussion we offer proposals for potential implications. Biofeedback games have shown promising outcomes across various populations and contexts, such as enhancing attention in neurodiverse groups, improving relaxation in therapeutic settings, and reducing anxiety and stress through real-time physiological feedback. However, there is a noticeable gap in the application of biofeedback games within teacher training programs, where such tools could play an essential role. This discussion will explore the implications for teacher training.

6.1. Emotion regulation and stress management in teacher training

The results from the review support the proposal that integrating biofeedback games into teacher programmes could significantly benefit not only the teachers themselves but also the students. These games, which were shown to be successful in anxiety and stress management (Almeqbaali et al., 2022; Burkhart et al., 2018; Chand & Khosla, 2022; Condron et al., 2009; Dillon et al., 2016; Parnandi et al., 2014; Weerdmeester et al., 2017; Wollmann et al., 2016; Zafar et al., 2017, 2020), could be highly beneficial in teacher training. As mentioned previously, early-career teachers often experience high levels of stress. Incorporating biofeedback games into teacher training programs can help educators develop emotional regulation skills, increasing their resilience to classroom stressors and preventing burnout. Teacher's emotional regulation and well-being are linked to their job retention (Sadraei et al., 2024), and while biofeedback games improve emotional well-being and help with stress management—indirectly easing burnout—the study by Rockstroh et al. (2021) is particularly significant. It directly shows a reduction in burnout symptoms, positioning biofeedback as not just a tool for emotional regulation but as an effective intervention for combating teacher burnout. As well as this, teachers who are better able to manage their emotions in turn create more emotionally safe and inclusive learning environments. Biofeedback games could enhance teachers' self-awareness and emotional control, which has positive implications for classroom management and student outcomes.

As mentioned, a key principle of CDS is the acknowledgement of systemic and structural pressures that teachers face and that ultimately drive stress and burnout. Integrating biofeedback games into teacher training programs offers an opportunity to address these pressures, providing teachers with tools to navigate and critique these conditions as opposed to placing teacher stress as a personal defect or inability to manage the career**.** This perspective demands a shift from an individual-focused narrative to one that acknowledges the broader systemic and organizational contexts, as well as highlighting the importance of teachers' emotional well-being for themselves and students alike. Furthermore, the application of biofeedback games in teacher training could foster collective well-being and coregulation by promoting shared emotional regulation strategies within educational institutions, which nurtures positive student-teacher interactions (Aldrup et al., 2024), and student success (Braun et al., 2020; Sáez-Delgado et al., 2022.

However, despite the potential of incorporating biofeedback games within teacher training programmes, practical barriers such as the costs of equipment remain significant obstacles, particularly in higher education (Leontyeva, 2018). Not only would higher education institutions need to afford the costs of the equipment, but there would also be financial needs for the training of the teachers to use the equipment. Nevertheless, biofeedback sensors are becoming increasingly available and with relatively simple designs stand as optimal non-invasive technologies.

6.2. Cognitive skills enhancement for professional development

The findings from the review which related to cognitive development also have key implications for teacher training programmes. The review highlighted biofeedback games as valid supports for attentional-cognitive performance (Ochi et al., 2017; Zafar et al., 2017, 2020), as well as for working memory (Suhail & Vinod, 2024). This has implications for teacher training as this could mean that they might be more effective in their teaching roles, which would lead to better learning outcomes for students. Improved attentional and cognitive abilities may also enable teachers to engage with students more effectively, fostering a positive classroom environment that enhances overall educational experiences. Additionally, equipping teachers with enhanced cognitive skills may empower them to adapt their instructional strategies to meet diverse student needs. Within the CDS framework, professional development through the use of cognitive training technologies like biofeedback games stand as tools that are incorporated into systemic teacher training curriculums, rather than merely supporting individual teacher performance.

Moreover, the review also found biofeedback games to be connected to self-efficacy (Rockstroh et al., 2021; Weerdmeester et al., 2017). Improvements in one's ability to manage their autonomic responses and emotional regulation may improve well-being and self-efficacy. In teaching contexts, self-efficacy has been suggested to not only be important for teaching skills (Walter, 2015), and efficacy (Karim et al., 2021) but also for preventing burnout (Friedman, 2003; Li, 2023). Thus, biofeedback training, through its ability to contribute to the management of emotions, could have implications for enabling teachers to feel more competent in their abilities, ultimately leading to improved job satisfaction. If teachers feel more confident in their roles, they may be more equipped to cope with the challenges of teaching, positively impacting their well-being, as well as that of their students. This creates a more resilient teaching workforce, as well as more emotionally safe and supportive learning environments.

