



RECONCEPTUALIZING TEACHER PROFESSIONAL COMPETENCE THROUGH MEDICAL BIOCHEMISTRY: A BIOPSYCHOLOGICAL FRAMEWORK LINKING BIOCHEMICAL HEALTH, COGNITIVE FUNCTION, AND EDUCATIONAL EFFECTIVENESS

Senapati Nayak ^{1,*}, Chandrashekhar Vazalwar ², Sambit Kumar Padhi ³, Manoj Kumar Patel ⁴ and Hemlata Patel ⁵

¹ Ex. Principal-in-Charge, Maa Education College, Pamgarh, Janjgir-Champa, Shaheed Nandkumar Patel Vishwavidyalaya, Raigarh, Chhattisgarh.

² Professor, Department of Education, Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisgarh.

³ HoD & Professor, Department of Education, Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisgarh.

⁴ Assistant Teacher, Kashidih, Chandrapur, Chhattisgarh, PhD. Scholar (Hindi), ISBM University, Gariyaband, Raipur, Chhattisgarh, India.

⁵ Assistant Teacher, Kashidih, Chandrapur, Chhattisgarh. Research Scholar (Education), ISBM University, Gariyaband, Raipur, Chhattisgarh, India.

* Corresponding Author

ORCID Details

Senapati Nayak: <https://orcid.org/0009-0008-5315-7366>

Chandrashekhar Vazalwar: <https://orcid.org/0009-0009-4739-0548>

Sambit Kumar Padhi: <https://orcid.org/0000-0002-7067-0814>

Manoj Kumar Patel: <https://orcid.org/0009-0002-3142-4052>

Hemlata Patel: <https://orcid.org/0009-0009-3082-0417>

Open Access Research Journal of Science and Technology, 2026, 18(01), 186–199

Publication history: Received on 06 September 2026; revised on 23 October 2026; accepted on 24 October 2026

Article DOI: <https://doi.org/10.53022/oarjst.2026.18.1.0098>

Copyright © 2026. Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0

ABSTRACT

Teacher professional competence has traditionally been theorized through pedagogical, cognitive, and motivational lenses, treating biological health as a peripheral concern rather than a core determinant of instructional capacity. This paper proposes a biopsychological reconceptualization of teacher competence that positions medical biochemistry—specifically micronutrient status, hormonal regulation, gut-brain signaling, sleep architecture, and stress-biomarker profiles—as a foundational layer underlying cognitive function and, by extension, classroom effectiveness. Drawing on peer-reviewed research published between 2020 and 2025 across educational psychology, endocrinology, nutritional science, and microbiome research, the paper synthesizes evidence linking biochemical dysregulation to impairments in working memory, attention, emotional regulation, and decision-making—the same cognitive-affective resources teachers draw on moment-to-moment in instructional practice. The paper proposes a biopsychological framework that models teaching competence as emerging from the interaction of biochemical health, cognitive-affective function, and pedagogical skill. The paper argues that teacher training, occupational wellness policy, and school-level health infrastructure should treat biochemical health as a professional-competence variable rather than a private lifestyle

matter. It outlines practical implications for teacher education programs, occupational health policy, and future interdisciplinary research.

Keywords: Teacher Competence, Biopsychology, Medical Biochemistry, Cognitive Function, Stress Biomarkers, Gut-Brain Axis, Educational Effectiveness

1 INTRODUCTION

Teaching is often described as one of the most cognitively and emotionally demanding professions, requiring sustained attention, rapid decision-making, emotional regulation, and working-memory-intensive multitasking throughout the instructional day (Wettstein, Schneider, Grosse Holtforth, & La Marca, 2021). Despite this, dominant models of teacher professional competence - including knowledge-skills-beliefs frameworks - have historically treated the teacher's body as incidental to competence, focusing instead on content knowledge, pedagogical content knowledge, and professional beliefs (Baumert & Kunter, 2013). This framing implicitly assumes that a teacher's cognitive and emotional resources are stable and biologically unconstrained, an assumption increasingly contradicted by evidence from stress physiology, nutritional neuroscience, and microbiome research.

A growing body of research shows that teachers experience substantial physiological stress during the instructional day, with measurable changes in salivary cortisol and alpha-amylase concentrations over a single teaching session (Mahfoodh et al., 2024). Chronic exposure to classroom stressors has also been linked to elevated allostatic load - a composite measure of cumulative physiological wear - with consequences for long-term health and, plausibly, for the cognitive resources teachers bring to instruction (Wettstein, Jenni, Schneider, Kühne, Grosse Holtforth, & La Marca, 2023). At the same time, separate literatures on micronutrient status (Singh et al., 2023), gut microbiota composition (Hameed et al., 2024), and sleep quality (Sánchez-Narváez, Velasco-Orozco, & Pérez-Archundia, 2023) each independently show associations with cognitive performance, mood regulation, and burnout risk. However, these biochemical and physiological literatures rarely intersect with mainstream teacher-competence research, which remains largely confined to pedagogical and psychological constructs.

This disconnect reflects a conceptual gap with practical consequences. If cognitive functions such as working memory, inhibitory control, and affective regulation are demonstrably sensitive to biochemical status, then teacher competence - insofar as it depends on these functions - is partly a biochemical phenomenon, not solely a pedagogical or motivational one. Conceptualizing competence in this way has implications for the design and funding of teacher training programs, school health policies, and occupational wellness initiatives.

This paper addresses three research questions. First, what does the 2020–2025 literature indicate about the relationship between biochemical health markers - including micronutrient status, hormonal regulation, gut-brain signaling, sleep quality, and stress biomarkers - and the cognitive functions relevant to teaching? Second, how can these relationships be integrated into a coherent biopsychological framework linking biochemical health, cognitive function, and educational effectiveness? Third, what practical implications does this framework have for teacher training, occupational health policy, and school-level infrastructure?

This inquiry is significant in two ways. Academically, it extends teacher-competence theory beyond its traditional psychological and pedagogical boundaries by incorporating biomedical evidence, thereby offering a more complete account of the physiological resources that underlie instructional performance. Practically, it reframes teacher wellness - often treated as a matter of individual responsibility or morale - as a component of professional infrastructure with direct bearing on instructional quality and, by extension, on student outcomes. The remainder of the paper reviews the relevant literature, proposes a biopsychological framework, critically examines the evidence base, and concludes with implications for teacher training and education policy.

2 LITERATURE REVIEW

2.1 Teacher Professional Competence: Contemporary Perspectives

Contemporary models of teacher professional competence extend well beyond simple content mastery. The influential COACTIV framework conceptualizes competence as a multidimensional construct spanning professional knowledge and skills, beliefs, and affective-motivational characteristics, including self-regulatory capacity (Baumert & Kunter, 2013). In this model, self-regulation is not incidental but constitutive of competence: the capacity to manage one's thoughts, behaviors, and emotional responses under classroom demands is treated as a professional skill in its own right, on par with pedagogical content knowledge. Recent instrument-development work has further expanded this multidimensionality, incorporating professional well-being and adaptive capacity as measurable dimensions of teacher

development (Kırkıç, Töre, Çetin, & Uysal, 2025). These frameworks create conceptual space - though they rarely operationalize it directly - for biological determinants of self-regulatory capacity to be considered part of competence rather than external to it. This literature largely lacks an explicit account of the physiological substrate that enables or constrains the affective-motivational and self-regulatory dimensions these models already recognize as central.

