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Understanding Teacher Emotions Through Electrodermal Activity in Teaching: A Narrative Review

Comprendere le emozioni degli insegnanti attraverso l'attività elettrodermica nell'insegnamento: una revisione narrativa

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Abstract:
Research demonstrates that the emotional state of teachers significantly impacts both their occupational health and the classroom environment. Stress and emotional variations affect teaching self-efficacy and students' outcomes, making the study of teacher emotions essential. Electrodermal activity (EDA) measures autonomic arousal through skin conductance changes and shows promise for biofeedback in pedagogical self-reflection, and teacher stress measurement. This paper presents a narrative review of literature on the use of EDA specifically with teachers, mapping key themes and research gaps, and discussing future research implications. With the rise of wearable EDA devices, there is significant potential for their use in teaching. Understanding teacher emotions through EDA can inform and refine strategies for self-reflection, stress management, and overall professional development.

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Keywords: teacher emotions, electrodermal activity, pedagogical self-reflection, student outcomes, narrative review.

Abstract:
La ricerca dimostra che lo stato emotivo degli insegnanti influisce significativamente sia sulla loro salute professionale che sull'ambiente in classe. Lo stress e le variazioni emotive influenzano l'autoefficacia nell'insegnamento e i risultati degli studenti, rendendo lo studio delle emozioni degli insegnanti essenziale. L'attività elettrodermica (EDA) misura l'arousal autonomico attraverso i cambiamenti della conduttanza cutanea (SC) e mostra il potenziale per il biofeedback nella riflessione pedagogica e nella misurazione dello stress degli insegnanti. Questo studio presenta una revisione narrativa della letteratura sull'uso dell'EDA con gli insegnanti, mappando i temi chiave e le lacune nella ricerca e discutendo le implicazioni per le ricerche future. Con l'aumento dei dispositivi indossabili per l'EDA, vi è un notevole potenziale per il loro utilizzo nell'insegnamento. Comprendere le emozioni degli insegnanti attraverso l'EDA può informare e affinare strategie per l'autoriflessione, la gestione dello stress e lo sviluppo professionale complessivo.

Parole chiave: emozioni dell'insegnante, attività elettrodermica, autoriflessione pedagogica, risultati degli student, revisione narrativa.

1. Introduction

Teacher emotions play a significant role in both their own mental and occupational well-being and classroom dynamics including students' learning outcomes. High levels of stress and emotional dysregulation among educators can lead to burnout, affecting teaching efficacy, student learning, and the classroom environment. These issues are particularly important in a time of increasing centrality of inclusive classrooms, in which the creation of safe and supportive environments is essential. In a digitally evolving era, innovative technology and devices are being pushed towards educational and classroom use. While existing research has focused on students' emotional regulation, the exploration of innovative technology to support teacher emotions remains scarce. Electrodermal activity[2] (EDA), a physiological measure of arousal, offers a promising objective measure of teacher emotional states. The narrative review aims to exhibit studies exploring EDA as an emotion measurement, and the application of this physiological marker with teachers in educational and professional settings, thus integrating these emerging areas of research.

2. Theoretical Framework

Research on teacher emotion is emerging as an increasingly important area within didactics due to its importance not only for teacher wellbeing (Dreer, 2024; Hascher & Waber, 2021; Stück et al., 2005; Turner & Garvis, 2023) but also for students' wellbeing (Frenzel et al., 2021). High levels of teacher stress and dysregulation contribute to prevalent issues like burnout (Brackett et al., 2010; Turner & Garvis, 2023), leading to educators potentially leaving the profession (Madigan & Kim, 2021b). As well as this, research indicates that teacher stress adversely affects teaching self-efficacy (Burić et al., 2020; von der Embse & Mankin, 2021) and students' learning outcomes (Madigan & Kim, 2021a; Pi et al., 2022). This research is particularly relevant in the context of inclusive classrooms, where the

