
Learning Fatigue in Online Education: Analysis of Students' Cognitive Saturation in the Digital Era

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ARTICLE INFO

Accepted :
05 April 2026
Revised :
20 April 2026
Approved :
07 May 2026
Published :
12 May 2026

Keywords:

*Cognitive Burnout,
Digital Fatigue,
Student Mental Health*

ABSTRACT

Learning fatigue, or learning saturation, in the context of online education is a phenomenon that is increasingly receiving serious attention among educational researchers and practitioners. This article presents a systematic review of recent studies on student cognitive fatigue in online learning in the digital era, analyzing its causal factors, impacts on achievement and mental health, and effective intervention strategies. The review integrates findings from more than twenty international studies published between 2021 and 2025. The analysis shows that cognitive overload, prolonged screen exposure, and minimal social interaction are the three main factors causing learning fatigue. The prevalence of screen fatigue was the highest, reaching 61.3% in the high category, followed by online concentration disorders at 57.2%. The most significant impacts include decreased learning motivation, academic burnout, and mental health disorders. Intervention strategies that have proven effective include the application of active learning methodologies, digital wellness frameworks, and the use of artificial intelligence for real-time cognitive-emotional state detection. The implications of these findings are relevant for online curriculum developers, higher education institutions, and policymakers in designing sustainable digital learning ecosystems.

INTRODUCTION

The transformation of education toward digital platforms has accelerated dramatically since the COVID-19 pandemic hit the world in early 2020. Educational institutions worldwide were forced to shift to online learning modalities in a very short time, presenting unprecedented pedagogical and psychological challenges (Bakhov et al., 2021). Although online education offers greater flexibility and accessibility, a phenomenon known as learning fatigue has emerged as an inevitable consequence of this transition.

Learning fatigue in a digital context refers to the cognitive, emotional, and physical exhaustion experienced by students as a result of excessive exposure to screen-based learning environments. Unlike conventional learning fatigue, learning fatigue in online education has more complex dimensions, involving the interaction of technological factors, instructional design, home learning conditions, and individual student characteristics (Romero-Rodríguez et al., 2023). This phenomenon, also known as Zoom fatigue referring to fatigue resulting from virtual meetings has become a significant focus of attention, particularly among college students (Basch et al., 2025).

How to cite:

Darwin D. (2026). Attention Crisis in Education: An Analysis of Declining Student Focus in the Age of Digital Distractions. *Journal Ludi Litterarri*, 2(4), 26-35. DOI: <https://doi.org/10.62872/d5hjt248>

Contemporary research indicates that learning fatigue not only impacts academic performance but also has broad implications for students' mental and psychological well-being. A study by Deep and Chen (2025) revealed a strong link between online learning boredom and academic burnout and serious mental health disorders. Meanwhile, an investigation by McCabe et al. (2023) found that students' perceptions of cognitive load in Zoom classes significantly impacted their learning effectiveness. In Indonesia, this phenomenon is increasingly relevant given the high internet penetration rate and the massive digital transformation in the education sector post-pandemic.

Cognitive fatigue in online learning can be understood through several theoretical frameworks. Sweller's Cognitive Load Theory provides a valuable foundation for understanding how human working memory limitations can be rapidly depleted in digital stimulus-rich learning environments. Furthermore, the Information Processing Model provides perspective on how information overload in online platforms can hinder memory encoding and retrieval. Cunff et al. (2024) expand on this understanding by examining how neurodiversity influences the experience of cognitive load in online learning, demonstrating that neurodivergent students face greater challenges.

This article aims to synthesize recent research findings on learning fatigue in online education, identify determinants contributing to student cognitive burnout, analyze the multidimensional impact of the phenomenon, and formulate evidence-based strategic recommendations for mitigation and intervention. This study is expected to provide meaningful theoretical and practical contributions to the development of a more humane, effective, and sustainable digital learning ecosystem.

METHODOLOGY

Research Design

This study employed a systematic literature review (SLR) approach that integrates and synthesizes findings from various empirical and conceptual studies on learning fatigue in the context of online education. This approach was chosen because of its ability to provide a comprehensive overview of the state-of-the-art knowledge on the topic under study, while also identifying research gaps that need to be filled by future studies.

Sources and Literature Selection Criteria

A systematic literature search was conducted through several leading academic databases, including Scopus, Web of Science, PubMed, and Google Scholar. Keywords used included combinations of: learning fatigue, cognitive fatigue, online learning, e-learning, digital fatigue, Zoom fatigue, cognitive load, burnout, and their variations in English and Indonesian. The publication period was limited to 2021 to 2025 to ensure the relevance and currency of the findings.