2.2 Stress Biomarkers in the Teaching Profession

Direct physiological monitoring of teachers during instruction provides some of the clearest evidence that classroom demands are metabolically costly. Salivary sampling across a teaching day has shown significant fluctuations in cortisol and alpha-amylase - established biomarkers of hypothalamic-pituitary-adrenal (HPA) axis and sympathetic nervous system activation - with younger, more experienced, and more highly educated teachers showing particularly pronounced alpha-amylase elevations before and during active teaching (Mahfoodh et al., 2024). These acute, within-day fluctuations sit atop a longer-term physiological picture. Longitudinal tracking of hair cortisol concentration, blood pressure, and body mass index - combined indices of allostatic load - indicates that neuroticism and perceived classroom disruption at baseline predict elevated psychological strain and physiological wear two years later, while a positive core self-evaluation functions as a protective factor (Wettstein et al., 2023). Because chronic HPA-axis activation is mechanistically linked to impaired prefrontal regulation of working memory and inhibitory control, this evidence positions classroom-induced stress physiology as a plausible pathway through which occupational demands erode the very cognitive resources teaching requires.

2.3 Hormonal Regulation and Cognitive-Affective Control

Beyond cortisol's role as a passive stress marker, emerging intervention research suggests that how stress is cognitively appraised can shape hormonal and cognitive outcomes. A randomized controlled trial testing a brief, video-based stress-mindset intervention among public school teachers found that reframing stress as adaptive altered salivary cortisol and dehydroepiandrosterone-sulfate (DHEA-S) profiles and produced measurable changes in performance on the Stroop cognitive-control task (Langrafe, Fernandes, Peixoto, & Nishiyama, 2025). This finding matters because it shows bidirectionality: hormonal regulation is not simply a downstream consequence of classroom stress. Rather, it can be modulated through psychological intervention, with corresponding effects on executive function - a core component of moment-to-moment instructional decision-making.

2.4 The Gut-Brain Axis

A parallel, still-emerging literature implicates gut microbial health as a determinant of cognitive functioning through the bidirectional gut-brain axis, a communication network operating via neural, hormonal, and immune signaling pathways. Cross-sectional studies measuring gut-health indicators alongside self-assessed cognition in adults found moderate associations between gut health and cognitive domains, including processing speed and memory (Hameed et al., 2024). An editorial synthesis of this broader literature frames gut-microbiome status as a correlate and potential moderator of stress resilience, suggesting that gastrointestinal health may buffer or exacerbate the cognitive impact of occupational stress exposure (Madison et al., 2025). Direct teacher-specific gut-brain research remains sparse; however, mechanistic plausibility, combined with teachers' well-documented elevated stress-biomarker profiles, makes this an important and underexplored dimension of teacher biochemical health that warrants targeted investigation.

2.5 Micronutrient Status and Cognitive Performance

Micronutrient status is among the most extensively studied biochemical determinants of cognitive function, though most research has focused on children and adolescents rather than working adults. A multicentric cross-sectional study of urban school-age children and adolescents found measurable associations between micronutrient status and cognitive test performance (Singh et al., 2023), reinforcing a broader pattern in the nutritional-cognition literature in which deficiencies in iron, B-vitamins, and related micronutrients are linked to impaired attention, memory, and processing speed. Although this evidence base has not been systematically extended to adult professional populations such as teachers, the underlying biochemical mechanisms - micronutrients functioning as cofactors in neurotransmitter synthesis and neuronal myelination - are not age-specific, suggesting plausible relevance to adult occupational cognitive performance, including the sustained attentional and working-memory demands of teaching.

2.6 Sleep Quality and Occupational Functioning

Sleep quality is another biochemical-physiological determinant of teacher cognitive capacity. Cross-sectional research on basic education teachers found significant correlations between burnout syndrome - particularly its emotional-exhaustion dimension - and sleep disturbance, with these relationships remaining significant even after accounting for depression and anxiety (Sánchez-Narváez et al., 2023). Because sleep disruption independently impairs prefrontal-dependent cognitive functions such as working memory and emotional regulation, and because burnout is bidirectionally related to stress-hormone dysregulation, sleep quality functions as both a biochemical outcome of

occupational stress and an independent contributor to cognitive impairment - a reciprocal relationship with direct relevance to instructional capacity and classroom presence.

2.7 Neurotransmitter Systems Underlying Attention, Motivation, and Emotional Regulation

Beyond the stress-hormone axis, a distinct neurochemistry literature identifies the neurotransmitter systems that directly support the cognitive-affective functions teaching requires. Acetylcholine, dopamine, and noradrenaline each contribute separately to top-down and bottom-up attentional control, with dopamine implicated primarily in sustained, goal-directed attentional selection and noradrenaline in arousal and rapid attentional shifting (Lockhofen & Mulert, 2021). Dopaminergic signaling is also central to motivation and effort allocation: it modulates the subjective value assigned to a goal relative to the effort required to pursue it, providing a plausible mechanism for the sustained, moment-to-moment motivational effort that teaching, as a cognitively and emotionally effortful profession, demands (Lockhofen & Mulert, 2021). At the same time, chronic stress exposure elevates noradrenaline and dopamine within the prefrontal cortex to supraphysiological levels, which paradoxically impairs rather than enhances prefrontal-dependent working memory and cognitive control, following an inverted-U dose-response relationship in which both too little and too much catecholaminergic signaling degrade performance (Arnsten, 2009). This mechanism offers a direct neurochemical explanation for why chronically stressed teachers may show declining working-memory and self-regulatory performance despite - or because of - sustained physiological arousal.

2.8 Brain-Derived Neurotrophic Factor and Physical Activity

Brain-derived neurotrophic factor (BDNF), a neurotrophic factor that supports synaptic plasticity, neurogenesis, and long-term memory consolidation, is another biochemical determinant of cognitive capacity that behavior can directly modify. A meta-analysis of randomized controlled trials found that both acute and long-term physical exercise significantly and reliably increase circulating BDNF in healthy adults, with long-term aerobic exercise producing the most pronounced effect (Wang, Zhou, Luo, & Cui, 2022). Because BDNF elevation is mechanistically linked to improved memory and mood regulation, regular physical activity constitutes one of the more directly actionable levers within the biochemical layer of the proposed framework - one that, unlike micronutrient or hormonal status, requires no supplementation or clinical intervention to modify.

2.9 Micronutrient Cofactors: Iron, B-Vitamins, Magnesium, and Zinc

Several micronutrients serve as direct biochemical cofactors in neurotransmitter synthesis and are independently implicated in cognitive and mood regulation. Iron is required for aromatic hydroxylase enzymes that synthesize dopamine, serotonin, and noradrenaline. Iron deficiency - even without anemia - is associated with impaired attention and memory, as well as heightened fatigue. A meta-analysis of oral iron supplementation trials in children and adolescents found measurable cognitive benefits from correcting deficiency (Chen et al., 2022). Vitamin B12 deficiency produces a well-documented spectrum of neuropsychiatric symptoms, including impaired concentration, apathy, and mood disturbance, mediated by disrupted one-carbon and folate metabolism (Sahu, Thippeswamy, & Chaturvedi, 2022). Systematic review evidence shows consistent associations between B12, B6, and folate status and cognitive performance (Zhang, Luo, Yuan, & Ding, 2020). Magnesium is a cofactor in glutamatergic and GABAergic neurotransmission and directly regulates HPA-axis activity. Magnesium deficiency is mechanistically and empirically linked to depression, anxiety, and impaired stress resilience (Varga et al., 2025). Zinc similarly modulates glutamate signaling and BDNF expression in brain regions that govern mood, and zinc deficiency is associated with depressive and anxious symptomatology (Varga et al., 2025). Collectively, these micronutrients function less as independent causal agents and more as rate-limiting cofactors - their sufficiency does not guarantee optimal cognitive function, but their deficiency reliably constrains it.

