

The canary in the coal mine: What neurodivergent learners reveal about cognitive sustainability in education 5.0

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The Canary in the Coal Mine: What Neurodivergent Learners Reveal about Cognitive Sustainability in Education 5.0

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Introduction

The accelerating digital transformation of higher education and workplace learning promised a new era of flexibility and accessibility. Yet, paradoxically, this shift has reinforced persistent inequities in instructional design and intensified the enduring tension between technological efficiency and human inclusion (OECD, 2025b). While digital learning has broadened access, its underlying design logics often remain anchored in the automation ethos of Industry 4.0, privileging standardisation, throughput, and scalability over authentic engagement (Li, 2022; Sima et al., 2020). This creates a critical friction with the emerging human-centred vision of Education 5.0, which foregrounds wellbeing, creativity, and cognitive sustainability as central design principles (Poláková et al., 2023; Vieira et al., 2023). Against this backdrop, technology must cease to be a mechanism of compliance and instead become a partner in human development, advancing inclusion, adaptability, and social purpose (Shahidi Hamedani et al., 2024).

This tension is apparent in asynchronous e-learning, employed here as a bounded case study (Stake, 1995) to explore issues relevant to broader digital landscapes. Defined as a structured, self-paced mode of online study delivered without real-time interaction (Meyer et al., 2014; Zeng et al., 2022), asynchronous environments force learners to interact solely with an interface rather than a human instructor (Amiti, 2020; Moore & Diehl, 2018). While these formats theoretically offer autonomy, they often demand high levels of executive function and cognitive flexibility

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3 while offering limited scaffolding (Ontañón & Zhu, 2021). For neurodivergent adults, this lack
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5 of human mediation amplifies the impact of design friction (Le Cunff et al., 2025), creating an
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7 environment where the interface itself acts as a gatekeeper. Consequently, these environments
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9 provide an ideal setting for investigating the interplay among cognitive, affective, and
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11 motivational load (Lister et al., 2021).
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17 To interrogate these frictions, we turn to Cognitive Load Theory (CLT) (Sweller et al., 2011).

18 Historically utilised to optimise instructional efficiency, CLT is applied here as a lens for equity.

19 By conceptualising the 'friction' described by participants as unnecessary extraneous load, CLT
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21 provides the analytical precision required to quantify the invisible 'cognitive tax' levied on
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23 neurodivergent learners (Paas et al., 2003; Sweller et al., 2011). This creates a necessary
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25 theoretical bridge: whereas CLT identifies the mechanism of exclusion (cognitive overload),
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27 Education 5.0 provides the ethical imperative to resolve it. Thus, this study examines how rigid
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29 design choices do not merely reduce learning efficiency but actively compromise the cognitive
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31 sustainability of the learner, undermining the very inclusion that digital transformation sought to
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33 achieve.
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43 **Problem Aim and Research Questions**

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46 Despite growing attention to digital accessibility, research on inclusion in e-learning remains
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48 dominated by formal higher-education settings (Le Cunff et al., 2025; Seufert et al., 2023).

49 Existing studies typically emphasise compliance or content accessibility rather than the
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51 instructional-design mechanisms that shape cognitive load, motivation, and engagement
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53 (Surbakti et al., 2024). Consequently, the experiences of neurodivergent adults, whose
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3 attentional, sensory, and cognitive differences make them acutely sensitive to design inequities,
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5 act as the 'canaries in the coal mine' for the broader learning ecosystem. Yet, despite this
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7 diagnostic value, their perspectives remain underrepresented within both research and
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9 institutional practice (Le Cunff et al., 2024; Lomellini et al., 2025; Theelen et al., 2022).
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13 This study, therefore, aims to explore how neurodivergent adults experience and interpret
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15 asynchronous e-learning as a microcosm of the wider digital learning ecosystem. The research is
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17 guided by the following questions:
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21 **RQ1:** What instructional-design features act as barriers or enablers for neurodivergent adult
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23 learners in asynchronous environments?
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26 **RQ2:** How do neurodivergent learners describe the influence of these design features on
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28 motivational load, shaping inclusion and cognitive sustainability in asynchronous digital
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30 learning?
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33 **RQ3:** How do neurodivergent learners across higher education and lifelong-learning contexts
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35 adapt or develop strategies to manage design-related cognitive and emotional demands?
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39 **Literature Review**