[2] This article will refer to an abbreviation of electrodermal activity as EDA.

emphasis on creating safe and supportive environments for all students is paramount. Whilst research has explored innovative devices for exploring and supporting students' emotions, for example for neurodiverse students (Zheng et al., 2019), fewer research has assessed the use of these for teachers (Bower & Carroll, 2017). Effective regulation of teacher emotions is crucial (Yin et al., 2016) for fostering positive student-teacher interactions (Aldrup et al., 2024), which are essential for the development and success of all students who require safe, regulated adults to promote co-regulation (Braun et al., 2020; Sáez-Delgado et al., 2022).

Electrodermal activity (EDA) also known as galvanic skin response[3] (GSR) acts by detecting changes in skin conductance which reflects the activity of the sympathetic branch of the autonomic nervous system (ANS) (Meijer et al., 2023; Tronstad et al., 2022), and has historically stood as a valid measure of physiological and emotional arousal (Li et al., 2022). EDA can be collected through wearable sensors, and these devices are becoming increasingly used in mainstream settings.

Studies integrating EDA into educational contexts have focused on its use in measuring student engagement (Disalvo et al., 2022; Fogarty et al., 2023; Gao et al., 2020; Juárez Varón et al., 2023) regulation (Betancourt et al., 2017; Redd et al., 2020), and behaviour (Van Laarhoven et al., 2021), with less focus instead on one of the most influential figures in the classroom, the teacher. Teacher emotion so far has largely been measured subjectively by tools such as self-report, interviews, and observations. These measures rely on either teachers' self-awareness of their emotions, or for an external observer's subjective interpretation, both of which risk inaccurate results due to hiding and concealing of emotions (Hagenauer & Volet, 2014). Given the large body of evidence for the impact of teacher emotion, it is crucial to understand this area further using more objective measures. Understanding these emotions can offer valuable insights into the challenges and stressors faced by teachers, thereby informing strategies to enhance their well-being and professional performance.

In the relatively niche context of the use of EDA in measuring teacher emotional states, the approach of a narrative review allows for a more flexible inclusion criteria, and the synthesis of results from a wider range of contexts, methodologies, and perspectives. The approach also enables the identification of themes as well as gaps in the literature. This narrative review used the following process: a clear and strategic search of the literature, depiction of the results through set themes, evaluation of the quality of data, and presentation of conclusions.

3. Methodology

3.1 Search strategy

A comprehensive, strategic search was conducted across two major databases: Scopus and Web of Science. Search terms included combinations of keywords such as 'electrodermal activity' OR 'EDA' OR 'galvanic skin response' OR 'GSR' AND 'teacher' OR 'educator' OR 'teaching staff'. Throughout several stages, variations of these terms were added and finalised to capture different aspects of physiological responses in educational professionals, as well as incorporating older terms for EDA. There were no date limits set in order to gain a complete and thorough overview of EDA use.

[3] Galvanic skin response (GSR) is an older, now less commonly used term for electrodermal activity which studies in this review may refer to, skin conductance is another variation of electrodermal activity.

3.2 Search results

Initially, the Web of Science database yielded 131 articles. After applying language filters to include only English and Italian publications and removing any date restrictions, the number of articles was reduced to 122. Subsequently, a detailed screening of titles and abstracts was conducted, which focused on identifying terms that clearly reflected the theme of EDA application in education. Identified abstracts were those which explicitly addressed the use of EDA as a physiological measure of emotion, specifically in educational settings. This identified 25 articles relevant to the review's objectives. Similarly, the Scopus database search initially resulted in 161 articles. Following the application of the same language filters, the number of articles decreased to 152. Title and abstract screening then identified 30 relevant articles. The chosen articles were imported into reference managing software Zotero, wherein duplicates of the same articles retrieved from both databases were removed. The final combined result from both databases, after removing duplicates, was 39 articles, which were subjected to a thorough full-text review. Full-text review involved detailed assessment focusing on the exclusion and inclusion criteria. Articles included for review included papers related to the measure of EDA in teachers. Exclusion criteria included studies that were not focused on the use of EDA in teachers, for example articles which investigated the use of EDA in student only samples. The decision to include theoretical papers as well as empirical studies was made, in order to provide a thorough, detailed overview. Only articles with that included EDA as a measure were included, for instance articles that used physiological measures including only heart rate (HR), but not EDA, were excluded. This process resulted in a further 20 articles being removed, leaving 19 articles deemed suitable for inclusion in this narrative review.