2.10 Hydration and Environmental Acoustic Load

Two additional biochemical-adjacent factors merit inclusion because of their direct, rapidly reversible effects on classroom cognitive performance. Mild dehydration - as little as one to two per cent of body mass - measurably impairs attention, working memory, and executive function, and reliably degrades mood and perceived task difficulty, according to a systematic review of hydration status and executive function in adults (Katz, Airaghi, & Davy, 2021). Because hydration status is continuously modifiable within a school day, unlike most other biochemical variables discussed here, it represents an unusually low-cost, high-leverage target for intervention. Separately, the classroom acoustic environment interacts with cognitive-biochemical status: a systematic review of noise effects on children's cognitive performance found that speech noise reliably impairs verbal working memory and that poor classroom acoustics are associated with fatigue and physiological strain among teachers who work within them for an entire instructional day (Gheller, Spicciarelli, Scimemi, & Arfé, 2023). Sustained exposure to a poor acoustic environment plausibly compounds allostatic load through the same sympathetic-arousal pathways implicated in classroom-disruption stress more broadly.

3 EMOTIONAL LABOR, COGNITIVE LOAD, AND ALLOSTATIC LOAD IN THE CLASSROOM

A recent theoretical synthesis explicitly links teachers' emotional labor - the continuous, effortful management of displayed versus felt emotion in front of students - to allostatic load, proposing that emotional labor imposes a cognitive-load burden that can progress through phases of compassion fatigue, burnout, and demoralization if unaddressed (Attwood, 2024). This synthesis estimates that teachers make on the order of 1,500 discrete decisions in a single school day, with negative student interactions increasing cognitive load and positive interactions stabilizing it (Attwood, 2024). This account aligns directly with the stress-biomarker and allostatic-load evidence reviewed above, reinforcing that the cognitive demands of teaching are not merely pedagogical but are continuously modulated by the same biochemical stress-response systems that regulate attention and emotion.

3.1 Synthesis

Taken together, this literature indicates that at least seven interrelated biochemical and biochemically adjacent subsystems - HPA axis/stress-hormone regulation, catecholaminergic and other neurotransmitter signaling, BDNF and neurotrophic support, micronutrient cofactor status, gut-brain signaling, sleep architecture, and hydration/acoustic environment - plausibly shape the cognitive-affective resources that teacher-competence frameworks already recognize as central, including self-regulation, working memory, and emotional control (Baumert & Kunter, 2013; Kırkıcı et al., 2025). Table 1 summarises the principal biochemical markers identified in this literature and their associated cognitive effects. In contrast, Table 2 summarises the neurotransmitter and hormonal systems most directly relevant to the cognitive-affective demands of teaching.

Table 1: Key Biochemical Markers and Their Cognitive Effects Relevant to Teachers

Biochemical Marker	Biological System	Associated Cognitive/Affective Effect	Representative Source
Salivary cortisol	HPA axis	Acute elevation impairs working memory and inhibitory control; chronic elevation is linked to allostatic load.	Mahfoodh et al. (2024). Wettstein et al. (2023)
Alpha-amylase	Sympathetic nervous system	Marker of acute autonomic arousal during active teaching; associated with subjective stress	Mahfoodh et al. (2024)
DHEA-S	Adrenal steroid axis	Counter-regulatory hormone; shifts with stress-mindset interventions alongside cognitive-control performance.	Langrafe et al. (2025)
Gut microbiota diversity	Gut-brain axis	Associated with processing speed and memory; potential moderator of stress resilience	Hameed et al. (2024); Madison et al. (2025)
Iron, B-vitamins (B6, B12, folate)	Micronutrient/neurotransmitter cofactors	Deficiency associated with impaired attention, memory, and processing speed	Singh et al. (2023)
Sleep-quality index (e.g., PSQI-type measures)	Circadian/restorative physiology	Poor sleep associated with emotional exhaustion and burnout; impairs prefrontal cognitive control	Sánchez-Narváez et al. (2023)
Allostatic load composite (hair cortisol, BP, BMI)	Cumulative stress physiology	Predicts long-term psychological strain; associated with reduced self-regulatory capacity	Wettstein et al. (2023)
BDNF (brain-derived neurotrophic factor)	Neurotrophic signalling	Supports synaptic plasticity, memory consolidation, and mood; reliably elevated by exercise	Wang et al. (2022)
Serum ferritin/iron status	Micronutrient cofactor (catecholamine and serotonin synthesis)	Deficiency, even without anemia, impairs attention, memory, and increases fatigue	Chen et al. (2022)

Vitamin B12, B6, folate	One-carbon metabolism/neurotransmitter cofactors	Deficiency linked to impaired concentration, apathy, and mood disturbance	Sahu et al. (2022); Zhang et al. (2020)
Magnesium	Glutamatergic/GABAergic cofactor; HPA-axis regulation	Deficiency linked to depression, anxiety, and impaired stress resilience	Varga et al. (2025)
Zinc	Glutamate signaling; BDNF expression	Deficiency associated with depressive and anxious symptoms	Varga et al. (2025)
Hydration status	Fluid/electrolyte balance	Mild dehydration (1–2% body mass) impairs attention, working memory, and mood.	Katz et al. (2021)

Table 2: Neurotransmitter and Hormonal Functions Relevant to Teaching

System	Primary Function	Relevance to Teaching Performance
Cortisol (HPA axis)	Mobilizes energy resources in response to perceived threat or demand	Acute classroom stressors trigger cortisol release; chronic elevation impairs working memory and prefrontal regulation
Dopaminergic signalling	Motivation, reward processing, sustained attention	Underlies engagement, task persistence, and motivational drive across a teaching day
Serotonergic signalling	Mood stabilization, impulse control	Supports emotional regulation during high-demand classroom interactions
Norepinephrine	Arousal, vigilance, rapid attentional shifting	Enables rapid responsiveness to classroom events; excessive levels linked to distractibility.
DHEA-S	Counter-regulatory/anti-glucocorticoid hormone	Buffers cortisol's cognitive-impairing effects; modifiable via psychological intervention
Acetylcholine	Orienting attention; learning and memory encoding.	Supports flexible allocation of attention across shifting classroom demands
Gut-derived neuroactive metabolites	Immune-neuroendocrine signaling via the vagus nerve	Plausible modulator of baseline mood and cognitive resilience under stress

Notably, the relationship between catecholamine signaling and prefrontal function follows an inverted-U pattern: both insufficient and excessive dopaminergic and noradrenergic activity impair working memory and cognitive control. Thus, chronic classroom stress can push teachers past the optimal point on this curve, even as it increases subjective arousal (Arnsten, 2009).

4 THEORETICAL FRAMEWORK

4.1 Biopsychological Model of Teacher Competence

Existing competence frameworks, such as COACTIV, differentiate knowledge, beliefs, and motivational-affective facets and explicitly include self-regulation as a competence dimension.

Existing competence frameworks, such as COACTIV, successfully differentiate knowledge, beliefs, and motivational-affective facets and explicitly include self-regulation as a competence dimension (Baumert & Kunter, 2013). However, these frameworks do not specify the biological substrate that enables or constrains self-regulatory and cognitive capacity from moment to moment. The framework proposed here - termed the Biopsychological Teacher Competence (BTC) model - extends multidimensional competence theory by adding an explicit biochemical health layer as the physiological foundation upon which cognitive-affective functioning, and in turn instructional performance, is built.