Inclusion criteria included: (1) studies that explicitly examined learning burnout or cognitive fatigue in the context of online learning; (2) publication in indexed academic journals or reputable international conference proceedings; (3) available in English or Indonesian; and (4) having a clear and verifiable research methodology. Studies that were not directly related to the formal education context, or that used samples outside of secondary and tertiary education levels, were excluded from this review.

Analysis Procedure

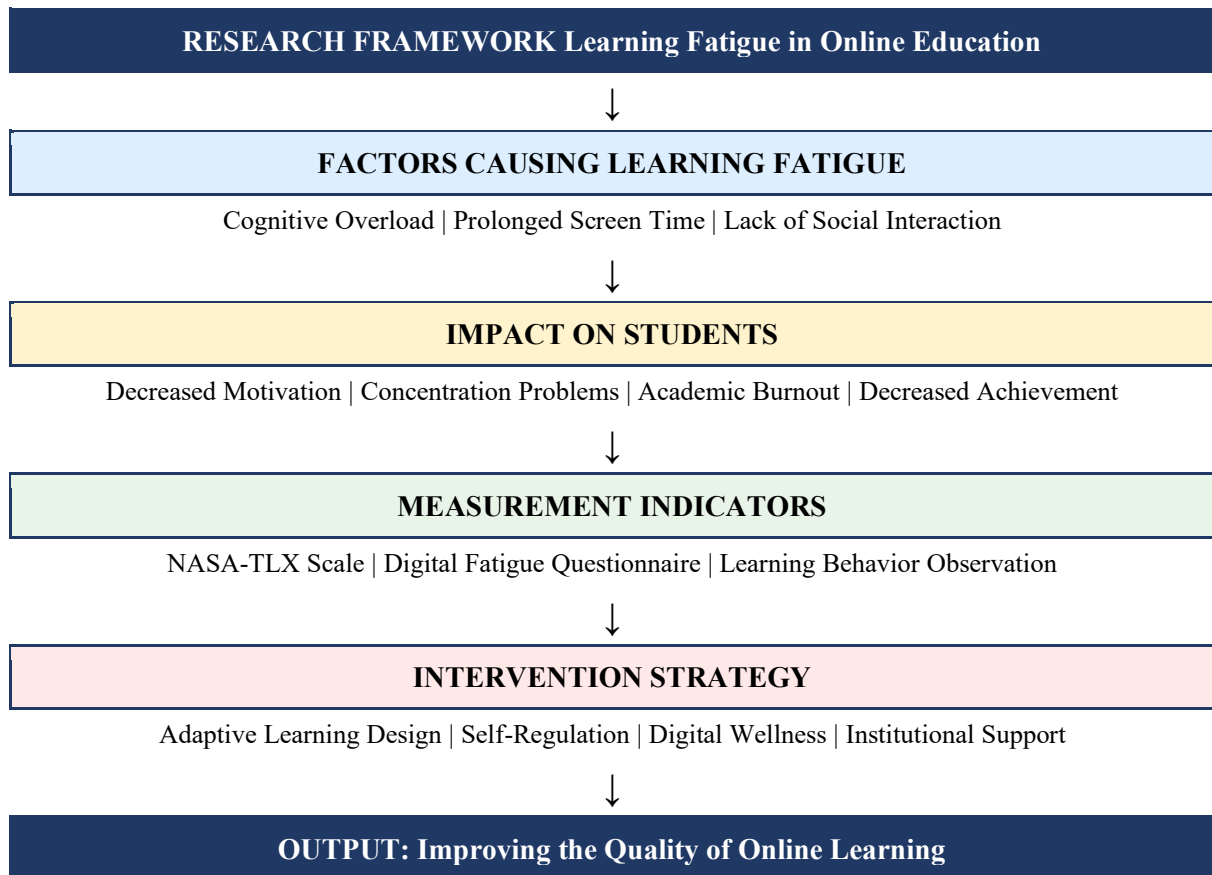
Data from each article meeting the selection criteria were systematically extracted using a standardized data collection form that included: author identity and year of

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publication, research design, sample characteristics, measurement instruments used, key findings, and study limitations. Thematic analysis was then applied to identify recurring patterns and themes emerging from the reviewed literature corpus. Triangulation of findings was performed by comparing results from different research methodologies to enhance the validity of conclusions.

Research Framework

Figure 1. Research Framework for Learning Fatigue in Online Education



Source: Adapted from a synthesis of various literature (Palalas & Doran, 2024; Firdaus et al., 2025)

RESULTS AND DISCUSSION

Prevalence and Dimensions of Learning Fatigue

A systematic review of the reviewed literature reveals that learning fatigue is a highly prevalent phenomenon in online education contexts, with varying levels of incidence depending on the dimensions measured, population characteristics, and learning environment conditions. Overall, findings from the reviewed studies indicate that the majority of students learning online experience at least one form of cognitive fatigue to varying degrees.