3.3 Data extraction and synthesis

The data extracted for the narrative review included key aspects of the study design, findings, and conclusions. The extracted data was then narratively reviewed in order to identify 3 themes, which are summarised, with key findings highlighted, in the results section:

1. EDA as a measure of teacher burnout and stress
2. EDA for pedagogical self-reflection
3. EDA for capturing teacher emotion and interaction dynamics.

Patterns and differences were discussed and findings within all 3 themes were integrated into a wider discourse on using EDA as a valid measure of teacher emotion. The discussion section outlined implications and future steps, as well as assessment of the quality of included studies, with a focus on methodologies and sample sizes. As no primary data was collected for this narrative review, there were no ethical considerations apart from to ensure an accurate depiction of the included studies.

4. Results

The application of electrodermal activity (EDA) measures in studying and addressing teacher emotions is an emerging area of research. EDA, which reflects physiological arousal and stress, offers a non-invasive method to objectively quantify physiological responses to stimuli encountered in teaching environments. Here we outline the results of the narrative review, divided into three main themes: evidence of EDA as a measure of teacher stress and burnout, EDA for pedagogical self-reflection and professional self-awareness, and EDA for measuring teacher emotions within interaction dynamics.

4.1 Electrodermal activity as a measure of teacher stress and burnout

Research has explored how EDA can be utilised to monitor and manage stress levels among teachers. In an earlier study, Al-Fudail & Mellar (2008) investigated teacher stress when using technology using GSR readings in combination with direct observation and interviews from 9 teachers across 32 hours of teaching activities. Through the use of GSR data, they identified that teachers did experience 'technostress' (p. 1104, Al Fudail & Mellar, 2008). Their findings demonstrate the validity of EDA as an objective physiological measure, particularly when combined with a subjective tool such as direct observation. The multi-method approach, also known as triangulation, offers a robust, nuanced understanding of stress in teachers.

In a longitudinal investigation over two academic years, Bustillo & Antón (2019) examined changes in EDA and heart rate (HR) of university teachers in response to stressful stimuli during teaching activities. They used a multisensory wristband on 3 lecturers. Whilst they found no significant variations in HR, significant changes in EDA were observed during teaching activities compared to non-teaching activities. The average EDA for teaching activities was consistently higher than for non-teaching activities, even for working days with more calm, less demanding sessions, suggesting that teaching activities induce a 'basic alert state' (p.1160, Bustillo & Antón, 2019) leading to increased EDA. These findings suggest that EDA provides insights into basic states of stress, not only in relation to acute stress responses to stressful stimuli, but also in relation to base states over longer periods of time, indicating potential burnout. The lack of variations in HR may also suggest EDA as a more sensitive, appropriate measure of stress.

Junker & Holodynski (2022) conducted a study in which the lessons of eight teachers were recorded, whilst their stress levels were measured by EDA. Teachers watched recordings of their lessons later and indicated stressful moments with a joystick. Findings showed that teachers did not consistently recall the same stress levels as they experienced during teaching. The study suggests that video feedback alone may not effectively help teachers cope with stress without the addition of real-time stress level information from EDA. These results highlight EDA's potential and importance for objectively measuring teacher stress.