The findings from the included studies also included support for the gaming element of biofeedback games to increase adherence to treatments due to increased engagement, this has relevant implications for biofeedback games within teacher training as teachers may be more inclined to use biofeedback techniques if they are more accessible and appealing.

The review highlights the importance of participatory design in biofeedback technologies, which is a principle rooted in CDS. Applying this principle within teacher training programs ensures that biofeedback games are tailored to the specific needs and experiences of educators, including those from marginalized or underrepresented backgrounds. This approach not only enhances the usability of these tools but also reinforces their alignment with inclusive and adaptive educational practices.

7. Limitations and future research directions

In a discussion of the potential of biofeedback games in teacher training, it is crucial to also address the methodological limitations in the existing research. One major limitation is the small sample sizes in many of the studies, utilising homogenous groups, sometimes exclusively male participants, thus limiting the generalisability of the findings. Additionally, though some studies pointed to the system usability and convenience of the biofeedback training game (Chao et al., 2023; Suhail & Vinod, 2024), the controlled lab settings in which a major part of the studies were conducted raises questions about how well these games would perform in the real-world settings. One study highlighted system resilience to sensor movement and noise in a non-

laboratory environment (Flowers et al., 2018), an important consideration due to the commonality of disruptions in classroom and non-controlled environments.

Many of the reviewed studies focused on biofeedback's use in therapeutic contexts, such as anxiety management and emotional regulation for specific populations. While this highlights biofeedback's potential for improving mental health, the use of penalisation within the games to encourage users to adapt their responses could be reflective of the medical model approach that seeks to 'normalize' or 'correct' behaviour. One study highlighted this further, reporting that within neurofeedback games, positive reinforcement is more effective than negative reinforcement (Reinschluessel et al., 2016). Moreover, it is important to consider the broader systemic or social stressors teachers face, an area that CDS emphasises. Through this lens, biofeedback games should empower teachers to manage stress and personal regulation, whilst considering also external, systemic stress factors.

Ethical considerations related to the implementation of biofeedback games in educational settings are also important to highlight. The continuous collection of biometric data could exacerbate stress or anxiety for some teachers. It is important that future implementations address these potential risks by using strict protocols for data privacy and security, as well as transparency in how the data is used. Schools and researchers must carefully consider and navigate these concerns to avoid inadvertent psychological harm.

Furthermore, one study examining a neurofeedback game found only marginal evidence supporting the game's claims (Coenen et al., 2020), underscoring the need for validation before widespread implementation. This is especially important when using these technologies with disabled or vulnerable groups to ensure, as mentioned earlier, they are used in a thoughtful, meaningful way (Connor & Beard, 2015). Additionally, the cost and accessibility of biofeedback tools present barriers for schools with limited funds or educators operating in resource-constrained environments. There remain important questions about not only how to ensure equitable access to these technologies across diverse educational contexts, but also how to sufficiently train teachers to use such tools.

A significant limitation of existing research is the narrow scope of participant demographics, due to the limited existing data, sample sizes are generally small and homogenous. Future investigations should aim to recruit larger and more diverse populations, accounting for socio-economic and cultural differences to enhance the generalisability of findings. Future research should focus on developing and testing biofeedback games designed specifically for teachers, using larger and more diverse sample sizes to ensure the generalisability and validity of the results. It will also be important to assess the long-term effects of these tools on teacher performance, emotional regulation, and student outcomes, as well as their integration into daily pedagogical practices. Longitudinal studies are necessary to assess the long-term effects of biofeedback on teacher well-being, classroom performance, and student outcomes. Additionally, future game designs should prioritize positive reinforcement mechanisms to enhance user engagement and outcomes (Reinschluessel et al., 2016).

8. Conclusion

Though in the early stages biofeedback games offer an innovative and promising approach to both education and therapeutic contexts. By integrating gamification with biofeedback, these games provide an engaging and effective way to enhance socio-emotional skills, cognitive abilities, and self-regulation techniques. As research on biofeedback games continues to expand, their potential to support stress management and emotional resilience within teacher

training programs increases, and access to these games becomes more widely available. However, as the field continues to grow, and biofeedback games become more accessible, it is essential to validate findings within diverse educational, and teacher training contexts.

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10. Authors' contributions

This article was the work of multiple authors. Savannah Olivia Mercer wrote sections 1, 3, 4, 5, 6 and 7. Giorgia Rita De Franches wrote sections 2, 4, 6, and 8.

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