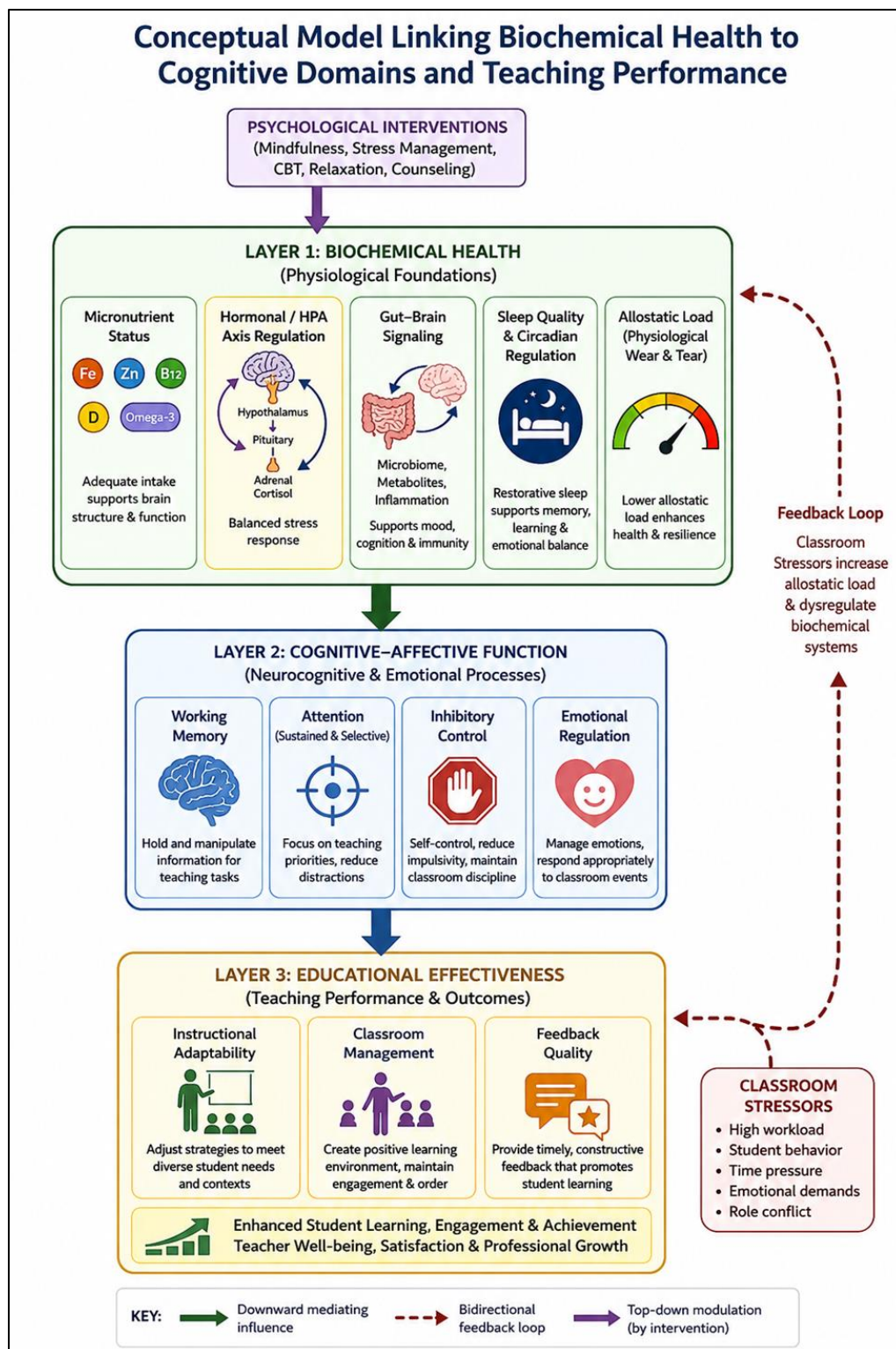


Figure 1: Conceptual model linking biochemical health to cognitive domains and teaching performance. The figure should depict three vertically stacked layers - biochemical health (micronutrients, hormonal/HPA regulation, gut-brain signaling, sleep, allostatic load), cognitive-affective function (working memory, attention, inhibitory control, emotional regulation), and educational effectiveness (instructional adaptability, classroom management, feedback quality) - connected by downward mediating arrows. Include a labeled bidirectional feedback loop connecting classroom stressors back to the biochemical layer, and a separate top-down arrow showing a psychological intervention directly modulating the hormonal subsystem.

The model proposes three interacting layers. The first, biochemical health, comprises five interrelated subsystems identified in the literature review: micronutrient status, hormonal/HPA-axis regulation, gut-brain signaling, sleep architecture, and cumulative stress-biomarker load (allostatic load). The second, cognitive-affective function, comprises the proximal psychological resources that teaching draws upon: working memory, sustained attention, inhibitory

control, emotional regulation, and decision-making speed. The third, educational effectiveness, comprises the observable outputs of teaching practice: instructional adaptability, classroom management, quality of formative feedback, and sustained engagement throughout the teaching day.

The model holds that biochemical health does not directly determine educational effectiveness; instead, cognitive-affective function mediates its influence. Chronic HPA-axis dysregulation, for instance, may impair working memory and inhibitory control through sustained glucocorticoid exposure and supraphysiological catecholamine signaling in the prefrontal cortex. This signaling follows an inverted-U dose-response curve, so both understimulation and overstimulation degrade performance (Arnsten, 2009). Repeated or unrelenting activation of this system produces cumulative physiological wear captured by the allostatic-load construct (McEwen, 2007), which in turn constrains a teacher's capacity for real-time instructional adaptation and calm classroom management (Wettstein et al., 2023). Sleep disturbance is modeled as acting through the same cognitive-affective mediators, with an added bidirectional feedback loop: poor sleep impairs emotion regulation, which increases perceived classroom stress, which further disrupts sleep (Sánchez-Narváez et al., 2023). Gut-brain signaling and micronutrient status are slower-moving background variables that shape the cognitive-affective layer's baseline resilience, moderating how strongly acute stressors translate into cognitive impairment (Hameed et al., 2024; Madison et al., 2025).

Two feedback loops complete the model. The first is a bottom-up loop in which occupational stressors - classroom disruption, workload, role ambiguity - elevate stress-hormone output, which, if chronic, degrades biochemical health via allostatic-load accumulation, disrupted sleep, and altered gut-microbial balance, creating a self-reinforcing cycle of biochemical and cognitive decline (Wettstein et al., 2023). The second is a top-down loop in which psychological intervention - such as stress-mindset reframing - can directly modulate hormonal output, improving cognitive-control performance without first requiring biochemical intervention (Langrafe et al., 2025). This bidirectionality is a defining feature of the model: it treats biochemical health as neither wholly determinative nor wholly malleable through psychological means alone, but as a system amenable to intervention from both physiological and psychological directions.

5 ANALYSIS AND DISCUSSION

5.1 Evidentiary Strength across the Model's Components

The strongest empirical support for the BTC model comes from the stress-biomarker literature, where within-day physiological monitoring provides direct, mechanistic evidence that classroom teaching measurably activates the HPA axis and the sympathetic nervous system (Mahfoodh et al., 2024). The finding that younger, more experienced, and more highly educated teachers exhibit particularly pronounced alpha-amylase elevations during active teaching is instructive: it suggests that stress reactivity does not simply decline with seniority, as might be assumed. Instead, it may reflect sustained engagement and accumulated exposure to classroom demands. This complicates a simple narrative in which experience alone buffers physiological stress and points toward the need for structural, not purely individual, interventions.