Malcik & Miklosikova (2017) also used EDA to investigate teachers' emotional involvement, which has been cited as an aggravating factor within teacher burnout (Bodenheimer & Shuster, 2020; Madaliyeva et al., 2015). Through a questionnaire alongside EDA data, the study assessed teachers' awareness of their emotional involvement. The use of GSR data assisted in their findings that emotions were found to manifest as immediate responses influenced by personal experiences, interests, and goals, affecting both subjective experiences and physiological changes. This dual approach showed insights into how emotions inform teachers' perceptions and cognitive processes, and the teachers stated they had found the experience to be didactic (Malcik & Miklosikova, 2017).

Interesting results relating to burnout come from a recent pilot study (Cecho et al., 2021), where EDA changes were analysed by skin conductance level (SCL) in 28 high-school teachers and 22 administrative workers at the beginning and end of the academic year. It was found that the teachers had significantly lower SCL at the end of the academic year. They conclude that EDA is a,

> *'...promising and objective, non-invasive tool for the determining pure sympathetic nervous system activity suitable in preventive occupational medicine that perfectly fits stress measurement'* (p.31, Cecho et al., 2021).

This reinforces the practicality of EDA for the early identification and prevention of potential future complications from occupational stress-related burnout and health problems. These findings underscore EDA's role not only in recognising acute stress, but also in empowering educators with tools to proactively address and mitigate its adverse effects for the prevention of the increasingly prevalent teacher burnout.

4.2. EDA for pedagogical self-reflection and professional self-awareness

Recently, research into the use of EDA within measures of teacher's emotional states has also explored the use of EDA to enable pedagogical self-reflection in teachers. Lake & Nardi (2023) used GSR data to study the emotions of mathematics teachers, in their study, GSR sensors tracked emotional changes in the participants during lessons. Pre- and post-lesson interviews, combined with video recordings and GSR data, demonstrated how emotional intensity influenced teaching actions. The GSR data provided objective physiological insights not captured by subjective methods alone, enhancing teacher reflection on emotional dynamics and their impact on lesson quality. Similarly, another study aimed to measure the physiological aspect of emotional experiences among university teachers during pedagogical micro-performances using GSR (Malcik & Miklosikova, 2018). Teachers' awareness of their emotional and physiological changes was assessed by a questionnaire, which also explored teaching experience, personality traits (introversion and extroversion), and external disturbances. Results from the questionnaire were compared with GSR measurements to understand correlations between subjective experiences and physiological responses. Findings indicated that GSR provided objective feedback that teachers could use for pedagogical self-reflection. Again, biofeedback combined with a subjective method of questionnaire responses, facilitated deeper insights into emotional processing and informed teachers' future pedagogical approaches based on their individual characteristics and emotional experiences. These studies support the potential of GSR, within a triangulation approach, as a tool for enhancing pedagogical self-awareness and effectiveness, to allow for professional development. Seppänen et al. (2021) using EDA investigated how manipulating real-life as opposed to fictional contexts modulates psychophysiological responses to social rejection in student teachers. 39 subjects experienced various social rejections (devaluing, interrupting, nonverbal rejection) during real-life interviews and fictional improvisation exercises. EDA, alongside other physiological measures like heart rate (HR), facial muscle activity, and electroencephalogram (EEG), was analysed. The results indicated that EDA demonstrated heightened sensitivity during fictional rejections, suggesting it as a robust indicator of emotional arousal even in simulated settings. This highlights EDA's potential as a measure of emotional responses in educational settings by offering insights into the emotional dynamics of teachers during interactions with students. Thus, while the study indirectly addresses teacher emotions through student-teachers experiences, it highlights EDA's relevance for educational research and practice.