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42 This literature review examines theoretical and empirical perspectives on inclusive digital
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44 learning, focusing on how human-centred design, neurodiversity, and cognitive load intersect
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46 within the emerging agenda of Education 5.0. To do this, it presents three key areas: 1)
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48 Humancentred digital learning and neurodiversity, 2) A-synchronous learning, autonomy and
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50 cognitive load, and 3) Inclusive frameworks and the theoretical gap.
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Human-Centred Digital Learning and Neurodiversity

Education 5.0 positions technology as a partner in human cognitive and creative development, foregrounding wellbeing and social value (Ahmed & Abdullah, 2025; Vieira et al., 2023). Yet digital-learning ecosystems, especially in higher education, continue to reflect industrial logics from earlier waves of digitalisation, privileging automation, linearity, and standardisation (Sima et al., 2020). Compliance-driven design features such as locked sequencing and time-on-task metrics prioritise control over cognition, producing interfaces that limit autonomy and depth (OECD, 2025a; Price, 2022)

The *Universal Design for Learning* (UDL) principles aim to embed inclusion by designing for learner variability through multiple means of engagement, representation, and expression, with later CAST guidance emphasising flexibility and systemic inclusion (CAST, 2018, 2024). Yet, Zakariyah et al. (2024) argue that its practical adoption is often superficial, implemented as a checklist rather than a design philosophy. Without explicit attention to cognitive architecture, flexibility and personalisation alone do not ensure inclusion; they risk reproducing inequity by overlooking how different learners process information (Le Cunff et al., 2024; Ontañón & Zhu, 2021). Human-centred design, therefore, requires both ethical intention and cognitive precision.

The concept of *Neurodiversity* reframes attentional and perceptual differences as natural variations rather than deficits (Van Daalen et al., 2025). Milton's (2012) double empathy concept further argues that misunderstanding emerges from reciprocal differences in perception and communication, not from deficits within the neurodivergent learner. Areheart (2008) cautions that deficit-oriented assumptions remain deeply embedded in policy and institutional practice, meaning neurodivergent learners often encounter environments that pathologise difference rather

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3 than adapting to it. Instead of signalling a deficit, this sensitivity acts as an early warning system,
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5 a 'canary in the coal mine', detecting design friction that affects all learners. Empirical
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7 engagement with neurodivergent adults in digital learning remains limited (Durgungoz &
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9 Durgungoz, 2025; Le Cunff et al., 2024), but emerging evidence highlights the importance of
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11 agency, affective load, and cognitive regulation. While neurodivergent learners often benefit
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13 from flexible pacing, multimodality, and anonymity, poorly structured autonomy or fragmented
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15 interaction can amplify extraneous and affective load, undermining self-regulation (Seufert et al.,
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17 2023; Le Cunff et al., 2025). Fiorella and Mayer's (2022) research on multimedia cognition
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19 reinforces that multimodality aids inclusion only when cognitive coherence is maintained and
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21 design minimises unnecessary friction.
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27 Together, UDL and Cognitive Load Theory (CLT) offer complementary but individually
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29 incomplete perspectives: UDL provides a framework for flexibility, while CLT offers tools to
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31 analyse processing demands. Positioned together, they support the use of neurodiversity as a
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33 diagnostic lens for equitable digital-learning design.
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37 Asynchronous Learning, Autonomy, and Cognitive Load

