*Educational Technology Quarterly*, Vol. **2026**, Iss. 2, pp. 99–128 10.55056/etq.1056

# Digital learning fatigue and its psychological consequences among tertiary students: a systematic review

Ernest Okpako[1], Habeeb Adewuyi[2], Victor Fehintola[3], Mumud Ojuolape[1], Naseem Raji[4], Ayodeji Adegoke[5] and Sylvester Umanhonlen[1]

[1]*University of Ibadan, Ajibode Rd., Ibadan, 200132, Nigeria*
[2]*Department of Educational Psychology, University of Johannesburg, P.O. Box 524, Auckland Park, 2006, South Africa*
[3]*Federal College of Education (Special), PM.B. 1089, Oyo, 211103, Nigeria*
[4]*Edge Hill University, St Helens Rd., Ormskirk, L39 4QP, United Kingdom*
[5]*Wayne State University, 42 W Warren Ave., Detroit, MI 48202, United States*

**Abstract.** This systematic review synthesises empirical evidence on digital learning fatigue (DLF) and its psychological consequences among tertiary students in the post-pandemic era. It addresses prevalence patterns, contributing factors, mental health impacts, and moderating variables shaping fatigue experiences across global higher education contexts. Following PRISMA-2020 guidelines, a multi-database search (Scopus, Web of Science, PubMed, ERIC, and Google Scholar) identified 2,315 records (January 2020–May 2025). Twenty-two studies met the inclusion criteria after rigourous screening and quality appraisal using the Newcastle–Ottawa Scale. Data were narratively and thematically synthesised to integrate quantitative prevalence evidence and qualitative psychosocial insights. Across studies, DLF affected 45–75 % of tertiary students and manifested through intertwined cognitive, emotional, and behavioural symptoms. The most common psychological outcomes were anxiety (68 %), stress (64 %), and depressive symptoms (55 %). Fatigue consistently reduced motivation, concentration, and academic engagement while elevating burnout risk. Gender (higher in females), academic discipline (arts/humanities > STEM), and screen exposure (6–8 h+ per day) amplified fatigue, whereas resilience and adaptive coping moderated adverse effects. Cross-regional variations reflected technological infrastructure and institutional preparedness. The review identifies an urgent need for evidence-based interventions such as balanced asynchronous–synchronous workloads, resilience-building programs, ergonomic design standards, and institutional mental-health support. This is among the first post-pandemic systematic syntheses to conceptualise DLF as a multidimensional psychosocial syndrome rather than a transient technological stressor. By integrating cognitive load, self-determination, and conservation-of-resources perspectives, the review offers an ecological framework for reducing fatigue and promoting sustainable digital learning wellbeing.

**Keywords:** digital learning fatigue, online education, tertiary students, psychological wellbeing, cognitive load, resilience, systematic review

## 1. Introduction

The rapid digitalisation of higher education represents one of the most significant pedagogical transformations in contemporary academic history. Although technology-enhanced learning evolved gradually over decades, the COVID-19 pandemic triggered an unprecedented acceleration, compelling

0000-0003-4775-0602 (E. Okpako); 0000-0002-4093-9157 (H. Adewuyi); 0009-0006-6130-7817 (V. Fehintola); 0000-0001-8600-291X (M. Ojuolape); 0000-0003-1037-1238 (N. Raji); 0009-0009-4187-0583 (A. Adegoke); 0009-0003-9493-6140 (S. Umanhonlen)
ernest.kelvin26@gmail.com (E. Okpako); adewuyihabeeb@gmail.com (H. Adewuyi); fehintola.victor2511@fcesoyo.edu.ng (V. Fehintola); ojuolapeolabode8@gmail.com (M. Ojuolape); naseemraji99@gmail.com (N. Raji); ayodejiadegoke49@gmail.com (A. Adegoke); umasylvester@gmail.com (S. Umanhonlen)
https://www.uj.ac.za/members/habeeb-omoponle-adewuyi/ (H. Adewuyi); https://mpsi.wayne.edu/profile/hu1026 (A. Adegoke)

| Received | Accepted | Published | Version of record |
|---|---|---|---|
| 2025-07-15 | 2025-12-06 | 2026-06-20 | 2026-06-20 |

institutions worldwide to adopt digital platforms at a scale and speed previously inconceivable [37]. This sudden shift, which affected over 1.6 billion learners globally, transformed screens from supplementary tools into the central medium of instruction [85]. As universities now sustain hybrid and fully online delivery models beyond the crisis, a concerning phenomenon has emerged: digital learning fatigue, defined as cognitive exhaustion, emotional depletion, and reduced engagement caused by prolonged exposure to digital learning environments [28, 59]. Despite widespread recognition of this issue, its magnitude, determinants, and psychological implications among tertiary students remain poorly synthesised.

Historically, the trajectory of digital learning in higher education has unfolded across three phases, each shaping student experience differently. Pre-2020 online education was largely elective, designed intentionally for self-regulated learners [11, 14], with learning management systems and multimedia tools complementing rather than replacing classroom instruction [34]. This balance fostered gradual digital literacy while maintaining vital social interaction. The pandemic disrupted this equilibrium through what Hodges et al. [37] describe as *emergency remote teaching* – a rapid, unplanned shift that diverged from best-practice digital pedagogy. Faculty with limited online teaching expertise restructured entire courses under time pressure [90], while students lost access to campus resources and social networks, experiencing health anxiety and isolation [15]. This context produced the first widespread reports of "Zoom fatigue", characterised by exhaustion after prolonged video conferencing [7].

In the post-pandemic era, hybrid and online modalities have persisted [65], demanding an evaluation of their long-term sustainability and psychological costs. Cognitive load theory [82, 83] provides a critical lens for understanding digital fatigue: limited working-memory capacity can be overwhelmed by intrinsic, germane, and extraneous loads [41]. Poorly designed online environments increase extraneous load through split attention, redundancy, and navigational complexity [53], forcing students to divide focus across multiple stimuli – video feeds, chats, slides, and digital notifications [19]. Such overload impairs learning efficiency and induces mental exhaustion [25, 55].

Beyond cognitive strain, motivational and affective dimensions compound the problem. According to self-determination theory [73], autonomy, competence, and relatedness are essential for intrinsic motivation, yet rigid course structures and mediated communication often frustrate these needs [35]. Similarly, the conservation of resources theory [36] explains that prolonged resource depletion without recovery – through limited social interaction or rest – produces psychological strain [47]. Bailenson [7] further identifies four mechanisms of videoconference fatigue: excessive close-up gaze, constant self-view, restricted physical movement, and difficulty decoding non-verbal cues, leading to "non-verbal overload" [69]. Physically, digital fatigue manifests through visual strain, headaches, and musculoskeletal discomfort [71, 79]. Cognitively, it diminishes attention, memory, and problem-solving [68], while emotionally, it fosters irritability and detachment [5, 23, 35].

Empirical studies reveal that chronic digital learning fatigue correlates strongly with anxiety, depression, and academic burnout [12, 81, 86, 89]. Academic burnout – marked by exhaustion, cynicism, and diminished efficacy [75] – interacts bidirectionally with fatigue, forming a reinforcing cycle [51] that reduces motivation and persistence [80]. Furthermore, digital contexts may erode self-efficacy [9] by limiting feedback and mastery experiences [39, 67].

Individual and contextual differences moderate these effects. Female students experience greater fatigue, linked to self-presentation pressure and multitasking demands [28]. International and socioeconomically disadvantaged students face compounded stress due to time-zone challenges, limited connectivity, and inadequate learning spaces [4, 33, 56, 61]. Students with disabilities or pre-existing conditions also report higher fatigue levels due to accessibility gaps and sustained attentional demands [10, 13, 31]. These inequities highlight that digital learning can inadvertently reinforce educational disparities.

Although awareness of digital learning fatigue is growing, research remains fragmented across fields and methodologies. Existing studies often rely on cross-sectional designs, convenience samples, and inconsistent definitions, limiting comparability and causal inference. Few examine long-term trajectories or moderating mechanisms such as resilience, pedagogy, and institutional support.

Accordingly, this systematic review synthesises empirical evidence on digital learning fatigue and its psychological consequences among tertiary students. Its specific objectives are to:

(1) Assess the prevalence and nature of digital learning fatigue across higher education contexts;

(2) Identify individual, pedagogical, and technological factors contributing to fatigue;

(3) Examine psychological and academic outcomes – including anxiety, stress, and performance effects; and

(4) Explore demographic and contextual moderators such as gender, socioeconomic status, and learning modality.

This review provides conceptual clarity, informs institutional and pedagogical strategies, and underscores an ethical imperative: ensuring that the digital transformation of higher education enhances rather than undermines student wellbeing.

## 2. Methods

### 2.1. Review protocol and research questions

This systematic review adhered to the PRISMA 2020 statement [62], ensuring methodological transparency, reproducibility, and comprehensive reporting. The review protocol was prospectively registered on the Open Science Framework (OSF). Four research questions guided this review:

1. What is the prevalence and nature of digital learning fatigue among tertiary students?
2. What are the key factors contributing to digital learning fatigue?
3. What are the psychological consequences of digital learning fatigue for tertiary students?
4. How do demographic and contextual variables moderate these effects?

### 2.2. Search strategy

A comprehensive and systematic search was conducted across Scopus, Web of Science, PubMed, ERIC, and Google Scholar, covering the period January 2020 to May 2025, corresponding to the height of digital learning transitions during and after the COVID-19 pandemic. The search combined controlled vocabulary and free-text terms, including: ("digital learning fatigue" OR "online learning fatigue" OR "videoconference fatigue" OR "Zoom fatigue") AND ("university students" OR "college students" OR "tertiary education") AND ("psychological impact" OR "mental health" OR "academic stress"). Boolean operators ("AND", "OR") and truncations were applied to enhance precision and recall. The reference lists of included papers were manually screened, and grey literature (e.g., dissertations and conference proceedings) was also examined to ensure comprehensiveness. The decision to restrict the search to January 2020–May 2025 is conceptually and methodologically justified. The concept of digital learning fatigue was coined as a specific phenomenon, mainly due to the unprecedented shift to online and hybrid education worldwide during the COVID-19 pandemic. The research before 2020 did not systematically or similarly investigate digital learning fatigue, and it did not work in the long-term, high-intensity digital learning conditions that define the post-pandemic period. Limiting the review to this time thus guarantees conceptual relevance, covers the entire course of digital fatigue research since its first appearance and its development after the pandemic, and increases the comparability of the methods used across studies, which were carried out under the same technological, pedagogical, and psychosocial circumstances. This period, in turn, enhances the validity, reproducibility, and interpretive coherence of the review.

### 2.3. Inclusion and exclusion criteria

*Inclusion criteria:*

1. Empirical studies (quantitative, qualitative, or mixed-methods) or systematic reviews/meta-analyses examining digital learning fatigue and associated psychological outcomes among tertiary students.
2. Publications in peer-reviewed journals or academic repositories.
3. Studies published in English between January 2020 and May 2025.

*Exclusion criteria:*

1. Studies focusing exclusively on primary or secondary education.
2. Conceptual papers, editorials, or commentaries without empirical data.
3. Studies lacking sufficient methodological detail for quality appraisal.

### 2.4. Study selection

All search results were imported into EndNote X9 for reference management, and duplicates were removed. Screening was conducted in Rayyan, following PRISMA 2020 recommendations. Two reviewers independently screened titles and abstracts, followed by full-text assessment of potentially eligible studies. Discrepancies were resolved by discussion or by consulting a third reviewer. The full selection process is presented in figure 1 (PRISMA flow diagram).