4.3 EDA for measuring teacher emotions within interaction dynamics

As suggested in the literature, teacher emotions and states of regulation also significantly impact student wellbeing (Braun et al., 2020). Regarding EDA for measuring and promoting teacher regulation, Caglar-Ozhan et al. (2022) utilised a combination of electroencephalogram (EEG), GSR, and facial expression data to capture the basic emotional states of 15 prospective teachers. The study used wristbands to collect data on the emotions of teachers when in a simulated virtual classroom

(SVC), for instance during student-teacher interactions or during student misbehaviour, which would then be used to provide affective recommendations. In their results, they reported that prospective teachers engaged in the 'cognitive reappraisal process' following the reception of an affective recommendation, which the authors asserted is suggestive of the teachers' attempts to achieve emotional balance, thus, regulation (Caglar-Ozhan et al., 2022). These findings emphasise the potential for improving student-teacher interaction dynamics by helping teachers better regulate their emotions through real-time physiological feedback. Paloniemi et al. (2022) explored EDA in the context of professional identity learning, a process through which professionals gain awareness of, reflect on, and internalize their professional commitments, values, career trajectories, and strengths and weaknesses in their professional practice (Paloniemi et al., 2022). They conducted a within-subjects design study in a controlled laboratory setting, integrating self-report data and EDA readings from 5 Finnish university teachers. The study confirmed EDA as a valid measure of arousal in emotional contexts and highlighted the importance of minimizing movements to avoid interference. The within-subject design helped control for individual differences such as age, sex, medication, physical exercise, temperature, and humidity. It also emphasized the need for careful synchronization of multiple data collection devices, which although time consuming, is more feasible in a laboratory setting. Qi et al. (2024) in their study of how dyadic emotional transmission shapes teacher-student relationships identified that existing methods have limits in regard to their sole reliance on self-report surveys or observations from teachers or students for collecting perceptions of each other's behaviour during these interactions. With reference to Pennings (2018) they reassert the importance of 'micro-level interaction processes as building blocks of interpersonal relationships in education' (Pennings, 2018, cited in Qi et al., 2024). Through the collection of GSR signals via wrist-worn devices in a naturalistic classroom teaching environment, they found that these teacher-student interactions improved 'physiological coupling', thus improving student-teacher cohesion. In a natural classroom setting they showed that GSR can detect relationships between teachers and students, as well as perceptions of each other, thus having significant implications for the use of EDA measures in improving classroom dynamics and how teachers can utilise this to improve their class environments. Singh & Arya (2023) examined 14 university teachers and 18 graduate learners engaged in online synchronous classes to predict teacher personalities and their influence on online teaching effectiveness from both learner and teacher perspectives. While primarily using questionnaire-based assessments, the research also recorded physiological measures such as EDA (GSR), alongside ECG, EMG. The findings highlighted that GSR enhanced the authenticity of personality predictions compared to self-reported data alone. This study suggests that integrating physiological responses, especially GSR, could improve the accuracy of personality assessments in educational contexts, thereby supporting more effective online teaching practices. These insights can contribute to better understanding and enhancing student-teacher interaction dynamics by providing a more accurate assessment of teacher personalities, which in turn can inform strategies for improving engagement and communication in online learning environments.

5. Discussion

5.1 Quality of studies

Whilst overall the review included a varied range of lab-controlled and real-life contexts, there is an overarching call for more research into EDA and teacher emotion in naturalistic, real-life, longitudinal settings, for greater generalisability. As well as this, another prevalent issue was sample

size, with most studies only analysing data from a small number of subjects. Dong and Miao (2024) emphasised the importance of the use of a variety of methods, combining subjective and objective measures of emotion. In general, most studies employed triangulation (reference) and utilised combinations of EDA data with subjective data inclusive of; self-report, interviews, and observations. This greatly enhanced the reliability of the data in that each data source complimented the other and allowed for more accurate depictions of the results. Some studies also employed more than one physiological measure, using EDA in combination with ECG, or HR readings, which also increased the specificity of conclusions.