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41 Asynchronous digital learning environments are often praised for accessibility, autonomy, and
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43 scalability (Clark & Mayer, 2016). Yet the assumption that greater autonomy automatically
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45 enhances engagement is not consistently supported (El-Sabagh, 2021; Durgungoz & Durgungoz,
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47 2025). While flexibility allows learners to manage competing demands, it also transfers
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49 substantial cognitive responsibility to the individual, often increasing extraneous load: the mental
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51 effort devoted to managing learning processes rather than mastering content (Sweller et al.,
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3 2019). Inclusion and learner experience, therefore, depend on how autonomy is scaffolded, not
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5 merely on its presence (Kirschner et al., 2018; Ontañón & Zhu, 2021).
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9 Empirical research reinforces this tension. When digital environments lack structure, feedback,
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11 or progression cues, learners report confusion, disorientation and reduced motivation to continue
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13 (Seufert et al., 2023; Theelen et al., 2022). For neurodivergent learners, this paradox is
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15 heightened; whilst flexibility promotes choice, it creates cognitive strain when regulation
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17 demands exceed working memory (Durgungoz & Durgungoz, 2025; Paas et al., 2003). Mayer's
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19 (2021) studies on multimedia platforms confirm that comprehension improves only when
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21 cognitive coherence is maintained; redundant or excessive stimuli fragment attention and elevate
22
23 extraneous load.
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28 Crucially, autonomy must be understood as a complex interplay of motivation and cognition.
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30 Pintrich's (2003) Self-Regulated Learning (SRL) framework emphasises that motivation,
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32 confidence (self-efficacy) and metacognitive regulation are interdependent processes. To sustain
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34 the effort required for regulation, learners require a clear structure and timely feedback. Without
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36 these scaffolds, the absence of guidance does not lead to independence but to cognitive setback
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38 (Surbakti et al., 2024). This necessitates a shift toward structured autonomy, which gradually
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40 reduces guidance as competence grows, supporting agency without overload (Kirschner et al.,
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42 2018). This, in turn, aligns with inclusive design principles that see independence as an outcome,
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44 not a prerequisite (CAST, 2018, 2024).
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50 Accordingly, inclusion in asynchronous learning depends on quality learner autonomy. Effective
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52 design uses adaptive scaffolding, multimodal clarity, and pacing control to manage cognitive
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load, promoting cognitive economy and equitable participation (Le Cunff et al., 2025; Theelen et al., 2022).

Inclusive Frameworks and Theoretical Gap

At a systemic level, Education 5.0 positions digital learning as a human-centred enterprise, emphasising cognition, creativity and wellbeing, rather than automation and scale (Ahmad et al., 2023; Vieira et al., 2023). Yet contemporary digital learning frequently reproduces the standardisation and efficiency logics of Industry 4.0, resulting in design practices that prioritise procedure and compliance over cognitive diversity (Sima et al., 2020; OECD, 2025). This tension highlights the need for frameworks that consider how learners genuinely process, regulate, and maintain effort in digital environments.

Universal Design for Learning (UDL) provides a foundation for inclusive intent through multiple means of engagement, representation, and expression (CAST, 2018, 2024). However, its implementation is often procedural rather than cognitive, emphasising flexibility without analysing how design decisions affect processing demands (Zakariyah et al., 2024). Flexibility alone does not guarantee inclusion; without cognitive calibration, it can reproduce inequity for learners with diverse attentional and regulatory profiles (Le Cunff et al., 2025).

Cognitive Load Theory (CLT) provides complementary insights by explaining how design impacts working-memory efficiency (Sweller et al., 2019). Yet, traditional applications of CLT underplay the affective and motivational dimensions critical in asynchronous learning, where learners must regulate attention and uncertainty without human scaffolding (Vasilaki &

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3 Mavrogianni, 2025). Surbakti et al's (2024) applied CLT research concludes that load is
4 relational and context-sensitive, shaped by both interface design and learner agency.
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9 Synthesising these frameworks provides a more complete foundation for human-centred digital
10 design. UDL foregrounds inclusion, CLT explains processing demands, and Education 5.0
11 provides the ethical imperative to align technology with human variability. Guided by these
12 frameworks, 'inclusive cognitive design' is defined as the intersection of cognitive efficiency,
13 learner autonomy, and equity. This integration positions neurodiversity as a diagnostic tool, a
14 'canary', for identifying design features that support or compromise cognitive sustainability in
15 asynchronous digital learning.
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26 Although research on digital learning and neurodiversity is expanding, several gaps remain.
27 Existing studies focus predominantly on higher education, leaving the experiences of
28 neurodivergent adults in professional and lifelong learning settings underexamined (Le Cunff et
29 al., 2024; Durgungoz & Durgungoz, 2025). In addition, much of the literature emphasises
30 accessibility compliance rather than the instructional-design mechanisms that shape cognitive,
31 emotional and motivational load in asynchronous environments (Ontañón & Zhu, 2021; Seufert
32 et al., 2023). Furthermore, while cognitive load has been widely explored, the interaction
33 between cognitive load, affective load, and learner agency remains insufficiently theorised. This
34 is concerning considering the evidence that emotional regulation significantly influences
35 processing and persistence in digital learning (Fiorella & Mayer, 2022; Skulmowski & Xu,
36 2022). Finally, although neurodivergent learners consistently show heightened sensitivity to
37 design friction (Le Cunff et al., 2025), this sensitivity has rarely been used as an analytic lens to
38 interrogate structural weaknesses in e-learning design. As a result, understanding remains limited
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3 regarding how digital environments support or undermine cognitive sustainability across diverse
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11 12 13 **Methodology** 14 15