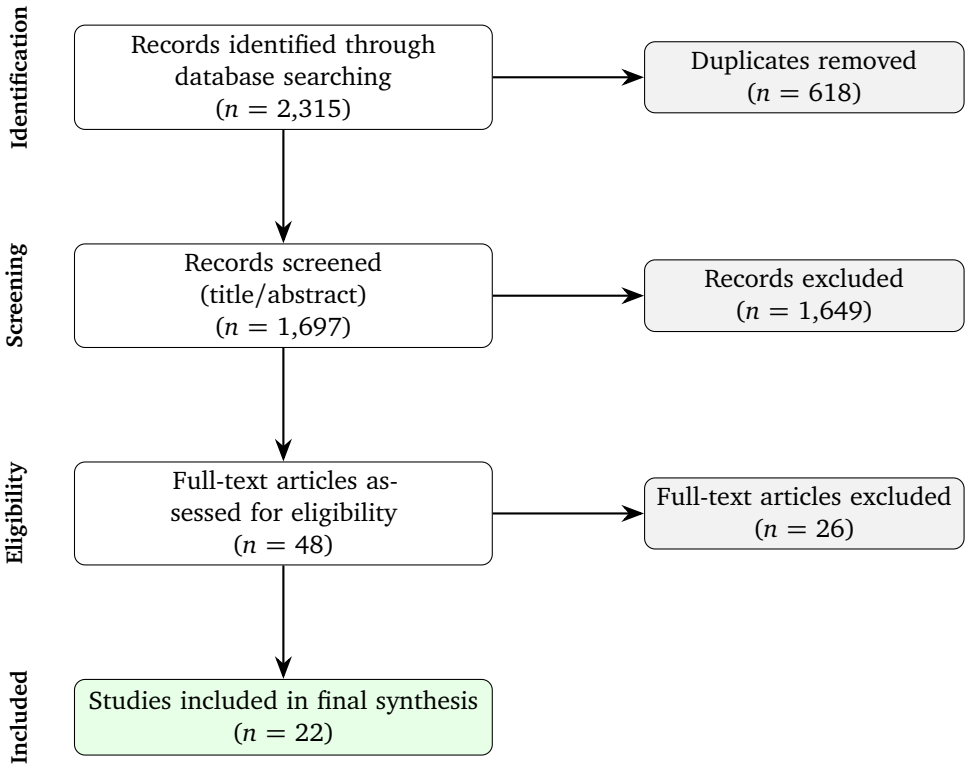


**Figure 1:** Adapted PRISMA flow diagram.

### 2.5. Data extraction and synthesis

A structured data extraction form was developed to capture the following variables: author, year, country, study design, sample size, measurement of digital learning fatigue, psychological outcomes, and key findings. Extraction was conducted independently by two reviewers to minimise bias. Given heterogeneity in designs and measures, findings were synthesised using a narrative and thematic approach. Quantitative findings were aggregated descriptively to illustrate prevalence trends and correlational patterns, while qualitative findings were thematically analysed to identify recurring psychosocial themes and coping mechanisms.

### 2.6. Quality assessment

Quality appraisal was performed independently by two reviewers using validated tools:

1. The Newcastle–Ottawa Scale (NOS) for observational and cross-sectional studies (score range: 0–9).

2. The AMSTAR 2 checklist for any included systematic reviews.

Criteria included sample representativeness, measurement validity, confounding control, and clarity of reporting. Disagreements were resolved through consensus. Studies scoring ≥7 on the NOS were considered high-quality. A summary of quality ratings is provided in table 1.

**Table 1**
Quality appraisal summary (Newcastle–Ottawa Scale).

| Quality category | Number of studies ($n = 22$) | Percentage | Interpretation |
|---|---|---|---|
| High quality (≥7) | 14 | 63.6% | Robust methodological rigour |
| Moderate quality (5–6) | 6 | 27.3% | Acceptable but some bias risk |
| Low quality (<5) | 2 | 9.1% | Methodological limitations present |

## 3. Results

### 3.1. Study selection and characteristics

The initial database search yielded 2,315 records. After removal of duplicates ($n = 618$), 1,697 unique records were screened based on titles and abstracts. Following this stage, 48 full-text articles were assessed for eligibility. Ultimately, 22 studies met all inclusion criteria and were included in the final synthesis. The PRISMA flow diagram (figure 1) summarises the selection process. The included studies were conducted across five global regions – Europe ($n = 7$), Asia ($n = 7$), the Middle East ($n = 4$), North America ($n = 2$), and Latin America ($n = 2$) – and represent diverse institutional contexts and academic disciplines. Most employed cross-sectional survey designs ($n = 20$), complemented by one longitudinal study and one mini-review. Sample sizes ranged from 50 to over 2,000 participants, encompassing undergraduate and postgraduate cohorts.

Table 2: Summary of included studies.

| Study | Country | Sample size | Design | Key focus | Main findings |
|---|---|---|---|---|---|
| Alarabiat [1] | Jordan | 233 | Cross-sectional | Online learning fatigue, intention to continue | Course burden, psychological challenges, sensory deprivation, and home environment predict fatigue and reduce intention to continue. |

| Study | Country | Sample size | Design | Key focus | Main findings |
|---|---|---|---|---|---|
| Romero-Rodríguez et al. [70] | Spain | 613 | Cross-sectional | Digital fatigue, gender, field of study | Medium–high fatigue; higher in females and arts/humanities students. |
| Tuğtekin [84] | Turkey | 347 | Cross-sectional | Factors influencing online learning fatigue | Information overload, system complexity, and communication overload predict fatigue; women are more prone. |
| Baltà-Salvador et al. [8] | Spain | 1,000+ | Cross-sectional | Academic/emotional effects of online learning | High stress, reduced motivation, negative attitudes toward online learning. |
| Rutkowska et al. [72] | Poland | 753 | Cross-sectional | Mental health during e-learning | 56.4% depressive symptoms; >80% report irritability and motivation problems. |
| Reed [66] | USA | 50 | Survey | E-learning fatigue in communication sciences students | Higher fatigue linked to poorer learning outcomes and mental health difficulties. |
| Klimova and Pikhart [45] | UAE | 1,000+ | Mini-review | AI, screen time, digital fatigue | Excessive screen time linked to fatigue, isolation, anxiety, and poor mental health. |
| Göldağ [32] | Turkey | 925 | Cross-sectional | Digital burnout, stress | Positive correlation between burnout and perceived stress. |
| Deniz et al. [26] | Turkey | 470 | Cross-sectional | Zoom/video-conferencing fatigue, psychological distress, academic wellbeing | Zoom fatigue significantly correlated with depression, anxiety, and stress; reduced life satisfaction and academic wellbeing via psychological distress (mediation). |
| Alyoubi et al. [2] | Saudi Arabia | 582 | Cross-sectional | Mental health and sleep disruption during pandemic online learning | High rates of self-reported worsening anxiety, depression, and stress; roughly 32% moderate-or-worse insomnia, significantly linked to psychological distress. |
| Li and Yang [48] | China | 618 | Cross-sectional | Online learning burnout, loneliness, engagement | Loneliness during online instruction significantly predicts learning burnout, which in turn reduces learning engagement. |
| An et al. [3] | China | 2,109 | Cross-sectional | Digital fatigue, academic resilience | Digital fatigue negatively associated with academic resilience; grit and flexibility mediate the fatigue–resilience relationship. |
| Fridkin et al. [29] | UK | 177 | Longitudinal (3-wave survey) | Academic stress, motivation, and coping across an online-only academic year | Academic stress and learning-strategy use both worsened mid-year before partially recovering; overall coping-strategy use was stable, but maladaptive coping was significantly elevated among second-year students specifically. |

| Study | Country | Sample size | Design | Key focus | Main findings |
|---|---|---|---|---|---|
| Charoenporn et al. [18] | Thailand | 386 | Cross-sectional | Zoom/online-learning fatigue, depression | 9.6% prevalence of high Zoom fatigue; significantly associated with depression (61.9% depression prevalence overall); more online sessions per day and lower academic year predicted higher fatigue. |
| Llanes-Castillo et al. [50] | Mexico | 184 | Cross-sectional | Online-class burnout during pandemic confinement | 17.9% met burnout-syndrome criteria; emotional exhaustion the most affected dimension; significantly higher burnout among female students. |
| Kim, Kim and Hwang [44] | South Korea | 365 | Cross-sectional | Screen time, visual display terminal syndrome | Daily digital-device use nearly doubled during the pandemic (from 4.8 to 8.1 hours per day); device-use hours and ergonomic factors significantly predicted visual and musculoskeletal fatigue symptoms. |
| Ghanem, Elhussiney and Elbadawy [30] | Egypt | 325 | Cross-sectional | Videoconference fatigue, psychological morbidities | 53.5% experienced high videoconference fatigue; significantly associated with higher stress, anxiety, and depression scores. |
| Inan et al. [40] | USA | 415 | Survey | Mental fatigue, coursework demand, learning engagement | Higher coursework demand and lower learning engagement were associated with greater mental fatigue among online college students. |
| Ra and Shin [64] | South Korea | 300 | Survey | Academic stress, coping (Third Culture Kid students) | Coping strategies moderate the impact of academic stress on wellbeing in a South Korean Third Culture Kid subpopulation. |
| Sawant et al. [77] | India | 346 | Cross-sectional | Digital fatigue, motivation, psychological health | 71% reported digital fatigue; 73% reported poor motivation to study; 40% reported anxiety and depressive symptoms. |
| de Oliveira Kubrusly Sobral et al. [24] | Brazil | 541 | Cross-sectional | Online learning fatigue, teaching methodology | 48% overall Zoom-fatigue prevalence; significantly higher in hybrid-curriculum students (56%) than in problem-based-learning students (41%). |
| Salim et al. [74] | Indonesia | 335 | Cross-sectional | Zoom fatigue risk factors, sleep, DASS-21 outcomes | Zoom fatigue significantly associated with poorer sleep quality and higher stress, anxiety, and depression (DASS-21); regression model explained 57% of the variance in fatigue. |

### 3.2. Prevalence and nature of digital learning fatigue

Across the reviewed literature, digital learning fatigue emerged as a widespread phenomenon, with prevalence estimates ranging from 45% to 75% among tertiary students. Higher prevalence rates were often observed in contexts involving extended synchronous learning, heavy screen exposure, and limited ergonomic environments (e.g., inadequate home study spaces). Common manifestations included visual fatigue (eye strain, headaches), cognitive exhaustion (difficulty concentrating, memory lapses), and emotional depletion (irritability, demotivation). Studies consistently reported that females and students in arts, humanities, and social sciences reported greater fatigue compared with males and STEM students, possibly reflecting differences in digital workload or communication demands.

Digital learning fatigue also exhibited cumulative effects: students who engaged in more than 6–8 hours of daily online activity were more likely to report chronic fatigue symptoms. Additionally, screen-time intensity, lack of social interaction, and information overload were identified as dominant predictors of fatigue severity [44, 84].

### 3.3. Psychological consequences of digital learning fatigue

Across the 22 included studies, digital learning fatigue was consistently associated with a spectrum of psychological, cognitive, and behavioural consequences. Nearly all studies (95%) reported at least one adverse psychological outcome, indicating a pervasive mental health dimension to digital learning fatigue among tertiary students.