5.2 Case Example: Longitudinal Allostatic Load among Swiss Teachers

A two-year longitudinal study of 42 teachers combined self-report measures with objective allostatic-load indicators - hair cortisol concentration, blood pressure, and body mass index - alongside videotaped lesson observations (Wettstein et al., 2023). Using a LASSO regression approach to avoid overfitting common in standard regression models, the study found that neuroticism and perceived student disruption at baseline were the strongest predictors of elevated psychological strain two years later. At the same time, a positive core self-evaluation emerged as the most consistent protective factor. This case is analytically important for two reasons. First, it demonstrates that classroom-level structural conditions - specifically, the frequency of student disruption - function as measurable biochemical stressors with consequences detectable two years later, not merely as subjective complaints. Second, it shows that individual disposition and physiological wear are entangled over time, supporting the BTC model's proposition that biochemical health and cognitive-affective functioning form a reinforcing cycle rather than a one-directional causal chain.

5.3 Case Example: A Stress-Mindset Intervention with Biochemical Outcomes

A randomized controlled trial with 63 Brazilian public school teachers (32 intervention, 31 control) tested an eight-day, video-based stress-mindset intervention adapted from Stanford University's Mind and Body Lab curriculum (Langrafe et al., 2025). The intervention significantly improved stress-mindset scores immediately post-intervention and at 30-day follow-up ($p < .001$; $\epsilon^2 = 0.664$), with corresponding shifts in salivary cortisol and DHEA-S and in performance on the Stroop cognitive-control task. This trial provides proof-of-concept evidence that a brief, low-cost, purely psychological intervention can shift biochemical stress markers and executive-function performance simultaneously, offering direct empirical support for the BTC model's top-down feedback pathway and a promising, scalable target for teacher professional development.

5.4 Boundaries and Open Questions in the Micronutrient and Gut-Brain Evidence

Evidence for the micronutrient and gut-brain components of the model is mechanistically plausible but empirically thinner when applied specifically to teachers. The clearest micronutrient-cognition evidence comes from a multicentric study of school-age children and adolescents rather than working adults (Singh et al., 2023), and the clearest gut-brain evidence comes from a general adult sample in Islamabad rather than a teacher-specific cohort (Hameed et al., 2024). Extrapolating these findings to teaching adults is reasonable given the shared underlying biochemistry - micronutrients as neurotransmitter cofactors and microbial metabolites as neuroactive signaling molecules - but it remains an extrapolation rather than a directly demonstrated relationship. This is a genuine limitation of the current evidence base and a priority area for future teacher-specific research, addressed further in the implications section below.

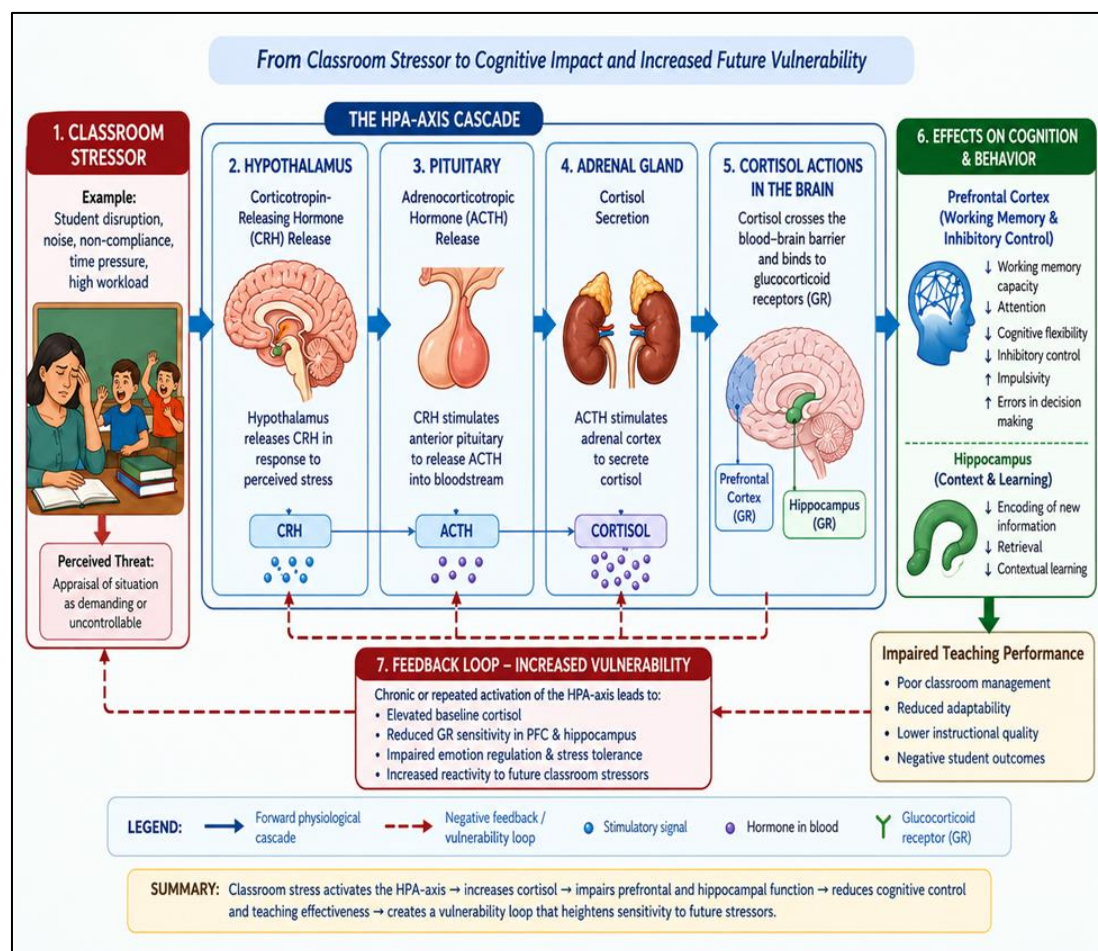


Figure 2: The HPA-axis stress cascade in a classroom context. The figure should trace the physiological cascade from a classroom stressor (e.g., student disruption) through hypothalamic corticotropin-releasing hormone release, pituitary adrenocorticotrophic hormone release, and adrenal cortisol secretion. It should show cortisol's downstream binding to glucocorticoid receptors in the prefrontal cortex and hippocampus, label the effects on working memory and inhibitory control, and include a feedback arrow showing how impaired regulation increases susceptibility to future classroom stressors.