16 This study was conducted within an interpretivist paradigm, acknowledging that learners'
17 experiences are socially constructed, contextually situated, and mediated by technological
18 environments (Creswell & Poth, 2018; Lincoln & Guba, 1985). This paradigm is best served by a
19 bounded case study design (Stake, 1995), allowing for deep exploration of a specific
20 phenomenon. Accordingly, asynchronous e-learning was adopted as the case study to gain
21 insight into the wider aspects of how neurodivergent learners experience the wider digital
22 learning ecosystem. The case was bounded by three dimensions: **(1)** the participant group, **(2)** the
23 learning context, and **(3)** the cognitive diversity within it. This design enabled deep exploration
24 of how digital environments mediate attention, motivation, and cognitive effort across varied
25 neurocognitive profiles. Although situated in higher education and workplace e-learning
26 contexts, the findings offer insights transferable to all lifelong learning contexts.
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42 **Eleven neurodivergent adult professionals (8 women, 3 men) participated in the study, all self-**
43 **identifying as neurodivergent and having completed at least one asynchronous digital learning**
44 **experience in the past year. E-learning exposure ranged from minimal compliance modules to**
45 **extensive interactive systems. The sample reflected a variety of neurodivergent profiles,**
46 **including autism, ADHD, and dyslexia, with the focus placed on experiential variation rather**
47 **than diagnostic categorisation. Participants, aged 38–59, were purposively recruited through**
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professional networks and supplemented via snowball sampling. This approach was appropriate for accessing a specialist and partially hidden population for whom trust and selfidentification are central (Noy, 2008).

The resulting heterogeneity provided strong information power (Malterud et al., 2015), as participants offered rich, detailed accounts directly aligned with the study aim. In interpretivist, depth-oriented qualitative research, particularly reflexive thematic analysis, sample adequacy is determined by the relevance, specificity, and richness of the data rather than statistical representativeness (Braun & Clarke, 2021; Creswell & Poth, 2018). The variation across industries, ages, and neurodivergent profiles enhanced the analytical value of the dataset by capturing diverse cognitive and digital experiences, consistent with purposive sampling principles aimed at obtaining information-rich cases (Patton, 2015). Table 1 outlines Participant ID and demographics.

Table 1: Participant demographics and professional characteristics

Participant ID	Neurodivergence (Self-Reported)	Gender	Age (years)	Industry / Sector	Data Collection Method
P1	ADHD	Female	45-54	Aviation/Air Transport	Online Semistructured Interview
P2	Dyslexia	Male	45-54	Information Technology and Legal Services	Online Semistructured Interview
P3	Dyslexia	Female	45-54	Health and Social Care	Online Semistructured Interview
P4	Dyslexia	Female	45-54	Pharmaceutical/Manufacturing	Online Semistructured Interview

P5	ADHD	Female	45-54	Health and Social Care	Online Semistructured Interview
P6	ADHD	Female	55+	Professional Services/Consultancy	Online Semistructured Interview
P7	ASD	Male	45-54	Healthcare (Allied Health – Chiropractic)	Semi-Structured Interview via asynchronous form
P8	ADHD	Female	33-44	Healthcare (Allied Health – Chiropractic)	Online Semistructured Interview
P9	ADHD	Female	33-44	Education and Events Management	Online Semistructured Interview
P10	ADHD, ASD, Dyslexia	Female	45-54	Information Technology/Public sector	Online Semi-Structured Interview
P11	Dyslexia	Male	55+	Pharmaceutical/Manufacturing	Online Semi-Structured Interview

Participants were offered a choice of interview methods to accommodate individual preferences, acknowledging that some neurodivergent adults may prefer asynchronous participation to reduce social and sensory load (Durgungoz & Durgungoz, 2025). This decision aligns with the 'Agency as Access' findings discussed later. Nine participants chose to complete semi-structured interviews via Microsoft Teams, while two chose an equivalent asynchronous questionnaire using a secure online form. Both formats employed the same interview guide ensuring conceptual consistency and methodological flexibility aligned with inclusive qualitative research

(Doyle, 2019). Online Interviews lasted 30–40 minutes and were recorded and transcribed verbatim with participants' consent.