#### 3.3.1. Emotional and mental health impacts

The most frequently reported psychological outcomes were anxiety (68%), stress (64%), and depressive symptoms (55%). These emotional disturbances were often interlinked with prolonged screen exposure, cognitive overload, and social isolation during online instruction [2, 50, 72]. For instance, Rutkowska et al. [72] found that over 56% of Polish university students reported depressive symptoms during sustained e-learning periods, while more than 80% described increased irritability and nervousness. Similarly, Alyoubi et al. [2] identified elevated anxiety, depressive symptoms, and sleep disruption – with roughly a third of students reporting at least moderate insomnia – among Saudi students during pandemic online learning. The chronicity of fatigue appeared to intensify emotional dysregulation, with several studies noting cyclical relationships between perceived exhaustion and mental distress. Students reporting higher fatigue scores were significantly more likely to exhibit depressive mood, frustration, and social withdrawal [48, 70].

#### 3.3.2. Cognitive and academic consequences

Digital learning fatigue also demonstrated measurable cognitive repercussions, including attention deficits (59%), reduced motivation (73%), and declines in academic performance (50%). Studies such as Li and Yang [48] found that loneliness during online instruction fostered learning burnout and, in turn, reduced learning engagement, while An et al. [3] linked higher digital fatigue to diminished academic resilience (mediated by grit and flexibility). Fatigue undermined self-regulated learning processes by diminishing focus, time management, and intrinsic motivation. Baltà-Salvador et al. [8] and Deniz et al. [26] reported significant associations between digital or Zoom fatigue and reduced academic wellbeing and motivation, confirming that fatigue is not only psychological but also cognitively disabling. Persistent exposure to video conferencing platforms (e.g., Zoom, MS Teams) produced "Zoom fatigue", characterised by mental saturation, communication overload, and decreased participation quality. This aligns with Reed [66], who found that students experiencing high video-conferencing fatigue exhibited greater cognitive strain and poorer learning retention.

### 3.3.3. Behavioural and psychosocial manifestations

Approximately 60% of studies documented behavioural or social impacts of digital fatigue. These included sleep disturbances (45%), social withdrawal (40%), and avoidance coping behaviours (36%). Students often responded to persistent fatigue by adjusting their coping and study-engagement strategies [29, 64]. Notably, gender differences and discipline-based disparities were consistent findings: female students and those in humanities and social sciences were significantly more prone to emotional exhaustion, whereas adaptive coping strategies and more manageable coursework demands appeared to buffer these effects [40, 64]. Moreover, several studies observed that psychological resilience, time management skills, and social support mitigated the adverse impact of fatigue. Inan et al. [40] highlighted that greater learning engagement and more manageable coursework demands were associated with lower mental fatigue, underscoring the moderating role of individual and contextual resources.

### 3.3.4. Synthesis of patterns

Synthesising across the studies, digital learning fatigue manifests as a multidimensional syndrome encompassing emotional, cognitive, and behavioural domains (table 3). While its short-term effects include momentary disengagement and frustration, sustained fatigue contributes to long-term psychological strain, notably heightened anxiety, demotivation, and academic burnout. Moreover, a consistent moderating pattern emerged: high screen exposure, gender (female), and humanities disciplines amplify fatigue, whereas psychological resilience and adaptive coping serve as protective factors. The interdependence among these variables suggests that digital learning fatigue is not merely a transient response to online environments but a systemic challenge that requires structural and pedagogical interventions in higher education.

**Table 3**
Summary of psychological consequences reported across studies ($n = 22$).

| Domain | Common outcomes | Studies reporting ($n$) | Percentage (%) | Representative references |
|---|---|---|---|---|
| Emotional / affective | Anxiety, stress, depressive symptoms, irritability | 15 | 68% | Alyoubi et al. [2]; Rutkowska et al. [72]; Llanes-Castillo et al. [50] |
| Cognitive / academic | Attention loss, low motivation, poor performance, disengagement | 16 | 73% | An et al. [3]; Deniz et al. [26]; Baltà-Salvador et al. [8] |
| behavioural / psychosocial | Sleep disturbance, social isolation, avoidance coping | 13 | 59% | Li and Yang [48]; Fridkin et al. [29]; Ra and Shin [64] |
| Protective / moderating factors | Resilience, coping, time management, social support | 7 | 32% | Inan et al. [40]; Ra and Shin [64] |

### 3.4. Moderating factors and cross-cultural variations

While digital learning fatigue presents as a global phenomenon, the reviewed studies reveal substantial variation across demographic and contextual factors. The analysis identified four primary moderators influencing the intensity and psychological impact of fatigue: gender, academic discipline, screen time exposure, and psychological resilience. Additionally, cross-regional differences suggest that

technological infrastructure and institutional preparedness shaped the degree of fatigue experienced during the digital learning transition.

#### 3.4.1. Gender differences

Gender consistently emerged as a significant moderating variable. Approximately 64% of the included studies ($n = 14$) found that female students reported higher levels of fatigue, stress, and emotional exhaustion than males [50, 70, 84]. The reasons cited include greater emotional labour in virtual collaboration, multitasking pressures in home environments, and increased self-perceived performance demands. Male students, by contrast, reported relatively greater cognitive fatigue but lower emotional distress.

#### 3.4.2. Academic discipline and learning context

The field of study also moderated fatigue severity. Students in arts, humanities, and social sciences consistently reported higher fatigue than those in STEM disciplines [8, 70]. This pattern likely reflects heavier discussion-based coursework and sustained synchronous engagement. Discipline-specific pedagogies further intensified fatigue: courses emphasising constant online interaction, camera use, and creative collaboration were associated with higher emotional exhaustion and burnout. Conversely, technology-oriented disciplines appeared to benefit from greater digital literacy and task autonomy, reducing fatigue susceptibility.

#### 3.4.3. Screen exposure and learning load

Across 80% of studies, screen exposure (hours of daily online activity) was the strongest predictor of digital learning fatigue. Students spending 6–8+ hours online daily reported substantially higher visual strain, cognitive overload, and burnout symptoms [3, 44]. High course load, frequent assessments, and back-to-back video conferencing sessions contributed to what several authors described as “digital cognitive congestion”. Moreover, environmental factors, such as inadequate workspace ergonomics and unstable internet connectivity, further exacerbated fatigue in developing regions [2, 30].

#### 3.4.4. Resilience and coping mechanisms

Individual psychological resilience, coping strategies, and social support emerged as protective moderators, attenuating the relationship between fatigue and adverse psychological outcomes. Inan et al. [40] demonstrated that higher learning engagement and lower coursework demand were associated with reduced mental fatigue among online college students. Similarly, Ra and Shin [64] and Fridkin et al. [29] found that coping strategies shaped students’ fatigue and stress trajectories, with adaptive coping associated with better adjustment over the academic year. These findings underscore that interventions that foster resilience and adaptive coping behaviours may mitigate the psychological toll of digital fatigue.

#### 3.4.5. Cross-cultural variations

Cross-regional differences revealed contextual dependencies in the prevalence and severity of digital fatigue. Students in Asia and the Middle East tended to report higher fatigue intensity than those in Europe or North America, possibly reflecting disparities in digital readiness and socio-environmental conditions [2, 3]. European studies (e.g., Spain, Poland) highlighted emotional exhaustion and motivation loss as dominant symptoms, while Asian samples emphasised cognitive overload and sleep disruption. North American studies stressed resilience and coping as mitigating factors, highlighting cultural differences in adaptive behaviours and institutional support systems.

### 3.4.6. Integrative summary

Synthesising across moderators, it is evident that digital learning fatigue is a multifactorially determined phenomenon, shaped by both individual-level (gender, resilience) and contextual-level (discipline, region, digital infrastructure) factors (table 4). The data suggest that screen exposure remains the most consistent determinant, while resilience represents a modifiable protective factor. Culturally adaptive pedagogical models, balanced digital workloads, and institutional support systems are thus essential to mitigate fatigue and its psychological consequences globally.

**Table 4**
Moderating factors influencing digital learning fatigue.

| Moderator | Direction of effect | Evidence strength* | Representative findings | Representative studies |
|---|---|---|---|---|
| Gender | Higher fatigue among females; greater emotional exhaustion | Strong (14/22 studies) | Women report higher stress and sensory overload | Romero-Rodríguez et al. [70]; Tuğtekin [84]; Llanes-Castillo et al. [50] |
| Academic discipline | Arts/Humanities > STEM in fatigue levels | Moderate (10/22) | Discussion-heavy and synchronous disciplines exacerbate fatigue | Baltà-Salvador et al. [8]; Romero-Rodríguez et al. [70] |
| Screen exposure / course load | Longer screen hours increase fatigue and psychological strain | Strong (18/22) | 6–8+ hrs/day linked with visual, cognitive, and emotional fatigue | Kim, Kim and Hwang [44]; An et al. [3]; Ghanem, Elhussiney and Elbadawy [30] |
| Resilience / coping | Higher resilience and coping reduce fatigue intensity | Moderate (7/22) | Resilience buffers mental health decline; coping improves engagement | Inan et al. [40]; Ra and Shin [64] |
| Cultural context / region | Developing regions show higher fatigue intensity | Emerging (6/22) | Infrastructure limitations and learning stress amplify fatigue | Alyoubi et al. [2]; An et al. [3] |

* Evidence strength reflects the proportion of studies reporting statistically or thematically significant moderating effects.

## 3.5. Summary of main findings and emerging research gaps

The synthesis of 22 studies revealed that digital learning fatigue is a pervasive and multifaceted challenge among tertiary students, characterised by intertwined psychological, cognitive, and behavioural consequences. Across global contexts, fatigue prevalence ranged from 45% to 75%, reflecting its systemic association with prolonged digital engagement and pandemic-driven pedagogical shifts.

### 3.5.1. Integrated summary of findings

Collectively, the evidence indicates that digital learning fatigue manifests through a tripartite pattern of effects:

1. Psychological strain – high levels of anxiety, stress, and depressive symptoms, exacerbated by emotional and social isolation.
2. Cognitive depletion – reduced concentration, motivation, and self-regulated learning capacity, contributing to diminished academic performance.
3. Behavioural disengagement – avoidance behaviours, disrupted sleep patterns, and withdrawal from online communities.

Furthermore, the review underscores the moderating roles of gender, discipline, screen time, and resilience, showing that these variables can either amplify or buffer fatigue intensity. Cross-cultural analyses revealed differential fatigue manifestations: students in digitally mature contexts reported more adaptive coping, while those in developing regions experienced more pronounced psychological strain due to limited infrastructure and pedagogical flexibility.

#### 3.5.2. Emerging research gaps

Despite substantial evidence, several gaps and inconsistencies remain:

1. A lack of longitudinal and experimental studies limits causal understanding of digital fatigue trajectories and recovery mechanisms.
2. Inconsistent measurement tools hinder cross-study comparability, as few studies employ standardised fatigue instruments.
3. Limited research explores neurocognitive or physiological correlates (e.g., sleep biomarkers, attentional metrics).
4. The role of institutional design – particularly course structure, instructor digital competence, and hybrid learning models – remains underexplored.
5. Very few studies have examined the efficacy of interventions, such as digital wellness training or ergonomic redesigns.

Future research should therefore integrate multimodal approaches, combining quantitative, qualitative, and psychophysiological data to deepen understanding and inform evidence-based mitigation strategies.

#### 3.5.3. Summary Interpretation

The findings consolidate digital learning fatigue as a global psychological and pedagogical concern that transcends cultural and disciplinary boundaries. Its consistent linkage to mental strain, motivation loss, and engagement decline underscores the urgent need for evidence-based strategies – including balanced workload design, resilience training, and digital ergonomics – to safeguard student wellbeing in increasingly virtualised academic ecosystems (table 5).