Yosep et al. (2024) documented a very high prevalence of screen fatigue among first-year nursing students, with over 61% of respondents reporting significant levels of fatigue. The study specifically identified excessive screen time averaging over eight hours per day as the strongest predictor of screen fatigue. This finding aligns with the findings of Sarangal and Nargotra's (2022) investigation, which reported digital fatigue in nearly half (48.7%) of students at higher education institutions during the COVID-19 pandemic.

McCabe et al. (2023) provide valuable insights into students' perceptions of cognitive load in Zoom classes. Their research revealed that factors such as the need to constantly monitor facial expressions in the video grid, the absence of natural nonverbal cues, and heightened social awareness paradoxically increase students' cognitive load compared to face-to-face learning. This demonstrates that learning fatigue in digital contexts has unique mechanisms that differ from conventional learning fatigue.

Table 1 below presents a summary of the prevalence of the various dimensions of learning fatigue identified from the reviewed literature, providing a comparative overview that allows for a comprehensive analysis of this phenomenon:

Table 1. Prevalence of Learning Fatigue Dimensions in Online Education

Dimensions of Learning Fatigue	High Prevalence (%)	Moderate Prevalence (%)	Low Prevalence (%)	Main References
Cognitive Overload	52.4	31.6	16.0	McCabe et al. (2023)
Screen Fatigue	61.3	27.4	11.3	Yosep et al. (2024)
Common Digital Fatigue	48.7	35.2	16.1	Sarangal & Nargotra (2022)
Decreased Motivation to Learn	45.9	38.6	15.5	Castro et al. (2025)
Burnout & Mental Health	39.8	42.1	18.1	Deep & Chen (2025)
Online Concentration Disorder	57.2	29.8	13.0	Shao et al. (2022)
Digital Academic Anxiety	43.5	36.9	19.6	Mosleh et al. (2021)

Source: Results of synthesis of various literature (2021-2025)

Determinant Factors of Learning Fatigue

An analysis of the reviewed literature corpus identified three main clusters of determinants contributing to learning fatigue in online education. First, technology and learning design factors, including information overload from dense digital content, less intuitive platform interfaces, and inconsistent internet connectivity. Shao et al. (2022) specifically examined how self-directed learning approaches interact with online

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cognitive fatigue, finding that students with less adaptive learning orientations were more susceptible to online cognitive fatigue.

The second determinant factor is individual student characteristics, including health status, the presence of chronic conditions, self-regulation levels, and neurocognitive characteristics. Inan et al. (2025) found that poor health and the presence of chronic conditions significantly exacerbated the impact of mental fatigue on students' grade expectations in online courses. Cunff et al. (2024) added a neurodiversity dimension by finding that neurodivergent students face qualitatively different challenges in managing online cognitive load.

The third determining factor is the institutional environment and support. Deep and Chen (2025) found that a lack of institutional support was one of the strongest predictors of academic burnout and ongoing learning fatigue. This study also innovatively explored the potential of artificial intelligence as an institutional tool to proactively detect and respond to learning fatigue. Meanwhile, Mpungose (2021) provided a teaching perspective, documenting how lecturers' reflections on Zoom usage directly impacted the quality of learning interactions, which in turn influenced student fatigue levels.

Impact of Multidimensional Learning Fatigue

A review of the existing literature shows that learning fatigue has multidimensional impacts, going beyond simply decreasing academic achievement. In the dimensions of learning motivation and engagement, Castro et al. (2025) documented a significant negative correlation between digital learning fatigue and student learning motivation. Their descriptive-correlational study found that students experiencing high levels of digital learning fatigue tended to exhibit lower intrinsic motivation, more passive engagement, and a tendency to engage in cyberloafing during online learning sessions.

In the mental health dimension, Mosleh et al. (2021) conducted a multicenter, cross-country study that revealed the complex relationship between mental health, learning behavior, and perceived burnout among college students during the pandemic. They found that symptoms of anxiety and depression were significantly correlated with reported levels of fatigue, forming a mutually reinforcing cycle of worsening mental health and increasing learning burnout. Tari and Mahaardhika (2025) reinforced these findings through a comprehensive literature review on digital burnout and mental health in online learning.

Agrawal and Krishna (2025) added an interesting dimension by examining the relationship between burnout, cyberloafing, and self-regulation in determining learning satisfaction. Their findings indicated that self-regulation serves as an important moderator in the relationship between burnout and cyberloafing behavior, suggesting that interventions targeting students' self-regulatory capacity could break this destructive cycle. Febriani et al. (2021) used a more quantitative approach by utilizing the NASA TLX and SOFI instruments to objectively and standardize the mental load of e-learning students.