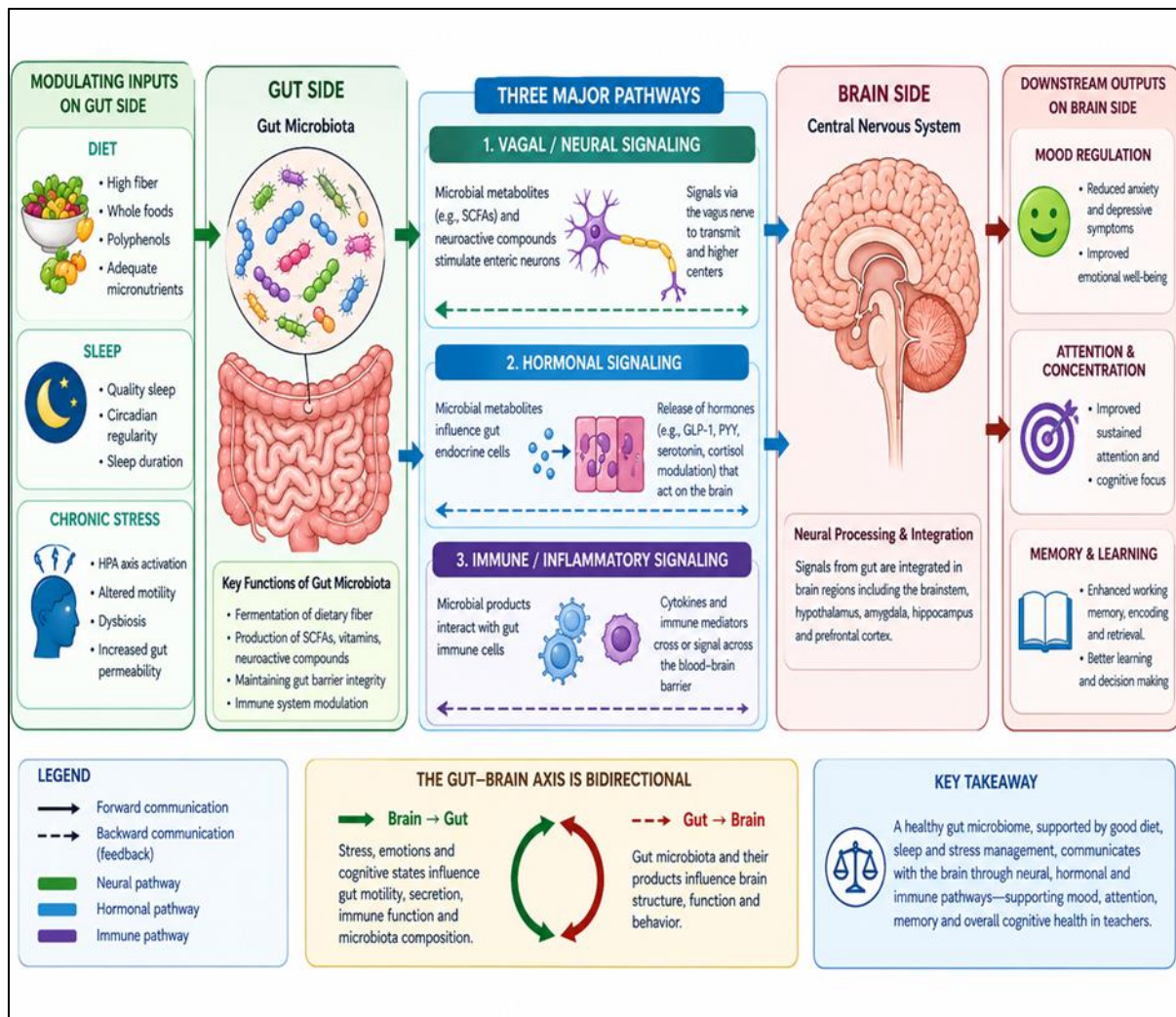


Figure 3: Bidirectional pathways of the gut-brain axis relevant to teacher cognitive health. The figure should show the gut microbiota connected to the central nervous system via three labeled pathways - vagal/neural signaling, hormonal signaling, and immune/inflammatory signaling - with diet, sleep, and chronic stress shown as modulating inputs on the gut side, and mood regulation, attention, and memory as downstream outputs on the brain side.

5.5 Interventions Bearing on the Biopsychological Pathway

A broader scoping review of interventions to reduce teacher stress and burnout identified substantial heterogeneity across 46 eligible studies involving 7,369 participants in 15 countries. Most research was conducted between 2010 and 2022, and relatively few studies incorporated physiological or biochemical outcome measures alongside self-report data (Agyapong, Brett-MacLean, Burbach, Agyapong, & Wei, 2023). This heterogeneity underscores a structural gap in the field: interventions are rarely evaluated using a combined psychological and biomarker approach. A broader scoping review of interventions to reduce teacher stress and burnout identified substantial heterogeneity across 46 eligible studies involving 7,369 participants in 15 countries. Most research was conducted between 2010 and 2022, and relatively few studies incorporated physiological or biochemical outcome measures alongside self-report data (Agyapong, Brett-MacLean, Burbach, Agyapong, & Wei, 2023). This heterogeneity underscores a structural gap in the field: interventions are rarely evaluated using a combined psychological-and-biomarker outcome design that would allow direct testing of the BTC model's mediating pathways. On the nutritional side, an umbrella review of workplace nutrition interventions found that their effectiveness on cognitive and behavioral outcomes remains inconclusive across the broader occupational-health literature, cautioning against assuming that nutrition-focused interventions will straightforwardly translate into improved workplace cognitive performance without more rigorous, occupation-specific trial designs (Hyży, Jaworski, Cieślak, Gotlib-Małkowska, & Panczyk, 2023). Table 3 summarises representative intervention and risk-factor studies that bear on the biopsychological pathway proposed here.

Table 3: Selected Intervention and Risk-Factor Studies Bearing on the Biopsychological Pathway

Study	Design	Population	Key Finding
Agyapong et al. (2023).	Scoping review (46 studies)	7,369 participants, 15 countries	Teacher wellbeing/burnout interventions are highly heterogeneous; few include physiological outcome measures.
Wettstein et al. (2023)	2-year longitudinal, LASSO regression	42 Swiss teachers	Neuroticism and classroom disruption predict allostatic load and psychological strain over time.
Langrafe et al. (2025).	Randomized controlled trial	63 Brazilian public school teachers	Stress-mindset intervention shifts cortisol, DHEA-S, and Stroop task performance.
Hyży et al. (2023).	Umbrella review of workplace nutrition interventions	General occupational populations	Effect: The effectiveness of workplace nutrition interventions on cognitive/behavioral outcomes remains inconclusive.

5.6 Emotional Labor as a Convergent Line of Evidence

Independent theoretical work on teachers' emotional labor converges on a strikingly similar model without directly drawing on the biochemical literature. This account frames teachers' continuous management of displayed emotion as a source of cognitive load that, if left unaddressed, can accumulate into compassion fatigue, burnout, and demoralization. It explicitly invokes allostatic load as the underlying physiological mechanism and estimates that teachers make approximately 1,500 discrete decisions per school day (Attwood, 2024). The convergence of an emotional-labor framework and a biochemical stress-physiology framework on the same construct - allostatic load - from two largely separate literatures strengthens confidence that classroom-induced physiological wear is a real and clinically meaningful phenomenon rather than an artifact of any single measurement approach.

5.7 Alternative Interpretations and Limitations

A fair reading of this evidence must acknowledge competing interpretations. Most of the cited studies are correlational or cross-sectional, leaving reverse causation plausible: teachers with stronger pedagogical skill and self-efficacy may experience less classroom disruption and, consequently, exhibit healthier biochemical profiles, rather than biochemical health causally producing competence. The BTC model's bidirectional feedback loops are intended to accommodate this possibility rather than deny it. However, the causal arrow from biochemistry to competence is currently better supported for the stress-hormone and sleep components of the model than for the micronutrient and gut-brain components, where teacher-specific evidence is still emerging. Traditional competence frameworks that emphasize training, pedagogical skill, and professional experience as the primary drivers of teaching quality (Baumert & Kunter, 2013; Kırkıç et al., 2025) remain well supported and are not displaced by this analysis; the biopsychological framework is best understood as complementary, specifying the physiological conditions under which existing pedagogical competencies can or cannot be reliably expressed.