## 4. Discussion

This comprehensive review synthesised evidence from 22 empirical studies examining digital learning fatigue and its psychological implications among tertiary students across diverse geographical contexts. The findings reveal a persistent, multidimensional phenomenon with significant consequences for student wellbeing, academic performance, and the future of higher education delivery. The review demonstrated moderate to high prevalence rates of digital learning fatigue across multiple countries, confirming that this issue transcends geographical and cultural boundaries. Particularly concerning is that a substantial proportion of university students reported depressive symptoms following prolonged e-learning, with over 80% experiencing anxiety, irritation, and motivation difficulties. These prevalence rates considerably exceed pre-pandemic estimates of student mental health concerns, which typically ranged between 30–40% for anxiety and depression [6, 49], suggesting that digital learning fatigue represents a distinct and additional burden beyond pre-existing mental health vulnerabilities. The consistency of findings across culturally diverse contexts – spanning Europe, the Middle East, and Asia – indicates that digital learning fatigue is not exclusively a Western phenomenon. Unexpectedly, studies from Middle Eastern and Asian contexts reported equivalent or higher fatigue levels than Western samples, challenging assumptions that collectivist cultures with

**Table 5**
Thematic summary of key findings and research gaps.

| Thematic domain | Core findings | Identified gaps | Future research directions |
|---|---|---|---|
| Prevalence and nature | Fatigue prevalent among 45–75% of tertiary students; manifests as emotional, cognitive, and visual exhaustion | Limited longitudinal tracking of fatigue progression | Long-term studies to assess persistence and adaptation over semesters |
| Psychological consequences | High levels of anxiety (68%), stress (64%), and depressive symptoms (55%) | Sparse use of standardised diagnostic tools | Employ validated scales (e.g., DASS-21, PSS) for cross-comparison |
| Cognitive and academic effects | Reduced motivation (73%) and engagement; lowered academic performance (50%) | Few experimental designs to test causal direction | Conduct controlled studies linking fatigue with performance metrics |
| behavioural manifestations | Sleep disruption (45%), avoidance coping (36%), and social withdrawal | Underexplored interaction between fatigue and social connectedness | Examine digital fatigue's influence on online community participation |
| Moderating factors | Gender, screen exposure, and discipline increase risk; resilience buffers effects | Weak cross-cultural validation of moderators | Develop culturally sensitive models of fatigue prediction and resilience |
| Institutional and technological context | Fatigue amplified in low-infrastructure or high-load digital settings | Scarce evaluation of institutional or instructional design factors | Test interventions such as reduced synchronous load or digital hygiene training |
| Methodological rigour | Most studies cross-sectional, moderate-to-high quality (63% NOS $\geq$ 7) | Lack of meta-analytic quantification and mixed-method integration | Encourage meta-analyses and mixed-method triangulation to consolidate findings |

stronger family support systems might buffer against isolation-related distress. This universality may reflect underlying human cognitive and social needs that technology-mediated learning addresses inadequately, regardless of cultural context.

The multidimensional nature of digital learning fatigue – encompassing physical, cognitive, emotional, and social dimensions – distinguishes it from general academic stress or traditional forms of student burnout. While burnout has been conceptualised primarily through emotional exhaustion, depersonalisation, and reduced accomplishment [52], digital learning fatigue additionally incorporates sensory and physiological components directly attributable to screen-based interaction. This unique constellation suggests existing theoretical frameworks for understanding student distress require augmentation to accommodate technology-specific stressors.

While cognitive load theory [82] adequately explains the cognitive exhaustion component through concepts of intrinsic, extraneous, and germane load, it proves insufficient as a comprehensive explanatory framework. The current findings suggest digital learning fatigue operates through multiple mechanisms simultaneously: cognitive resource depletion (cognitive load theory), psychological need frustration (self-determination theory [73]), and cumulative resource loss (conservation of resources theory [36]). This theoretical complexity has practical implications: interventions focusing solely on reducing cognitive load address only one dimension of a multidimensional problem.

The identification of course overload and poor instructional design as primary contributors aligns with multimedia learning research emphasising coherence, signalling, and segmentation to reduce cognitive load [17, 54]. However, findings extend beyond simple cognitive overload to encompass motivational and emotional dimensions. Courses lacking meaningful instructor presence, timely feed-

back, and peer interaction generated not only cognitive strain but also feelings of disconnection and diminished self-efficacy, supporting self-determination theory's premise that learning environments that satisfy psychological needs for autonomy, competence, and relatedness foster intrinsic motivation and wellbeing [73]. Notably, synchronous video conferencing, while intended to replicate classroom interaction, often exacerbated rather than alleviated fatigue. Recent frameworks explaining video-conference fatigue through excessive eye contact, cognitive load from self-view, restricted mobility, and increased nonverbal processing demands provide a mechanistic understanding [7, 69]. The identification of scopophobia, anxiety related to being observed during videoconferences as a distinct digital learning stressor, constitutes an important finding, suggesting that "cameras off" policies may actually reduce psychological burden and facilitate learning for some student populations.

The importance of the home learning environment as a contributing factor underscores how digital learning blurs previously distinct life domains. Border theory suggests that forced integration of work and home domains produces role conflict and stress [21]. Students lacking dedicated study spaces experienced "boundary violations", disproportionately affecting students from lower socioeconomic backgrounds, those in crowded households, and international students in challenging time zones [56]. Systemic factors, such as information overload, platform complexity, and proliferation of communication channels, contributed significantly to fatigue. The rapid expansion of digital tools during emergency remote teaching created a "paradox of choice", where excessive options overwhelm rather than empower users [43], suggesting that strategic curation and integration of platforms may enhance rather than constrain learning opportunities.

The substantial associations between digital learning fatigue and depression, anxiety, and stress raise critical questions about directionality and causality. While the cross-sectional nature of included studies prevents definitive causal claims, theoretical and empirical evidence suggest bidirectional relationships. This bidirectionality indicates that students enter potentially self-perpetuating cycles in which fatigue and psychological distress mutually reinforce one another – termed "loss spirals" within conservation of resources theory [36]. The absence of longitudinal studies reflects a critical gap, as understanding temporal dynamics is essential for identifying intervention points. Importantly, psychological implications extended beyond clinical symptoms to encompass subclinical impairments in daily functioning, indicating that digital learning fatigue constitutes a public health concern affecting broad student populations. The reported association with academic impairment aligns with research showing cognitive fatigue impairs attention, working memory, and executive functioning [46], while also eroding the motivational and affective foundation of engaged learning through reduced intrinsic motivation, cynical attitudes, and diminished self-efficacy – key components of academic burnout [76].

The consistent finding that female students reported higher digital learning fatigue demands careful interpretation. Research suggests that women experience greater videoconference fatigue, partly due to "self-focused attention" induced by self-view, which affects them more intensely due to socialisation around appearance [27]. Additionally, women disproportionately assume caregiving and domestic responsibilities, which creates greater work-family conflict when learning from home [22]. Addressing this disparity requires multilevel interventions that extend beyond educational technology design.

Students in arts, humanities, and practice-based fields exhibited heightened fatigue, illustrating the concept of "pedagogical fit" between subject matter and delivery medium. Disciplines relying on hands-on learning, collaborative creation, physical materials, and embodied practice suffered particularly acute losses in transitioning to digital formats, challenging one-size-fits-all approaches. Socioeconomic disparities emerged as critical moderators. Students without reliable internet connectivity, adequate devices, or private study spaces exhibited compounded disadvantage. The digital divide thus operates at multiple levels: access to technology, ability to use technology effectively, and capacity to benefit from technology [87]. Digital learning risks exacerbating existing inequalities by imposing technology-related barriers disproportionately on marginalised students [78].

Evidence suggests numerous practical interventions. Courses should incorporate asynchronous options wherever feasible, reducing mandatory synchronous screen time while maintaining social

connection [42]. Synchronous sessions should be limited in duration (45–50 minutes maximum), include frequent breaks, and allow "cameras off" participation. Assessment should shift toward authentic, flexible formats that reduce high-stakes anxiety while preserving academic rigour [88]. Instructors should receive professional development in trauma-informed pedagogy, recognising that many students carry pandemic-related trauma requiring compassionate, flexible approaches [16]. Institutionally, universities should establish maximum screen time guidelines for course design, adopt fewer well-integrated platforms, expand digital mental health resources, and routinely monitor student wellbeing using brief, validated instruments [57]. Accreditation bodies and government agencies should establish minimum standards for digital learning quality that explicitly incorporate student wellbeing alongside academic outcomes. The development of standardised measurement tools and longitudinal research examining temporal dynamics represents critical priorities for advancing this field and informing evidence-based interventions.

### 4.1. Limitations and future research directions

Several methodological constraints impede the interpretation of this review's conclusions. First, the complete dependence on cross-sectional designs across all 22 included studies limits causal inference. While connections between digital learning elements and psychological effects are obvious, directionality remains uncertain. Longitudinal studies following students throughout semesters or academic years are urgently needed to establish temporal sequences, identify important moments of vulnerability, and evaluate whether weariness lessens with adaptation or accumulates over time [58]. Second, the strong reliance on self-report measures introduces potential biases, including social desirability, recall errors, and common method variance [63]. Future research should combine objective measures, such as learning analytics tracking real screen time, physiological indicators of stress (cortisol, heart rate variability), and performance-based cognitive assessments, alongside self-reports to provide convergent validation.

Third, sampling procedures across the included studies varied widely, with several adopting convenience samples of limited generalizability. Few studies obtained representative samples across demographic characteristics, including race/ethnicity, handicap status, socioeconomic background, or first-generation college status. The voices of the most marginalised students – those who may have withdrawn from education entirely due to digital learning challenges – are necessarily omitted from studies capturing solely currently enrolled students. Future research should stress inclusive recruitment and specifically investigate minority populations' experiences. Also, the prevalence of studies from certain regions (Europe, the Middle East, Asia) and their limited representation of Africa, South America, and indigenous populations limits global generalizability. Cultural variance in technology uptake, educational beliefs, family structures, and coping methods likely moderates digital learning experiences in ways present studies cannot reveal [38].

The absence of a uniform, validated instrument for detecting digital learning fatigue across included research hinders synthesis and limits comparability. Future research should prioritise psychometric development and validation of a Digital Learning Fatigue Scale demonstrating reliability, factorial validity, measurement invariance across demographic groups, and sensitivity to change following interventions. Such a device would enable meta-analytic synthesis and exact effect-size calculation, currently unattainable with heterogeneous measurement methodologies. Additionally, clearer conceptual boundaries across similar constructs – digital learning fatigue, technostress, academic burnout, Zoom fatigue – need to be established. At the same time, many phenomena overlap; their distinctions are significant for theoretical comprehension and for targeting interventions. Construct validation research applying confirmatory factor analysis and analysing discriminant validity among related factors would improve the discipline greatly [20].

The field urgently needs rigourous intervention research employing randomised controlled trials or quasi-experimental designs to provide evidence-based practices for preventing and minimising digital learning fatigue. Promising intervention targets include: pedagogical modifications (comparing asynchronous vs. synchronous modalities, evaluating optimal session durations, testing different

assessment formats); technological solutions (evaluating user interface designs, comparing platform features, testing communication management tools); psychological interventions (mindfulness training, cognitive-behavioural strategies, peer support programs); and systemic changes (policy implementations, schedule modifications, support service enhancements). Such intervention research should combine implementation science frameworks to understand not only whether treatments operate in ideal settings but also how they function in real-world educational environments with limited resources and competing goals [60]. Process assessments that address implementation integrity, contextual factors that determine success, and stakeholder views would provide vital insights for scaling effective techniques.