Participants drew on a broad but typical range of asynchronous e-learning contexts encountered in both higher education and workplace environments. These primarily included corporate Learning Management System (LMS) modules, higher-education compliance or mandatory training units, and Massive Open online Courses (MOOC), most of which were SCORM-based and delivered through standard LMS platforms. These modules commonly used click-through slide decks, embedded video segments, timed progression, locked navigation, and auto-generated quizzes which are all characteristic features of contemporary asynchronous compliance training and online professional development. This shared architecture allowed meaningful comparison across participant experiences, despite the diversity of sectors and learning purposes. Informed by CLT and UDL, questions were thematically structured around five domains: (1) accessibility and design; (2) cognitive and sensory experience; (3) strategies and self-regulation; (4) motivation and feedback; and (5) future vision and inclusion. The interviews followed an interpretivist, conversational approach that prioritised participant agency and situated meaning-making (Lincoln & Guba, 1985).

Data were analysed with reflexive thematic analysis using Braun and Clarke's six-phase framework (2006, 2021). The process began with familiarisation via repeated reading and reflexive memos. Initial line-by-line coding identified descriptive and interpretive elements related to cognitive, emotional, and motivational learning aspects. Codes were grouped into candidate themes reflecting cognitive load, autonomy, and affective regulation. Theme review re-examined extracts for coherence and representativeness. Themes were collaboratively defined

and named by both researchers to ensure rigour, minimise bias, and produce the analytic narrative. To demonstrate how meaning was developed within our reflexive thematic analysis, the table below provides an illustrative example:

Table 2: Illustrative Analytic Pathway (Excerpt → Code → Theme) (Author's own, 2025)

Stage of coding process	Example
Excerpt P1	“Many systems assume a linear learning style ... I often feel trapped within a predetermined route that restricts my natural learning process.”
Initial code	Forced linearity as cognitive entrapment; frustration due to loss of pacing control
Interpretive Notes	Meaning interpreted as an affective response to restricted learner agency
Mainn Theme	Agency as access

Credibility was achieved through reflexive transparency and analytic depth, rather than participant validation, reflecting the interpretivist position that meaning is co-constructed and not simply verified by respondents (Lincoln & Guba, 1985). Both researchers maintained reflexive journals, recording interpretive decisions, positional reflections, and evolving assumptions to enhance transparency and mitigate bias (Berger, 2013; Doyle, 2019). Ethical approval was secured from both participating universities' research ethics committees, adhering to CABS ethical principles for research with professionals. All participants provided informed consent, were assigned pseudonyms, and had identifying details removed for confidentiality.

Results/Findings

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3 Our reflexive thematic analysis revealed three intersecting themes that define the neurodivergent
4 experience in digital learning, exposing systemic weaknesses that dominate and characterise
5 industrialised design. These themes are: (1) Accessibility Re-defined: Agency as Access, (2) The
6 McDonald's Metaphor: Superficial Design as Extraneous Load, and (3) The Neurodivergent
7 Learner as the Canary in the Coal Mine.
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17 Cross-case analysis revealed consistent experiential patterns across the diverse demographic
18 variables of age, gender, and industry. Crucially, while specific regulatory preferences varied
19 slightly by neurotype (e.g., autistic participants emphasising pattern disruption versus ADHD
20 participants emphasising pacing velocity), the underlying experience of 'friction' and 'affective
21 load' was ubiquitous across the sample. The thematic convergence across distinct diagnostic
22 profiles (ADHD, Dyslexia, ASD) suggests that the identified barriers are not condition-specific
23 idiosyncrasies, but structural flaws in the design architecture that affect the neurodivergent
24 spectrum broadly.
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38 Theme 1: Accessibility Re-defined: Agency as Access