6 IMPLICATIONS FOR TEACHER TRAINING AND POLICY

If cognitive-affective function is genuinely biochemically mediated, teacher training and school-level policy should treat biochemical health as part of professional infrastructure rather than a purely private concern. Several concrete implications follow from the framework and evidence reviewed above.

6.1 Integrating Biochemical Health Literacy into Teacher Education

Pre- and in-service teacher education programs could incorporate basic physiological literacy - covering stress physiology, sleep hygiene, and the cognitive relevance of nutrition - as part of professional self-regulation training, consistent with the self-regulatory dimension already recognized in multidimensional competence models (Baumert & Kunter, 2013). Competency instruments such as the Teacher's Professional Development Competencies Scale illustrate a growing institutional willingness to measure well-being-adjacent constructs (Kırkıç et al., 2025); extending these instruments to include brief, validated proxies for sleep quality and perceived stress would operationalize the biochemical layer without requiring invasive biomarker testing.

6.2 Structuring the School Day around Physiological Recovery

Because classroom disruption is a demonstrated predictor of long-term allostatic load (Wettstein et al., 2023), school administrators should consider scheduling practices that build in genuine, protected non-instructional recovery periods

rather than treating breaks as administratively negotiable. This structural intervention, rather than one based on individual responsibility, targets the bottom-up stressor pathway identified in the BTC model at its source.

6.3 Scaling Low-Cost Psychological Interventions with Biochemical Reach

The demonstrated capacity of brief stress-mindset interventions to shift both hormonal profiles and cognitive-control performance (Langrafe et al., 2025) makes them attractive candidates for inclusion in professional development, given their low cost and short duration relative to more intensive clinical or nutritional interventions. Policy bodies and school systems should pilot and evaluate these interventions using combined psychological and physiological outcome measures to address the evaluation gap identified in the broader teacher well-being intervention literature (Agyapong et al., 2023).

6.4 Proceeding Cautiously on Nutrition-Focused Interventions

Given that workplace nutrition interventions show inconsistent effectiveness in the broader occupational literature (Hyży et al., 2023), schools should avoid assuming that cafeteria or dietary-guideline changes alone will meaningfully improve teacher cognitive performance. Nutrition-focused initiatives should be piloted, evaluated, and adjusted iteratively rather than mandated as a blanket policy, and should be paired with - not substituted for - structural workload and scheduling reforms.

6.5 Voluntary, Non-Punitive Wellness Screening

When schools or districts consider incorporating sleep-quality or perceived-stress screening into existing occupational health check-ups, such screening should remain strictly voluntary, be decoupled from performance evaluations or promotion decisions, and be framed as a support resource rather than a surveillance mechanism. The ethical risks of biochemical or physiological monitoring in the workplace - including stigmatization, privacy violations, and the potential misuse of health data in personnel decisions - are substantial, and any implementation of the practical recommendations above must be designed with these risks explicitly in mind.

6.6 Addressing Low-Cost, High-Leverage Physiological Factors

Not every biochemical lever requires clinical intervention or institutional funding. Hydration status is continuously modifiable within a school day and measurably affects attention and working memory within a single lesson (Katz et al., 2021). Hydration status is continuously modifiable within a school day and measurably affects attention and working memory within a single lesson (Katz et al., 2021). Ensuring teachers have realistic access to water during instructional blocks is a near-zero-cost intervention with direct cognitive relevance. Similarly, classroom and staffroom acoustic quality, implicated in both attentional performance and cumulative fatigue (Gheller et al., 2023), is a facilities-level variable that schools can audit and improve independently of curriculum or staffing changes. Regular physical activity, which reliably elevates BDNF and thereby supports memory and mood regulation (Wang et al., 2022), is likewise a modifiable behavioral lever that professional development and staff wellness programming can support without requiring supplementation or medical intervention.

6.7 Funding Interdisciplinary, Teacher-Specific Research

Finally, given the evidentiary gap identified in the discussion section - particularly the lack of teacher-specific research on micronutrients and the gut-brain axis - research funding bodies and teacher education faculties should prioritize interdisciplinary studies that directly link biochemical markers to classroom-observed teaching quality in working teacher populations, rather than relying on extrapolation from child, general-adult, or other occupational samples.

7 CONCLUSION

This paper has argued that teacher professional competence, as currently theorized, underspecifies the biological conditions under which its recognized cognitive-affective dimensions - self-regulation, working memory, and emotional control - can be reliably expressed. Reviewing peer-reviewed research from 2020 to 2025 across stress physiology, hormonal regulation, the gut-brain axis, micronutrient science, and sleep research, the paper identified five interrelated biochemical subsystems with plausible and, in several cases, directly demonstrated relevance to teacher cognitive functioning. The proposed Biopsychological Teacher Competence (BTC) model integrates these subsystems into existing multidimensional competence theory, positioning biochemical health as a mediated, bidirectional influence on educational effectiveness rather than as either an irrelevant background factor or a wholly determining one.

The evidence base supporting this framework is uneven. It is strongest for the relationship among stress-hormone dysregulation, allostatic load, and cognitive-affective function, with direct teacher-sample studies demonstrating both bottom-up stress pathways and top-down psychological-intervention pathways. It is comparatively weaker, though

mechanistically plausible, for the micronutrient and gut-brain axis components, where the strongest available evidence comes from non-teacher populations and awaits direct replication among working educators.

Practically, the framework suggests that teacher training programs, school scheduling practices, occupational health policy, and educational research funding should treat biochemical health as a legitimate component of the professional competence infrastructure, while proceeding cautiously and ethically with respect to nutrition-focused mandates and any form of workplace physiological screening. Future research should prioritize longitudinal, teacher-specific studies that combine biomarker measurement with classroom-observed teaching quality, as well as randomized trials testing combined psychological and nutritional interventions with dual behavioral and biochemical outcome measures. Such work would allow the field to move from a plausible biopsychological model toward a rigorously tested account of how biochemical health shapes the everyday cognitive work of teaching.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