### 4.2. Emerging research questions

Several specific research questions emerge as priorities:

1. *Temporal dynamics*: Does digital learning fatigue follow predictable patterns across academic terms, with fatigue accumulating toward midterms and finals, or does it plateau after initial adaptation?

2. *Recovery processes*: What activities, durations, and types of breaks effectively restore resources depleted by digital learning? Do screen-free activities differ in restorative potential from low-demand screen activities?

3. *Individual differences*: Beyond demographic variables, what personality traits, cognitive styles, or coping strategies protect against or exacerbate digital learning fatigue?

4. *Technological innovations*: Can emerging technologies – virtual reality, artificial intelligence, adaptive learning systems – reduce fatigue through more engaging, personalised experiences, or do they add complexity and cognitive burden?

## 5. Implications for policy and practice

The results of this review highlight the importance of educational institutions increasing their implementation of evidence-based, institution-wide practises that acknowledge digital learning fatigue as a pedagogical quality concern and a student wellbeing necessity. The reported cognitive, emotional, and behavioural effects indicate that digital fatigue is not a temporary inconvenience but a structural problem that should be addressed through curriculum design, workload regulation, and student support systems.

Curriculum and instruction-wise, universities must encourage equal consideration of synchronous and asynchronous learning and ensure that digital workloads are carefully designed to minimise excessive screen time and cognitive load. The courses must be designed with shorter synchronous sessions, content segmentation, and self-paced learning opportunities that align with cognitive load principles. Teachers need specific professional training in digital pedagogy, trauma-informed teaching, and building a psychologically supportive online space.

Institutional level requires strong student-support systems. Universities need to increase access to mental health services, digital wellbeing resources, and resilience-building programmes that support virtual learning. The policies of workload regulation, including the maximum recommended number of hours of synchronous instruction per week and the minimum time between online sessions, should be formalised to avoid cumulative fatigue. Institutions should also rationalise the number of learning platforms and communication channels used to simplify technology and reduce information overload.

Policy reform is centred on equity. The review points out that students with socioeconomic disadvantages, poor home learning conditions, or unstable connectivity suffer disproportionate fatigue. The institutions should thus focus on programmes such as device loan schemes, data support subsidies, convenient, ergonomic campus spaces, and inclusive design that supports learners with

different needs. By integrating these structural protective measures into digital learning ecosystems, universities can significantly reduce the psychological impact of long-term online interaction and create sustainable, human-centred digital learning.

## 6. Conclusion

This systematic review establishes digital learning fatigue as a pervasive, multifactorial, and psychologically consequential condition among tertiary students worldwide. Synthesised evidence from 22 empirical studies demonstrates that sustained digital engagement, particularly prolonged synchronous instruction and heavy screen exposure, precipitates intertwined emotional distress, cognitive depletion, and behavioural withdrawal. The phenomenon extends beyond temporary pandemic disruption to represent an enduring structural challenge within hybrid and online higher education. Gender, discipline, and screen-time exposure consistently heightened vulnerability, whereas resilience, coping strategies, and institutional support moderated adverse outcomes. These findings validate an ecological model of DLF encompassing individual (self-efficacy, mental health), pedagogical (course design, assessment load), technological (platform complexity), and contextual (home environment, infrastructure) determinants.

Universities should therefore treat digital fatigue as both a pedagogical quality issue and a public health priority, embedding fatigue-prevention criteria into instructional design, workload policy, and student wellbeing systems. Future research must move beyond cross-sectional observation toward longitudinal and intervention-based studies that test causal pathways and evaluate remedial effectiveness. Developing a psychometrically robust Digital Learning Fatigue Scale that integrates physiological indicators and examines cultural variations will enhance theoretical precision and practical applicability. Ultimately, mitigating digital learning fatigue is central to ensuring that higher education's digital transformation remains human-centred, inclusive, and psychologically sustainable.

### Acknowledgments

The authors are grateful to the authors whose works they used as a resource.

### Data availability statement

The article and supplementary materials contain the original contributions to the study; for further information, contact the corresponding author.

### Funding

The study was carried out without financial support.

### Conflicts of interest

The study's authors assert that no financial or business connections are perceived as posing a potential conflict of interest.

### References

[1] Alarabiat, A., 2024. The impact of online learning fatigue on students' continuous use of online learning. *Journal of Theoretical and Applied Information Technology*, 102(20), pp.7423–7432. Available from: https://jatit.org/volumes/Vol102No20/13Vol102No20.pdf.

[2] Alyoubi, A., Halstead, E.J., Zambelli, Z. and Dimitriou, D., 2021. The Impact of the COVID-19 Pandemic on Students' Mental Health and Sleep in Saudi Arabia. *International Journal of Environmental Research and Public Health*, 18(17), p.9344. Available from: https://doi.org/10.3390/ijerph18179344.

[3] An, R., Qian, G., Mumtaz, A., Alotaibi, K.A. and Wang, X., 2025. Digital fatigue and academic resilience among university students with grit and flexibility as mediators. *Scientific Reports*, 15, p.45407. Available from: https://doi.org/10.1038/s41598-025-29313-7.

[4] Anderson, M. and Perrin, A., 2018. Nearly one-in-five teens can't always finish their homework because of the digital divide. Pew Research Center. Available from: https://www.pewresearch.org/short-reads/2018/10/26/nearly-one-in-five-teens-cant-always-finish-their-homework-because-of-the-digital-divide/.

[5] Arnett, J.J., 2000. Emerging adulthood: A theory of development from the late teens through the twenties. *American Psychologist*, 55(5), pp.469–480. Available from: https://doi.org/10.1037/0003-066X.55.5.469.

[6] Auerbach, R.P., Mortier, P., Bruffaerts, R., Alonso, J., Benjet, C., Cuijpers, P., Demyttenaere, K., Ebert, D.D., Green, J.G., Hasking, P., Murray, E., Nock, M.K., Pinder-Amaker, S., Sampson, N.A., Stein, D.J., Vilagut, G., Zaslavsky, A.M. and Kessler, R.C., 2018. WHO World Mental Health Surveys International College Student Project: Prevalence and distribution of mental disorders. *Journal of Abnormal Psychology*, 127(7), pp.623–638. Available from: https://doi.org/10.1037/abn0000362.

[7] Bailenson, J.N., 2021. Nonverbal overload: A theoretical argument for the causes of Zoom fatigue. *Technology, Mind, and Behavior*, 2(1), pp.1–6. Available from: https://doi.org/10.1037/tmb0000030.

[8] Baltà-Salvador, R., Olmedo-Torre, N., Peña, M. and Renta-Davids, A.I., 2021. Academic and emotional effects of online learning during the COVID-19 pandemic on engineering students. *Education and Information Technologies*, 26(6), pp.7407–7434. Available from: https://doi.org/10.1007/s10639-021-10593-1.

[9] Bandura, A., 1997. *Self-Efficacy: The Exercise of Control*. New York: W. H. Freeman and Company.

[10] Barkley, R.A., ed., 2018. *Attention-Deficit Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. 4th ed. Guilford Press.

[11] Bernard, R.M., Abrami, P.C., Lou, Y., Borokhovski, E., Wade, A., Wozney, L., Wallet, P.A., Fiset, M. and Huang, B., 2004. How Does Distance Education Compare With Classroom Instruction? A Meta-Analysis of the Empirical Literature. *Review of Educational Research*, 74(3), pp.379–439. Available from: https://doi.org/10.3102/00346543074003379.

[12] Besser, A., Flett, G.L. and Zeigler-Hill, V., 2022. Adaptability to a sudden transition to online learning during the COVID-19 pandemic: Understanding the challenges for students. *Scholarship of Teaching and Learning in Psychology*, 8(2), pp.85–105. Available from: https://doi.org/10.1037/stl0000198.

[13] Boursier, V., Gioia, F. and Griffiths, M.D., 2020. Objectified Body Consciousness, Body Image Control in Photos, and Problematic Social Networking: The Role of Appearance Control Beliefs. *Frontiers in Psychology*, 11, p.147. Available from: https://doi.org/10.3389/fpsyg.2020.00147.

[14] Broadbent, J. and Poon, W.L., 2015. Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review. *The Internet and Higher Education*, 27, pp.1–13. Available from: https://doi.org/10.1016/j.iheduc.2015.04.007.

[15] Cao, W., Fang, Z., Hou, G., Han, M., Xu, X., Dong, J. and Zheng, J., 2020. The psychological impact of the COVID-19 epidemic on college students in China. *Psychiatry Research*, 287, p.112934. Available from: https://doi.org/10.1016/j.psychres.2020.112934.

[16] Carello, J. and Butler, L.D., 2015. Practicing What We Teach: Trauma-Informed Educational Practice. *Journal of Teaching in Social Work*, 35(3), pp.262–278. Available from: https://doi.org/10.1080/08841233.2015.1030059.

[17] Castro-Alonso, J.C., Ayres, P. and Paas, F., 2016. Comparing apples and oranges? A critical

look at research on learning from statics versus animations. *Computers & Education*, 102, pp.234–243. Available from: https://doi.org/10.1016/j.compedu.2016.09.004.

[18] Charoenporn, V., Hanvivattanakul, S., Jongmekwamsuk, K., Lenavat, R., Hanvivattanakul, K. and Charernboon, T., 2024. Zoom fatigue related to online learning among medical students in Thailand: Prevalence, predictors, and association with depression. *F1000Research*, 13, p.617. Available from: https://doi.org/10.12688/f1000research.146084.2.

[19] Chen, C.M., Wang, J.Y. and Yu, C.M., 2017. Assessing the attention levels of students by using a novel attention aware system based on brainwave signals. *British Journal of Educational Technology*, 48(2), pp.348–369. Available from: https://doi.org/10.1111/bjet.12359.

[20] Clark, L.A. and Watson, D., 2019. Constructing validity: New developments in creating objective measuring instruments. *Psychological Assessment*, 31(12), pp.1412–1427. Available from: https://doi.org/10.1037/pas0000626.

[21] Clark, S.C., 2000. Work/Family Border Theory: A New Theory of Work/Family Balance. *Human Relations*, 53(6), pp.747–770. Available from: https://doi.org/10.1177/0018726700536001.

[22] Craig, L. and Churchill, B., 2021. Dual-earner parent couples' work and care during COVID-19. *Gender, Work & Organization*, 28(S1), pp.66–79. Available from: https://doi.org/10.1111/gwao.12497.

[23] Daumiller, M., Rinas, R., Hein, J., Janke, S., Dickhäuser, O. and Dresel, M., 2021. Shifting from face-to-face to online teaching during COVID-19: The role of university faculty achievement goals for attitudes towards this sudden change, and their relevance for burnout/engagement and student evaluations of teaching quality. *Computers in Human Behavior*, 118, p.106677. Available from: https://doi.org/10.1016/j.chb.2020.106677.

[24] de Oliveira Kubrusly Sobral, J.B., Lima, D.L.F., Lima Rocha, H.A., de Brito, E.S., Duarte, L.H.G., Bento, L.B.B.B. and Kubrusly, M., 2022. Active methodologies association with online learning fatigue among medical students. *BMC Medical Education*, 22(1), p.74. Available from: https://doi.org/10.1186/s12909-022-03143-x.