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41 The first, and perhaps most foundational, theme revealed a profound disconnect between
42 institutional definitions of accessibility and the lived, cognitive, and emotional realities of
43 neurodivergent learners. For our participants, accessibility in professional settings risked
44 becoming a passive, compliance-based feature (such as alt-text or colour contrast) (Lewthwaite,
45 2014). At the same time, they desired an active, deeply felt experience of agency.
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3 This theme, which we termed 'Agency as Access,' captures how participants consistently
4 reframed control over their information flow, such as the ability to skip, scan, adjust pacing, or
5 revisit content, as a non-negotiable prerequisite for inclusion (Meyer et al., 2014). When design
6 features, most notably locked navigation and forced linear sequencing, stripped them of this
7 control, it felt like a form of cognitive entrapment. This entrapment was the primary source of
8 what we identify as Affective Load: the debilitating emotional and regulatory effort required to
9 manage design-induced friction (Kalyuga & Plass, 2025).
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21 P7 (ASD), for example, described the visceral experience of being "trapped" by a non-skippable
22 module that felt infuriating and demeaning. The design forced linearity conflicts directly with his
23 cognitive architecture, stating how:
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28 "Many systems assume a linear learning style, but my autistic cognition prefers to
29 crossreference and synthesise information in a non-sequential way. Without a search bar
30 or modular navigation, I often feel trapped within a predetermined route that restricts my
31 natural learning process."
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40 For P7, the "trap" is cognitive, where the design "restricts" the very mechanism he uses for
41 learning, a phenomenon closely linked to the interruption of monotopic flow (Murray et al.,
42 2005).
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49 This cognitive mismatch, in turn, manufactures an unmanageable affective load. P2 (Dyslexia),
50 who also relies on a non-linear strategy of scanning text, explained how the system's rigid,
51 timebased structure reframed his natural learning style as a form of personal failure:
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5 “So, when people who create these things, or let's say in work, they send them out and
6 they say, oh, it'll just take you 20 minutes. I never fit into that category. So I feel like I
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8 have to cheat.”
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14 Here, the design's friction is an indictment. The 'affective load' for P2 is the emotional effort of
15 feeling "othered" and being forced to "cheat" simply to navigate a system that was not built for
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17 him. The lack of agency not only frustrates but also erodes his self-efficacy and confidence
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19 (Bandura, 1986; Ryan & Deci, 2000).
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26 P2's use of the word "cheat" is particularly revealing of the power dynamics at play. We interpret
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28 this framing as evidence that the system internalises the 'Medical Model' of disability, and
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30 continues to locate the failure within the individual (Oliver, 2017).
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35 By labelling their necessary coping mechanism (scanning/skipping) as "cheating," P2 has
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37 internalised the system's logic: that the linear, slow, compliant path is the "moral" path to
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39 learning. However, through the lens of the Canary in the Coal Mine, we must re-code this
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41 behaviour. P2 is not cheating; they are engaging in what we observed as Pedagogical Repair.
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43 They are actively attempting to fix a broken interface to make it compatible with their cognitive
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45 needs. That the system classifies this act of self-regulation as a transgression exposes the rigidity
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47 of the environment. The Canary is signalling that the air is toxic (the design is rigid), but the
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49 system blames the canary for not breathing in the correct manner (Goodley, 2014).
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3 This erosion of confidence is rooted in the design's denial of essential cognitive strategies. The
4 one-size-fits-all linear path actively blocks the very methods neurodivergent learners depend on.
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7 P1 (ADHD) detailed her entire strategic toolkit. Locked design rendered this toolkit useless:
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12 "...habitually would leave to the last minute... scan read... fast forward or speed up the
13 videos... click through videos or slides... frustrating when there isn't the opportunity."
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19 P1's quote is a diagnostic list of agency-based needs. Her sense of frustration at the lack of
20 opportunity to use these strategies is a form of cognitive entrapment. This is the direct cause of
21 the affective load P2 described. When these necessary strategies are blocked, the learner is left
22 trapped, angry, and, as P11 (dyslexic traits) stated in his interview, "not learning... just clicking a
23 button to get to the end". However, P1's testimony disrupts this. We interpret the need to "speed
24 up" is not merely a preference for haste; but as a regulation strategy to match the external flow of
25 information with their internal cognitive processing speed. When an ADHD brain, which often
26 thrives on high-velocity information intake, is forced to decelerate to the speed of a spoken
27 narration, the "surplus" cognitive capacity does not sit idle. Instead, it rapidly fills with
28 distraction and frustration. In this context, the "locked" navigation bar is not a quality assurance
29 feature; it is a mechanism of cognitive dysregulation.
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47 For these participants, true access is not the ability to view the content; it is the freedom to
48 navigate and process it on their own terms (Seale, 2006). Ultimately, the Agency-as-Access
49 theme exposes a critical tension in the transition to Education 5.0. While the rhetoric of modern
50 education promises human-centric, personalised, and flexible learning (Vieira et al., 2023), the
51 architectural reality of these platforms often remains firmly rooted in an Industrial (Education
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3 2.0/3.0) paradigm. The prevalence of locked navigation and linear forcing functions prioritises
4 institutional compliance (proving the user was present for x minutes) over learner agency
5 (ensuring the user understood the concept). We acknowledge that such forcing functions are
6 frequently mandated by external regulatory bodies for compliance training to verify time-on-task
7 for Continuing Professional Development (CPD) accreditation. However, this exposes a
8 fundamental systemic tension: the compliance metric of 'time-on-task' is actively hostile to the
9 cognitive metric of 'learning transfer.' While the rigid enforcement of linearity may satisfy the
10 regulator's need for auditability, it directly sabotages the learner's need for cognitive regulation.
11 The system effectively succeeds in capturing the user's time while failing to support their mind.
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26 For our neurodivergent participants, this industrial logic is not just annoying; in its current form,
27 it is disabling. By stripping away the ability to control time (pacing) and space (sequencing),
28 these systems infantilise the learner, reducing them to passive recipients of data rather than
29 active constructors of knowledge (Price, 2022). As P7 and P11's experiences attest, when the
30 learner is treated as a component to be processed rather than a human to be engaged, the result is
31 performative compliance, in clicking buttons to survive the experience, rather than authentic
32 learning.
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45 **Theme 2: The McDonald's Metaphor: Superficial Design as Extraneous Load**