REFERENCES

- [1] Agyapong, B., Brett-MacLean, P., Burbach, L., Agyapong, V. I. O., & Wei, Y. (2023). Interventions to reduce stress and burnout among teachers: A scoping review. *International Journal of Environmental Research and Public Health*, 20(9), 5625. <https://doi.org/10.3390/ijerph20095625>
- [2] Agyapong, B., Obuobi-Donkor, G., Burbach, L., & Wei, Y. (2022). Stress, burnout, anxiety, and depression among teachers: A scoping review. *International Journal of Environmental Research and Public Health*, 19(17), 10706. <https://doi.org/10.3390/ijerph191710706>
- [3] Arnsten, A. F. T. (2009). Stress signaling pathways that impair prefrontal cortex structure and function. *Nature Reviews Neuroscience*, 10(6), 410–422. <https://doi.org/10.1038/nrn2648>
- [4] Attwood, A. I. (2024). A perspective on psychological factors affecting the emotional labor of teachers. *Frontiers in Education*, 9, Article 1291698. <https://doi.org/10.3389/feduc.2024.1291698>
- [5] Baumert, J., & Kunter, M. (2013). The COACTIV model of teachers' professional competence. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, & M. Neubrand (Eds.), *Cognitive activation in the classroom: The COACTIV project* (pp. 25–48). Springer.
- [6] Chen, Z., Yang, H., Wang, D., Sudfeld, C. R., Zhao, A., Xin, Y., Chen, J. C., Fawzi, W. W., Xing, Y., & Li, Z. (2022). Effect of oral iron supplementation on cognitive function among children and adolescents in low- and middle-income countries: A systematic review and meta-analysis. *Nutrients*, 14(24), 5332. <https://doi.org/10.3390/nu14245332>
- [7] El Dib, R., Periyasamy, A. G., de Barros, J. L., França, C. G., Senefonte, F. L., Vesentini, G., Alves, M. G. O., da Silva Rodrigues, J. V., Goma, H., Gomes Júnior, J. R., et al. (2021). Probiotics for the treatment of depression and anxiety: A systematic review and meta-analysis of randomized controlled trials. *Clinical Nutrition ESPEN*, 45, 75–90. <https://doi.org/10.1016/j.clnesp.2021.07.027>
- [8] Gheller, F., Spicciarelli, G., Scimemi, P., & Arfé, B. (2023). The effects of noise on children's cognitive performance: A systematic review. *Environment and Behavior*, 55(9–10), 698–734. <https://doi.org/10.1177/00139165241245823>
- [9] Hameed, M., Noor, F., Hussain, H., Khan, R. G., Ur Rashid, S. H., Atiq, A., Ali, H., Rida, S. E., & Abbasi, M. A. (2024). Gut-brain axis: Investigating the effects of gut health on cognitive functioning in adults. *Cureus*, 16(7), e64286. <https://doi.org/10.7759/cureus.64286>
- [10] Hyży, A., Jaworski, M., Cieślak, I., Gotlib-Małkowska, J., & Panczyk, M. (2023). Improving eating habits at the office: An umbrella review of nutritional interventions. *Nutrients*, 15(24), 5072. <https://doi.org/10.3390/nu15245072>
- [11] Kang, J. H., Vyas, C. M., Okereke, O. I., et al. (2022). Marine n-3 fatty acids and cognitive change among older adults in the VITAL randomized trial. *Alzheimer's & Dementia: Translational Research & Clinical Interventions*, 8(1), e12288. <https://doi.org/10.1002/trc2.12288>
- [12] Katz, B., Airaghi, K., & Davy, B. (2021). Does hydration status influence executive function? A systematic review. *Journal of the Academy of Nutrition and Dietetics*, 121(10), 1284–1305. <https://doi.org/10.1016/j.jand.2020.12.021>

- [13] Kim, T., Kim, S., Kang, J., Kwon, M., & Lee, S.-H. (2022). The common effects of sleep deprivation on human long-term memory and cognitive control processes. *Frontiers in Neuroscience*, 16, Article 883848. <https://doi.org/10.3389/fnins.2022.883848>
- [14] Kırkıç, K. A., Töre, E., Çetin, E., & Uysal, O. K. (2025). Teacher's Professional Development Competencies Scale (TPDCS) SAGE Open. <https://doi.org/10.1177/21582440251382637>
- [15] Kocamer Şahin, Ş., & Aslan, E. (2024). Inflammation as a neurobiological mechanism of cognitive impairment in psychological stress. *Journal of Integrative Neuroscience*, 23(5), Article 101. <https://doi.org/10.31083/j.jin2305101>
- [16] Langrafe, A., Jr., F., L. C., P., E. M., & Nishiyama, A. (2025). Rethinking stress in education: Cortisol and DHEA-S biomarker outcomes of a mindset intervention. *Frontiers in Behavioral Neuroscience*. <https://doi.org/10.3389/fnbeh.2025.1685319>
- [17] Lensen, J. H., Stoltz, S. E. M. J., Kleinjan, M., Kraiss, J. T., Scholte, R. H. J., & Speckens, A. E. M. (2024). Mindfulness-based stress reduction for elementary school teachers: A randomized controlled trial. *Frontiers in Education*, 9, Article 1385375. <https://doi.org/10.3389/educ.2024.1385375>
- [18] Lensen, J. H., Stoltz, S. E. M. J., Kleinjan, M., Speckens, A. E. M., Kraiss, J. T., & Scholte, R. H. J. (2021). Mindfulness-based stress reduction intervention for elementary school teachers: A mixed-methods study. *Trials*, 22, Article 826. <https://doi.org/10.1186/s13063-021-05804-6>
- [19] Lockhofen, D. E. L., & Mulert, C. (2021). Neurochemistry of visual attention. *Frontiers in Neuroscience*, 15, Article 643597. <https://doi.org/10.3389/fnins.2021.643597>
- [20] Madison, A. A., Turroni, S., Duff, A. F., Galley, J. D., Mackos, A. R., & Veerappa, A. (2025). Editorial: Gut-brain axis correlates, mediators, and moderators of stress resilience or vulnerability. *Frontiers in Behavioral Neuroscience*. <https://doi.org/10.3389/fnbeh.2025.1629472>
- [21] Mahfoodh, O. H. A., et al. (2024). Examining biomarkers of stress over the process of teaching among teachers of English as a foreign language. *Psychology in the Schools*, 61, 2115–2131. <https://doi.org/10.1002/pits.23151>
- [22] McEwen, B. S. (2007). Physiology and neurobiology of stress and adaptation: Central role of the brain. *Physiological Reviews*, 87(3), 873–904. <https://doi.org/10.1152/physrev.00041.2006>
- [23] Sahu, P., Thippeswamy, H., & Chaturvedi, S. K. (2022). Neuropsychiatric manifestations in vitamin B12 deficiency. *Vitamins and Hormones*, 119, 457–470. <https://doi.org/10.1016/bs.vh.2022.01.001>
- [24] Sánchez-Narváez, F., Velasco-Orozco, J. J., & Pérez-Archundia, E. (2023). Burnout syndrome and sleep quality in basic education teachers in Mexico. *International Journal of Environmental Research and Public Health*, 20(13), 6276. <https://doi.org/10.3390/ijerph20136276>
- [25] Singh, A., et al. (2023). Micronutrients and cognitive functions among urban school-going children and adolescents: A cross-sectional multicentric study from India. *PLOS ONE*, 18(2), e0281247. <https://doi.org/10.1371/journal.pone.0281247>
- [26] Varga, P., Lehoczki, A., Fekete, M., Jarecsny, T., Kryczyk-Poprawa, A., Zábó, V., Major, D., Fazekas-Pongor, V., Csípfő, T., & Varga, J. T. (2025). The role of magnesium in depression, migraine, Alzheimer's disease, and cognitive health: A comprehensive review. *Nutrients*, 17(13), 2216. <https://doi.org/10.3390/nu17132216>
- [27] Wang, Y.-H., Zhou, H.-H., Luo, Q., & Cui, S. (2022). The effect of physical exercise on circulating brain-derived neurotrophic factor in healthy subjects: A meta-analysis of randomized controlled trials. *Brain and Behavior*, 12(4), e2544. <https://doi.org/10.1002/brb3.2544>
- [28] Wettstein, A., Jenni, G., Schneider, I., Kühne, F., Grosse Holtforth, M., & La Marca, R. (2023). Predictors of psychological strain and allostatic load in teachers: Examining the long-term effects of biopsychosocial risk and protective factors using a LASSO regression approach. *International Journal of Environmental Research and Public Health*, 20(10), 5760. <https://doi.org/10.3390/ijerph20105760>
- [29] Wettstein, A., Schneider, S., Grosse Holtforth, M., & La Marca, R. (2021). Teacher stress: A psychobiological approach to stressful interactions in the classroom. *Frontiers in Education*, 6, Article 681258. <https://doi.org/10.3389/educ.2021.681258>
- [30] Zhang, C., Luo, J., Yuan, C., & Ding, D. (2020). Vitamin B12, B6, or folate and cognitive function in community-dwelling older adults: A systematic review and meta-analysis. *Journal of Alzheimer's Disease*, 77(2), 781–794. <https://doi.org/10.3233/JAD-200534>