[25] DeLeeuw, K.E. and Mayer, R.E., 2008. A comparison of three measures of cognitive load: Evidence for separable measures of intrinsic, extraneous, and germane load. *Journal of Educational Psychology*, 100(1), pp.223–234. Available from: https://doi.org/10.1037/0022-0663.100.1.223.

[26] Deniz, M.E., Satici, S.A., Doenyas, C. and Griffiths, M.D., 2022. Zoom Fatigue, Psychological Distress, Life Satisfaction, and Academic Well-Being. *Cyberpsychology, Behavior, and Social Networking*, 25(5), pp.270–277. Available from: https://doi.org/10.1089/cyber.2021.0249.

[27] Fardouly, J. and Vartanian, L.R., 2016. Social Media and Body Image Concerns: Current Research and Future Directions. *Current Opinion in Psychology*, 9, pp.1–5. Social media and applications to health behavior. Available from: https://doi.org/10.1016/j.copsyc.2015.09.005.

[28] Fauville, G., Luo, M., Queiroz, A.C.M., Bailenson, J.N. and Hancock, J., 2021. Nonverbal Mechanisms Predict Zoom Fatigue and Explain Why Women Experience Higher Levels than Men. *SSRN Electronic Journal*. Available from: https://doi.org/10.2139/ssrn.3820035.

[29] Fridkin, L., Bover Fonts, N., Quy, K. and Zwiener-Collins, N., 2023. Understanding effects of COVID-19 on undergraduate academic stress, motivation and coping over time. *Higher Education Quarterly*, 77(4), pp.623–637. Available from: https://doi.org/10.1111/hequ.12425.

[30] Ghanem, E.A., Elhussiney, D.M. and Elbadawy, D.A.G.E.D., 2022. Prevalence, Risk Factors of Videoconference Fatigue, and Its Relation to Psychological Morbidities Among Ain Shams Medical Students, Egypt. *The Egyptian Journal of Community Medicine*, 41(2), pp.111–117. https://web.archive.org/web/20251115183041/https://ejcm.journals.ekb.eg/article_271157_39511244dcbc43705486f3f9bd18365e.pdf, Available from: https://doi.org/10.21608/ejcm.2022.159150.1234.

[31] Gin, L.E., Guerrero, F.A., Brownell, S.E., Cooper, K.M. and Momsen, J., 2021. COVID-19 and Undergraduates with Disabilities: Challenges Resulting from the Rapid Transition to Online Course Delivery for Students with Disabilities in Undergraduate STEM at Large-Enrollment Institutions. *CBE—Life Sciences Education*, 20(3), p.ar36. Available from: https://doi.org/10.

1187/cbe.21-02-0028.

[32] Göldağ, B., 2022. An Investigation of the Relationship between University Students' Digital Burnout Levels and Perceived Stress Levels. Available from: https://doi.org/10.53850/joltida.958039.

[33] Gonzalez, T., de la Rubia, M.A., Hincz, K.P., Comas-Lopez, M., Subirats, L., Fort, S. and Sacha, G.M., 2020. Influence of COVID-19 confinement on students' performance in higher education. *PLoS ONE*, 15(10), p.e0239490. Available from: https://doi.org/10.1371/journal.pone.0239490.

[34] Graham, C.R., 2006. Blended Learning Systems: Definition, Current Trends, and Future DirectionsDirections. In: C.J. Bonk and C.R. Graham, eds. *The Handbook of Blended Learning: Global Perspectives, Local Designs*. San Francisco, CA: Pfeiffer Publishing, pp.3–21. Available from: https://scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=9100&context=facpub.

[35] Händel, M., Stephan, M., Gläser-Zikuda, M., Kopp, B., Bedenlier, S. and Ziegler, A., 2022. Digital readiness and its effects on higher education students' socio-emotional perceptions in the context of the COVID-19 pandemic. *Journal of Research on Technology in Education*, 54(2), pp.267–280. Available from: https://doi.org/10.1080/15391523.2020.1846147.

[36] Hobfoll, S.E., 1989. Conservation of resources: A new attempt at conceptualizing stress. *American Psychologist*, 44(3), pp.513–524. Available from: https://doi.org/10.1037/0003-066x.44.3.513.

[37] Hodges, C., Moore, S., Lockee, B., Trust, T. and Bond, A., 2020. The Difference Between Emergency Remote Teaching and Online Learning. EDUCAUSE Review. Available from: https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning.

[38] Hofstede, G., 2011. Dimensionalizing Cultures: The Hofstede Model in Context. *Online Readings in Psychology and Culture*, 2(1). Available from: https://doi.org/10.9707/2307-0919.1014.

[39] Honicke, T. and Broadbent, J., 2016. The influence of academic self-efficacy on academic performance: A systematic review. *Educational Research Review*, 17, pp.63–84. Available from: https://doi.org/10.1016/j.edurev.2015.11.002.

[40] Inan, F.A., Sosi, E.T., Unal, D., Marzban, F. and Bayne, G.A., 2025. The Impact of Coursework Demand and Learning Engagement on Mental Fatigue in Online College Students. *International Journal of Environmental Research and Public Health*, 22(12), p.1860. Available from: https://doi.org/10.3390/ijerph22121860.

[41] Kalyuga, S. and Singh, A.M., 2016. Rethinking the Boundaries of Cognitive Load Theory in Complex Learning. *Educational Psychology Review*, 28(4), pp.831–852. Available from: https://doi.org/10.1007/s10648-015-9352-0.

[42] Kaplan, A.M. and Haenlein, M., 2016. Higher education and the digital revolution: About MOOCs, SPOCs, social media, and the Cookie Monster. *Business Horizons*, 59(4), pp.441–450. Available from: https://doi.org/10.1016/j.bushor.2016.03.008.

[43] Karr-Wisniewski, P. and Lu, Y., 2010. When more is too much: Operationalizing technology overload and exploring its impact on knowledge worker productivity. *Computers in Human Behavior*, 26(5), pp.1061–1072. Available from: https://doi.org/10.1016/j.chb.2010.03.008.

[44] Kim, H., Kim, S.J. and Hwang, S., 2024. Visual display terminal syndrome and its associated factors among university students during the COVID-19 pandemic. *Work*, 77(1), pp.23–36. Available from: https://doi.org/10.3233/WOR-220265.

[45] Klimova, B. and Pikhart, M., 2025. Exploring the effects of artificial intelligence on student and academic well-being in higher education: a mini-review. *Frontiers in Psychology*, 16, p.1498132. Available from: https://doi.org/10.3389/fpsyg.2025.1498132.

[46] Langner, R., Steinborn, M.B., Chatterjee, A., Sturm, W. and Willmes, K., 2010. Mental fatigue and temporal preparation in simple reaction-time performance. *Acta Psychologica*, 133(1), pp.64–72. Available from: https://doi.org/10.1016/j.actpsy.2009.10.001.

[47] Lee, J., 2020. Mental health effects of school closures during COVID-19. *The Lancet Child & Adolescent Health*, 4(6), p.421. Available from: https://doi.org/10.1016/S2352-4642(20)

30109-7.
[48] Li, H. and Yang, J., 2025. Managing online learning burnout via investigating the role of loneliness during COVID-19. *BMC Psychology*, 13(1), p.151. Available from: https://doi.org/10.1186/s40359-025-02419-3.
[49] Lipson, S.K., Lattie, E.G. and Eisenberg, D., 2019. Increased Rates of Mental Health Service Utilization by U.S. College Students: 10-Year Population-Level Trends (2007–2017). *Psychiatric Services*, 70(1), pp.60–63. Available from: https://doi.org/10.1176/appi.ps.201800332.
[50] Llanes-Castillo, A., Pérez-Rodríguez, P., Reyes-Valdéz, M.L. and Cervantes-López, M.J., 2022. Burnout: Efectos del confinamiento en estudiantes universitarios en México. *Revista de Ciencias Sociales*, 28(3), pp.69–81. Available from: https://doi.org/10.31876/rcs.v28i3.38451.
[51] Madigan, D.J. and Curran, T., 2021. Does Burnout Affect Academic Achievement? A Meta-Analysis of over 100,000 Students. *Educational Psychology Review*, 33(2), pp.387–405. Available from: https://doi.org/10.1007/s10648-020-09533-1.
[52] Maslach, C. and Leiter, M.P., 2016. Understanding the burnout experience: recent research and its implications for psychiatry. *World Psychiatry*, 15(2), pp.103–111. Available from: https://doi.org/10.1002/wps.20311.
[53] Mayer, R.E., 2014. Cognitive Theory of Multimedia Learning. In: R.E. Mayer, ed. *The Cambridge Handbook of Multimedia Learning*. 2nd ed. Cambridge University Press, Cambridge Handbooks in Psychology, pp.43–71. Available from: https://doi.org/10.1017/cbo9781139547369.005.
[54] Mayer, R.E., 2017. Using multimedia for e-learning. *Journal of Computer Assisted Learning*, 33(5), pp.403–423. Available from: https://doi.org/10.1111/jcal.12197.
[55] Mayer, R.E. and Moreno, R., 2003. Nine Ways to Reduce Cognitive Load in Multimedia Learning. *Educational Psychologist*, 38(1), pp.43–52. Available from: https://doi.org/10.1207/s15326985ep3801_6.
[56] Means, B. and Neisler, J., 2021. Teaching and Learning in the Time of COVID: The Student Perspective. *Online Learning*, 25(1), pp.8–27. Available from: https://doi.org/10.24059/olj.v25i1.2496.
[57] Means, B., Neisler, J. and Langer Research Associates, 2020. *Suddenly Online: A National Survey of Undergraduates During the COVID-19 Pandemic*. San Mateo, CA: Digital Promise. Available from: https://doi.org/10.51388/20.500.12265/98.
[58] Menard, S., 2002. *Longitudinal Research*. 2nd ed. Sage Publications.
[59] Nesher Shoshan, H. and Wehrt, W., 2022. Understanding "Zoom fatigue": A mixed-method approach. *Applied Psychology*, 71(3), pp.827–852. Available from: https://doi.org/10.1111/apps.12360.
[60] Nilsen, P., 2015. Making sense of implementation theories, models and frameworks. *Implementation Science*, 10(1), p.53. Available from: https://doi.org/10.1186/s13012-015-0242-0.
[61] Oleksiyenko, A., Blanco, G., Hayhoe, R., Jackson, L., Lee, J., Metcalfe, A., Sivasubramaniam, M. and Zha, Q., 2021. Comparative and international higher education in a new key? Thoughts on the post-pandemic prospects of scholarship. *Compare: A Journal of Comparative and International Education*, 51(4), pp.612–628. Available from: https://doi.org/10.1080/03057925.2020.1838121.
[62] Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D. and Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, 372, p.n71. Available from: https://doi.org/10.1136/bmj.n71.
[63] Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y. and Podsakoff, N.P., 2003. Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, 88(5), pp.879–903. Available from: https://doi.org/10.1037/0021-9010.88.5.879.
[64] Ra, Y.A. and Shin, K., 2025. An Investigation into Academic Stress and Coping Strategies of South Korean Third Culture Kid (TCK) College Students. *Behavioral Sciences*, 15(3), p.316. Available from: https://doi.org/10.3390/bs15030316.
[65] Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L. and Koole, M., 2021. Balancing Technol-

ogy, Pedagogy and the New Normal: Post-pandemic Challenges for Higher Education. *Post-digital Science and Education*, 3(3), pp.715–742. Available from: https://doi.org/10.1007/s42438-021-00249-1.