5.2 Strengths and challenges of using EDA

When compared with other measures of emotion, stress and burnout in teachers, the use of EDA comes with strength and challenges. Firstly, EDA stands as a non-invasive method suitable for various settings due to ease of use and rare issues with discomfort. EDA was also seen to offer high sensitivity in detecting psycho-physiological arousal (Seppänen, 2020), whilst Bustillo & Antón's (2019) results highlighted EDA as detecting changes that HR did not, which could again relate to increased sensitivity of this measure of physiological arousal. A challenge highlighted in the review is the difficult and time-consuming nature of using EDA in synchronised combination with other measures of emotion (Paloniemi et al., 2022). Whilst a combination of measures does undoubtedly offer increased validity and reliability of results, the logistical planning needed may stand as one of the reasons that a lot of studies have been in controlled settings, with fewer subjects. Despite the prominent benefits of EDA, there are notable limitations and doubts about its application in educational settings. A significant issue that could hinder the diffusion of EDA in teacher training is the concern regarding the collection of biometric data, which raises ethical challenges (Pereira, 2020). Research has also highlighted teacher resistance (Griffiths & Goddard, 2015; Howard, 2013) and anxiety related to integrating new technologies (Henderson & Corry, 2021). Menabò et al. (2021) reported that perceived usefulness and perceived ease of use both increased behavioural intentions to use technology among Italian teachers. Additionally, a study by Gobbo and Girardi (2006) found that Italian teachers' beliefs about technology integration are influenced by their level of competence, affecting how they implement technology. These findings suggest that comprehensive training on how to use EDA devices, as well as the benefits of using such technology, should be included in training programs prior to the dissemination of such research. Other factors that could hinder the integration of assistive technology such as EDA are historical influences and systematic beliefs regarding inclusive education. Though Italy has been historically influential for the way in which it mainstreams students with disabilities (Aiello & Pace, 2020), there have been calls for system revisions considering innovative approaches (Marsili et al., 2021).

5.3 Research gaps and future directions

Overall, a review of the use of EDA has presented promising findings as a measure of teacher emotion. By combining physiological data with subjective data, we can gain specific, accurate insights into teacher emotion within educational settings. Future research could focus more on the EDA as a predictor of burnout. Burnout and stress awareness should become a focus of EDA research, to better understand the broader implications of prolonged periods of stress on teachers within educational settings. Furthermore, research could explore occupational wellbeing interventions for teachers, using longitudinal EDA data as a measure of efficacy. Whilst this narrative review presented

some studies which explored student-teacher interactions, more specific research for real-time biofeedback whilst teaching could be an area of potential research, to foster emotional self-awareness within teachers with a view to promote teacher regulation, thus the enhancement of emotionally safe, supportive classroom environments. Prior to the implementation of EDA studies of this nature, future research could take a qualitative approach to understanding perspectives that teachers may have regarding the use of EDA as a measure of their emotional states in order to provide insights into the types of concerns that should be addressed in training programmes as a precursor to implementation.

6. Conclusion

As part of the foundational steps for a wider project which aims to explore future teacher emotions using physiological markers such as EDA, this narrative review of 19 articles has demonstrated EDA as a useful tool providing specific and accurate insights when combined with subjective data. Through the identification of clear thematic contexts, we exhibit the promise of EDA in understanding teacher stress and its implications, suggesting future research directions for EDA as a predictor of burnout and stress. The review has identified the strengths and challenges of using EDA as a measure of emotion, as well as highlighted the need for more longitudinal research conducted in naturalistic settings. Exploring real-time biofeedback during teaching can foster emotional self-awareness, promoting emotionally supportive classroom environments. Given the impact of teacher emotions on both their occupational health and student outcomes, further research into EDA in educational settings is vital. These findings will help guide our future work and experiments exploring future teacher emotions using innovative technology and EDA as an objective, reliable measure of arousal. Understanding teacher emotions through EDA can help address aggravating and mitigating factors involved in teacher burnout, enhancing their well-being and professional performance, leading to overall more optimal classrooms.

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