Effective Intervention Strategies

A literature synthesis identified several intervention strategies that demonstrated evidence of effectiveness in mitigating learning fatigue. First, the application of active learning methodologies has been shown to significantly reduce the prevalence of online learning fatigue, particularly in medical education settings. De Oliveira Kubrusly Sobral et al. (2022) documented that the use of case-based learning, problem-based learning, and team-based learning in online formats effectively reduced cognitive monotony, a key driver of digital learning fatigue.

Second, the digital wellness framework developed by Palalas and Doran (2024) offers a holistic approach to managing digital wellbeing in the context of online learning. This framework integrates the physical, psychological, social, and spiritual dimensions of digital wellbeing, providing practical guidance for educational institutions in designing healthier and more sustainable online learning environments. Implementation of this framework includes establishing clear screen time limits, introducing digital mindfulness practices, and developing comprehensive digital literacy.

Third, the use of artificial intelligence technology for real-time detection and response to learning fatigue is an increasingly promising approach. Maazouzi and Retbi (2025) demonstrated the effectiveness of a multimodal detection system that integrates visual and textual data using deep learning techniques to identify students' emotional and cognitive states during e-learning sessions. Manurung et al. (2024) complemented this approach by developing a facial expression-based fatigue identification system using transfer learning, which can be integrated into online learning platforms to provide early warnings when students exhibit signs of cognitive fatigue.

Fourth, modifications to the design of online learning sessions—as explored by Basch et al. (2025) in the context of Zoom have been shown to be effective in reducing fatigue. Evidence-based strategies include limiting session length, introducing structured breaks, varying activity formats, reducing reliance on full-on camera formats, and increasing interactive elements that encourage active engagement. An et al. (2025) add a positive psychological perspective by demonstrating the role of grit and cognitive flexibility as significant mediators in the relationship between digital fatigue and academic resilience.

Pedagogical and Policy Implications

The synthesized findings from this literature review have broad implications for various stakeholders in the digital education ecosystem. For curriculum designers and online learning content developers, the results of this study emphasize the importance of instructional design principles that are responsive to human cognitive limitations. Hung et al. (2024) illustrate the importance of considering the differences between synchronous and asynchronous learning in terms of cognitive load and the overall learning experience, suggesting that the right combination of both modalities can optimize learning outcomes while minimizing the risk of fatigue.

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For higher education institutions, Inan et al.'s (2025) findings on the impact of coursework demand on student mental fatigue highlight the need for a more coordinated approach to academic workload management. Estandian et al.'s (2022) provide valuable comparative data on mental fatigue in traditional versus online learning, confirming that transitioning to a digital format without adequate pedagogical adaptations can significantly increase the risk of mental fatigue. Zhao and Wang (2024) add an important perspective on boredom as a dimension that often overlaps with fatigue but has distinct antecedents and intervention implications.

Firdaus et al. (2025) provide a perspective on the trends and impacts of psychological and cognitive burden in education, underscoring the urgency of systemic responses from various levels of the education ecosystem from macro policies at the national level to micro practices at the classroom level. Sanusi et al. (2025) deepen our understanding of the coping strategies students use to deal with digital fatigue, demonstrating that empowering students with adaptive coping strategies is a crucial component of a holistic response to the phenomenon of learning fatigue

CONCLUSION

This systematic review confirms that learning fatigue, or cognitive burnout, in online education is a complex, multidimensional, and far-reaching phenomenon that demands a coordinated response from all stakeholders in the digital education ecosystem. Three key identified determinants cognitive overload, prolonged screen exposure, and a deficit in meaningful social interactions interact synergistically to create conditions conducive to the occurrence of digital learning burnout at an alarming rate.

The high prevalence of learning fatigue across its various dimensions, with screen fatigue reaching 61.3% and online concentration impairment at 57.2%, indicates that this is not simply an individual issue but a systemic crisis demanding structural solutions. The impacts extend beyond declining academic performance to encompass mental health, intrinsic motivation, and students' long-term psychological well-being.

Furthermore, the literature synthesis also identified several promising intervention strategies: the application of active learning methodologies, the implementation of a holistic digital health framework, the use of artificial intelligence for early fatigue detection, and evidence-based modifications to learning designs. The significant potential of artificial intelligence in real-time detection and intervention for learning fatigue represents a research frontier that deserves continued development.

For future research directions, this review recommends: first, longitudinal studies that track students' learning fatigue trajectories over the course of a semester or a full academic year to understand the dynamics of its development; second, community-based research that considers local contextual variables, particularly in the Indonesian context with its high diversity of digital access; third, the development and validation of learning fatigue measurement instruments that are sensitive to cultural differences and socio-economic contexts; and fourth, controlled clinical trials of various intervention strategies to build a stronger evidence base for effective policy implementation.

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