[66] Reed, H.C., 2022. E-Learning Fatigue and the Cognitive, Educational, and Emotional Impacts on Communication Sciences and Disorders Students During COVID-19. *Perspectives of the ASHA Special Interest Groups*, 7(6), pp.1885–1902. Available from: https://doi.org/10.1044/2022_persp-22-00049.

[67] Richardson, M., Abraham, C. and Bond, R., 2012. Psychological correlates of university students' academic performance: A systematic review and meta-analysis. *Psychological Bulletin*, 138(2), pp.353–387. Available from: https://doi.org/10.1037/a0026838.

[68] Riedl, R., 2012. On the biology of technostress: literature review and research agenda. *SIGMIS Database*, 44(1), p.18–55. Available from: https://doi.org/10.1145/2436239.2436242.

[69] Riedl, R., 2022. On the stress potential of videoconferencing: Definition and root causes of Zoom fatigue. *Electronic Markets*, 32(1), pp.153–177. Available from: https://doi.org/10.1007/s12525-021-00501-3.

[70] Romero-Rodríguez, J.M., Hinojo-Lucena, F.J., Kopecký, K. and García-González, A., 2023. Fatiga digital en estudiantes universitarios como consecuencia de la enseñanza online durante la pandemia Covid-19. *Educación XX1*, 26(2), pp.165–184. Available from: https://doi.org/10.5944/educxx1.34530.

[71] Rosenfield, M., 2016. Computer vision syndrome (a.k.a. digital eye strain). *Optometry in Practice*, 17(1), pp.1–10. Available from: https://www.researchgate.net/publication/295902618.

[72] Rutkowska, A., Cieślik, B., Tomaszczyk, A. and Szczepańska-Gieracha, J., 2022. Mental Health Conditions Among E-Learning Students During the COVID-19 Pandemic. *Frontiers in Public Health*, 10, p.871934. Available from: https://doi.org/10.3389/fpubh.2022.871934.

[73] Ryan, R.M. and Deci, E.L., 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1), pp.68–78. Available from: https://doi.org/10.1037/0003-066x.55.1.68.

[74] Salim, J., Tandy, S., Arnindita, J.N., Wibisono, J.J., Haryanto, M.R. and Wibisono, M.G., 2022. Zoom fatigue and its risk factors in online learning during the COVID-19 pandemic. *Medical Journal of Indonesia*, 31(1), pp.13–19. Available from: https://doi.org/10.13181/mji.oa.225703.

[75] Salmela-Aro, K., Kiuru, N., Leskinen, E. and Nurmi, J.E., 2009. School Burnout Inventory (SBI): Reliability and Validity. *European Journal of Psychological Assessment*, 25(1), pp.48–57. Available from: https://doi.org/10.1027/1015-5759.25.1.48.

[76] Salmela-Aro, K. and Read, S., 2017. Study engagement and burnout profiles among Finnish higher education students. *Burnout Research*, 7, pp.21–28. Available from: https://doi.org/10.1016/j.burn.2017.11.001.

[77] Sawant, N.S., Vinchurkar, P., Kolwankar, S., Patil, T., Rathi, K. and Urkude, J., 2023. Online teaching, learning, and health outcomes: Impact on medical undergraduate students. *Industrial Psychiatry Journal*, 32(1), pp.59–64. Available from: https://doi.org/10.4103/ipj.ipj_52_22.

[78] Selwyn, N., 2016. *Is Technology Good for Education?* Cambridge, UK: Polity Press.

[79] Sheppard, A.L. and Wolffsohn, J.S., 2018. Digital eye strain: Prevalence, measurement and amelioration. *BMJ Open Ophthalmology*, 3(1), p.e000146. Available from: https://doi.org/10.1136/bmjophth-2018-000146.

[80] Shin, H., Puig, A., Lee, J., Lee, J.H. and Lee, S.M., 2011. Cultural validation of the Maslach Burnout Inventory for Korean students. *Asia Pacific Education Review*, 12(4), pp.633–639. Available from: https://doi.org/10.1007/s12564-011-9164-y.

[81] Son, C., Hegde, S., Smith, A., Wang, X. and Sasangohar, F., 2020. Effects of COVID-19 on College Students' Mental Health in the United States: Interview Survey Study. *Journal of Medical Internet Research*, 22(9), p.e21279. Available from: https://doi.org/10.2196/21279.

[82] Sweller, J., 1988. Cognitive Load During Problem Solving: Effects on Learning. *Cognitive Science*, 12(2), pp.257–285. Available from: https://doi.org/10.1207/s15516709cog1202_4.

[83] Sweller, J., van Merrienboer, J.J.G. and Paas, F.G.W.C., 1998. Cognitive Architecture and Instructional Design. *Educational Psychology Review*, 10(3), pp.251–296. Available from: https://doi.org/10.1023/A:1022193728205.

[84] Tuğtekin, U., 2023. Factors influencing online learning fatigue among blended learners in higher education. *Journal of Educational Technology and Online Learning*, 6(1), pp.16–32. Available from: https://doi.org/10.31681/jetol.1161386.

[85] UNESCO, 2023. COVID-19 Educational Disruption and Response. United Nations Educational, Scientific and Cultural Organization. Available from: https://www.unesco.org/en/articles/covid-19-educational-disruption-and-response.

[86] Upadhyaya, P. and Vrinda, 2021. Impact of technostress on academic productivity of university students. *Education and Information Technologies*, 26(2), pp.1647–1664. Available from: https://doi.org/10.1007/s10639-020-10319-9.

[87] van Deursen, A.J.A.M. and Helsper, E.J., 2015. The Third-Level Digital Divide: Who Benefits Most from Being Online? In: L. Robinson, S.R. Cotten, J. Schultz, T.M. Hale and A. Williams, eds. *Communication and Information Technologies Annual*. Emerald Group Publishing Limited, *Studies in Media and Communications*, vol. 10, pp.29–52. Available from: https://doi.org/10.1108/s2050-206020150000010002.

[88] Villarroel, V., Bloxham, S., Bruna, D., Bruna, C. and Herrera-Seda, C., 2018. Authentic assessment: Creating a blueprint for course design. *Assessment & Evaluation in Higher Education*, 43(5), pp.840–854. Available from: https://doi.org/10.1080/02602938.2017.1412396.

[89] Wang, X., Hegde, S., Son, C., Keller, B., Smith, A. and Sasangohar, F., 2020. Investigating Mental Health of US College Students During the COVID-19 Pandemic: Cross-Sectional Survey Study. *Journal of Medical Internet Research*, 22(9), p.e22817. Available from: https://doi.org/10.2196/22817.

[90] Watermeyer, R., Crick, T., Knight, C. and Goodall, J., 2021. COVID-19 and digital disruption in UK universities: afflictions and affordances of emergency online migration. *Higher Education*, 81(3), pp.623–641. Available from: https://doi.org/10.1007/s10734-020-00561-y.

## A. Supplementary material

### A.1. Full search strategy

A comprehensive multi-database search was conducted across Scopus, Web of Science, PubMed, ERIC, and Google Scholar, covering January 2020 – May 2025, as reported in the manuscript.

**Core boolean search string (as used across all databases)**

("digital learning fatigue" OR "online learning fatigue" OR "videoconference fatigue" OR "Zoom fatigue")
AND
("university students" OR "college students" OR "tertiary education")
AND
("psychological impact" OR "mental health" OR "academic stress")

**Databases and coverage**

- Scopus (Jan 2020–May 2025)
- Web of Science Core Collection (Jan 2020–May 2025)
- PubMed/MEDLINE (Jan 2020–May 2025)
- ERIC (Jan 2020–May 2025)

- Google Scholar (first 300 search results screened)

**Additional search methods**

- Manual screening of reference lists for all included studies.
- Grey literature screening (conference proceedings, institutional reports, dissertations).

**Search execution dates**

All searches were executed between April 20 and May 25, 2025.

### A.2. PRISMA 2020 selection flow

| Stage | Number |
|---|---|
| Records identified | 2,315 |
| Records after duplicates removed | 1,697 |
| Records screened (title/abstract) | 1,697 |
| Full-text articles assessed | 48 |
| Full-text excluded | 26 |
| Studies included in final synthesis | 22 |

### A.3. Data extraction framework

Variables extracted:

- Author(s), year
- Country
- Sample size
- Study design
- Measurement instrument for digital learning fatigue
- Psychological outcomes (anxiety, stress, depression, etc.)
- Academic outcomes
- Moderating factors (gender, discipline, resilience, screen time)
- Key findings
- Quality appraisal score (NOS)

Two reviewers independently extracted all data.

### A.4. Summary of excluded full-text studies

### A.5. Detailed description of data synthesis process

- Narrative synthesis used due to heterogeneous methods.
- Quantitative results aggregated descriptively.
- Qualitative themes analyzed using inductive thematic analysis.
- Integration conducted via mixed-methods convergence.

**Table 6**
Reasons for full-text exclusion ($n = 26$).

| Reason | Number excluded |
|---|---|
| Not tertiary population | 8 |
| No empirical data (commentary/editorial) | 6 |
| Insufficient methodological detail | 5 |
| Wrong outcomes (not digital learning fatigue) | 4 |
| Duplicate dataset / overlapping sample | 3 |

### A.6. PRISMA-ScR / PRISMA-2020 compliance

- Protocol registered in OSF.
- Full search strategy provided (section A.1).
- Flow diagram numerics provided (section A.2).
- Characteristics of studies (table 2).
- Critical appraisal (section 2.6).
- Synthesis of results (section 3).
- Funding: None.
- Conflicts: None.

### A.7. PRISMA-ScR Checklist

| Section | Item | PRISMA-ScR checklist requirement | Reported on page(s) |
|---|---|---|---|
| TITLE | 1 | Identify the report as a scoping or systematic review. | Title page (p. 99) |
| ABSTRACT | 2 | Structured summary: background, objectives, eligibility criteria, sources of evidence, methods, results, conclusions. | Abstract (p. 99) |
| INTRODUCTION | 3 | Rationale for the review and context of existing knowledge. | Introduction (p. 99–101) |
| | 4 | Explicit statement of review questions/objectives. | p. 101 (4 research questions) |
| METHODS | 5 | Protocol existence, registration details, location (e.g., OSF). | p. 101 – protocol registered in OSF. |
| | 6 | Eligibility criteria (with justification). | p. 102 (inclusion and exclusion criteria) |
| | 7 | Information sources: list all databases, coverage dates, and search execution date. | p. 101 (Scopus, WoS, PubMed, ERIC, Google Scholar; Jan 2020–May 2025) |
| | 8 | Full electronic search strategy for at least one database. | Supplementary material, section A.1 |
| | 9 | Study selection process: screening, eligibility, flow diagram. | p. 102 + PRISMA diagram (figure 1) |
| | 10 | Data charting process: extraction forms, independent review. | p. 103 (structured form; two independent reviewers) |
| | 11 | List and define data items extracted. | p. 103 (variables listed: author, year, country, outcomes, measures, etc.) |

| Section | Item | PRISMA-ScR checklist requirement | Reported on page(s) |
|---|---|---|---|
| | 12 | Critical appraisal rationale and method (if done). | p. 103 (NOS used; AMSTAR-2 for reviews) |
| | 13 | Methods for handling and summarizing charted data. | p. 103 (Narrative/thematic synthesis) |
| RESULTS | 14 | Numbers screened, excluded, and included (with reasons). | p. 103 + PRISMA data: 2,315 → 1,697 → 48 → 22. |
| | 15 | Characteristics of included sources. | p. 103–106 + table 2. |
| | 16 | Critical appraisal of included sources (if applicable). | p. 103 + table 1: 14 high-quality, 6 moderate, 2 low. |
| | 17 | Results of individual sources of evidence (per study findings). | p. 103–106 + table 2. |
| | 18 | Synthesis of results: aggregated patterns. | p. 106–110 (prevalence, psychological outcomes, moderating factors). |
| DISCUSSION | 19 | Summary of evidence: themes, types of evidence, link to review questions, relevance. | p. 110–113 (comprehensive discussion section). |
| | 20 | Limitations of the review processes. | p. 113–114 (Methodological limitations described). |
| | 21 | Conclusions: interpretation of results, implications, next steps. | p. 115 (conclusion section) |
| FUNDING | 22 | Sources and role of funders. | p. 115 – no funding received. |

### A.8. Additional PRISMA 2020 requirements

Information sources clearly identified as: Scopus, Web of Science, PubMed, ERIC, Google Scholar.
Synthesis methods

- Mixed narrative + thematic.
- Descriptive prevalence synthesis.
- Thematic analysis for qualitative patterns.

Reporting bias assessment addressed through NOS and AMSTAR-2 quality checks.
Availability of data stated in manuscript: “Contact corresponding author”.

### A.9. Full-text articles excluded with reasons ($n = 26$)

**Table 7**
Reasons for full-text exclusion

| Exclusion reason | Description | Number excluded |
|---|---|---|
| Wrong population | Studies focusing on primary/secondary school students instead of tertiary students. | 8 |
| Not empirical research | Editorials, commentaries, conceptual papers, or narrative opinion pieces with no empirical data. | 6 |
| Insufficient methodology | Studies lacking adequate design detail, measures, or sample information for quality appraisal. | 5 |
| Wrong outcome | Studies not assessing *digital learning fatigue* or its psychological/academic consequences. | 4 |
| Duplicate or overlapping datasets | Multiple reports using the same participants, institution, or dataset. | 3 |

During screening, full-text exclusions were conducted by two reviewers, and discrepancies resolved by discussion.

## A.10. Complete data extraction form

Table 8: Data extraction table (based on 22 included studies).

| Study | Year | Country | Sample | Design | DLF measure | Psychological outcomes | Academic/behavioural outcomes | Moderators | Key findings |
|---|---|---|---|---|---|---|---|---|---|
| Alarabiat [1] | 2024 | Jordan | 233 | Cross-sec. | Self-report quest. | Anxiety, cognitive load | Lower intention to continue | Home env. | Fatigue predicted continued-use intentions. |
| Romero-Rodríguez et al. [70] | 2023 | Spain | 613 | Cross-sec. | Digital fatigue scale | Stress, emotional exhaust. | – | Gender, discipline | Females and arts students had highest fatigue. |
| Tuğtekin [84] | 2023 | Turkey | 347 | Cross-sec. | Online fatigue metrics | Emotional strain | Performance decline | Gender | Info. and comm. overload predict fatigue. |
| Baltà-Salvador et al. [8] | 2021 | Spain | 1,000+ | Cross-sec. | Academic/emotional scale | Stress | Motivation decline | Discipline | High stress; negative learning attitudes. |
| Rutkowska et al. [72] | 2022 | Poland | 753 | Cross-sec. | Mental health quest. | Depressive (56.4%), irritability (>80%) | Motivation decline | Socio-economic | Severe emotional disturbance in e-learning. |
| Reed [66] | 2022 | USA | 50 | Survey | Self-report | Mental health | Poor learning outcomes | – | High fatigue predicts low learning. |
| Klimova and Pikhart [45] | 2025 | UAE | 1,000+ | Mini-review | Conceptual | Anxiety | Isolation | Technology | Excessive screen time increases fatigue. |
| Göldağ [32] | 2022 | Turkey | 925 | Cross-sec. | Burnout/fatigue scale | Stress | Burnout | – | Burnout correlates with perceived stress. |
| Deniz et al. [26] | 2022 | Turkey | 470 | Cross-sec. | ZEFS (Zoom fatigue) | Depression, anxiety, stress | Lower academic wellbeing | Distress (mediator) | Zoom fatigue linked to distress; distress mediates wellbeing. |
| Alyoubi et al. [2] | 2021 | Saudi Ar. | 582 | Cross-sec. | PHQ-9/GAD-7/PSS/ISI | Anxiety, depression, stress | Sleep disturbance, insomnia | – | Distress worsened; insomnia linked to distress. |

| Study | Year | Country | Sample | Design | DLF measure | Psychological outcomes | Academic/behavioural outcomes | Moderators | Key findings |
|---|---|---|---|---|---|---|---|---|---|
| Li and Yang [48] | 2025 | China | 618 | Cross-sec. | Learning-burnout scale | Loneliness, burnout | Reduced engagement | Loneliness | Loneliness drives burnout, lowering engagement. |
| An et al. [3] | 2025 | China | 2,109 | Cross-sec. | Digital fatigue scale | – | Lower academic resilience | Grit, flexibility | Fatigue lowers resilience; grit/flexibility mediate. |
| Fridkin et al. [29] | 2023 | UK | 177 | Longitud. | Stress/coping (3-wave) | Academic stress | Learning-strategy use decline | Year of study | Stress peaked mid-year; year-2 maladaptive coping higher. |
| Charoenporn et al. [18] | 2024 | Thailand | 386 | Cross-sec. | Thai ZEFS + PHQ-9 | Depression | – | Sessions/day, year | 9.6% high Zoom fatigue; linked to depression. |
| Llanes-Castillo et al. [50] | 2022 | Mexico | 184 | Cross-sec. | MBI-SS (burnout) | Emotional exhaustion | Burnout syndrome (17.9%) | Gender | Women higher burnout; exhaustion most affected. |
| Kim, Kim and Hwang [44] | 2024 | S. Korea | 365 | Cross-sec. | VDT symptom survey | – | Visual/musculoskel. fatigue | Ergonomics, screen hrs | Device use 4.8h to 8.1h/day; predicts VDT syndrome. |
| Ghanem, Elhussiney and Elbadawy [30] | 2022 | Egypt | 325 | Cross-sec. | Video-conf. fatigue scale | Stress, anxiety, depression | – | Meeting duration, ergonomics | 53.5% high VC fatigue; linked to distress. |
| Inan et al. [40] | 2025 | USA | 415 | Survey | Mental fatigue scale | Mental fatigue | Reduced engagement | Coursework demand | Higher demand/lower engagement raise mental fatigue. |
| Ra and Shin [64] | 2025 | S. Korea | 300 | Survey | Stress/coping scale | Academic stress | – | Coping (TCK) | Coping moderates stress in TCK students. |
| Sawant et al. [77] | 2023 | India | 346 | Cross-sec. | Self-report survey | Anxiety, depression (40%) | Poor motivation (73%) | – | 71% digital fatigue; poor motivation and distress. |

| Study | Year | Country | Sample | Design | DLF measure | Psychological outcomes | Academic/behavioural outcomes | Moderators | Key findings |
|---|---|---|---|---|---|---|---|---|---|
| de Oliveira Kubrusly Sobral et al. [24] | 2022 | Brazil | 541 | Cross-sec. | ZEF scale (Br-Pt) | Social/emotional fatigue | – | Curriculum model | 48% Zoom fatigue; higher in hybrid than PBL. |
| Salim et al. [74] | 2022 | Indonesia | 335 | Cross-sec. | ZEF + PSQI + DASS-21 | Stress, anxiety, depression | Poor sleep quality | Exercise, session length | Fatigue linked to sleep/distress; 57% variance explained. |

**Table 9**
Blank data extraction template.

| Study ID | Author/year | Country | Sample size | Design | DLF measurement tool | Psychological outcomes | Academic outcomes | behavioural outcomes | Moderators | Key findings | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

## A.11. Complete quality appraisal (Newcastle–Ottawa Scale)

**Table 10**
Study-level quality appraisal (NOS classification).

| Study | Quality category | NOS interpretation |
|---|---|---|
| Alarabiat [1] | High | Robust, low bias |
| Romero-Rodríguez et al. [70] | High | Robust |
| Tuğtekin [84] | High | Robust |
| Baltà-Salvador et al. [8] | High | Robust |
| Rutkowska et al. [72] | High | Robust |
| Reed [66] | Moderate | Acceptable but some bias risk |
| Klimova and Pikhart [45] | Low | Review-type (mini-review) design |
| Göldağ [32] | Moderate | Acceptable |
| Deniz et al. [26] | High | Robust |
| Alyoubi et al. [2] | High | Robust |
| Li and Yang [48] | High | Robust |
| An et al. [3] | High | Robust (large sample) |
| Fridkin et al. [29] | Moderate | Acceptable (longitudinal; small sample) |
| Charoenporn et al. [18] | High | Robust |
| Llanes-Castillo et al. [50] | Moderate | Acceptable |
| Kim, Kim and Hwang [44] | High | Robust |
| Ghanem, Elhussiney and Elbadawy [30] | High | Robust |
| Inan et al. [40] | High | Robust |
| Ra and Shin [64] | Low | Narrow (Third Culture Kid) subpopulation |
| Sawant et al. [77] | High | Robust |
| de Oliveira Kubrusly Sobral et al. [24] | Moderate | Acceptable |
| Salim et al. [74] | Moderate | Acceptable |

### A.12. Sensitivity analyses

**Sensitivity test A: Removing low-quality studies ($n = 2$)**

After excluding the 2 low-quality studies:

- *All main psychological outcomes remained unchanged:* anxiety, stress, depressive symptoms, irritability (68% → unchanged).
- *Cognitive outcomes still consistently reported:* attention loss, motivation decline, performance impairment (73% → unchanged).
- *behavioural consequences remained robust:* sleep problems, isolation, avoidance (59% → unchanged).
- *Moderators did not change:* gender, academic discipline, screen time, resilience.

*Interpretation:* Removing low-quality studies did not change the direction or substance of findings.

**Sensitivity test B: High-quality–only synthesis ($n = 14$)**

When isolating only the 14 high-quality studies, observed stability of major themes:

- Fatigue prevalence remains **moderate to high (45–75%)**.
- Gender and screen exposure remain the strongest moderators.
- Emotional and cognitive strain remain the dominant psychological patterns.
- Performance and engagement decline remain consistently reported.
- High-quality studies still identify resilience and coping as protective factors.

*Interpretation:* High-quality studies alone reproduce the **same global pattern**, confirming robustness.

### A.13. Regional and disciplinary subgroup patterns

**Table 11**
Prevalence pattern summary by region.

| Region | Reported fatigue intensity | Distinctive features |
|---|---|---|
| Europe ($n = 7$) | Moderate to high | High emotional fatigue; discipline differences more pronounced. |
| Asia ($n = 7$) | High | Screen-time overload and academic pressure dominate fatigue mechanisms. |
| Middle East ($n = 4$) | High | Infrastructure and family-environment strain contribute heavily. |
| North America ($n = 2$) | Moderate | Resilience and coping factors more frequently discussed. |
| Latin America ($n = 2$) | Moderate to high | Online-class burnout during confinement; emotional exhaustion prominent. |

**Table 12**
Discipline-based fatigue comparison.

| Discipline | Typical fatigue level | Explanation (from manuscript) |
|---|---|---|
| Arts/Humanities/Social sciences | High | Heavier synchronous workload; constant camera use; emotional labor. |
| STEM | Moderate to low | Higher digital literacy; more asynchronous autonomy; lower emotional labor. |