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48 Our second theme captures the participants' profound rejection of superficial engagement tactics.
49 We termed this the 'McDonald's Metaphor' after participants described gamified, visually
50 overstimulating designs as "bright colours but devoid of nutrition", P7 (ASD).
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3 Crucially, our findings show that the seduction of the 'tool', as in prioritising the novelty of an
4 app or AI interface over pedagogical substance, is not a harmless aesthetic choice. Instead, it acts
5 as a primary source of extraneous cognitive load. Instead of supporting learning (germane load),
6 these elements actively compete for finite cognitive resources, forcing the learner to process
7 superficial distractions at the expense of the core content (Chen et al., 2018).
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17 The critique offered by P7 extends beyond aesthetic preference, it exposes a fundamental flaw in
18 how 'engagement' is operationalised in the digital age. Educational psychology has long warned
19 of the 'Seductive Details Effect' (Harp & Mayer, 1998) in which interesting but irrelevant
20 material interferes with learning. Our data suggests that for neurodivergent learners, modern
21 elearning interfaces have industrialised this effect. The "bright colours" and gamified elements
22 are not merely benign decorations; they represent a high-volume Extraneous Load that actively
23 competes with Germane Load (the cognitive effort required for schematic construction) (Fiorella
24 & Mayer, 2022). For P7, the interface acts as a "cognitive noise generator." The mental energy
25 required to filter out the "bright colours" to reach the actual content leaves fewer resources for
26 processing the information itself. The design, intended to "hook" the learner, instead creates a
27 barrier of sensory friction.
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45 The data suggests a sharp distinction between functional game mechanics (like progress bars,
46 which P3 noted provided a sense of "moving on and achieving") and performative gamification
47 (narratives, avatars, or forced interactivity). For the neurodivergent "Operator" (P11), these
48 performative elements are obstacles. P9 (ADHD) describes a visceral reaction to this type of
49 prolonged, under-stimulating engagement. Referring to a module that took four hours, P9 recalls
50 being "bored out of my brain", noting that the boredom was so acute it triggered a need to
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3 “distract myself with something else, which just made the process worse”. We interpret this
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5 reaction as an illustration of the failure of extrinsic motivation when intrinsic value is absent
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8 (Deci & Ryan, 1985; Ryan & Deci, 2000).
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12 Similarly, P2 (Dyslexia) admits to a behaviour that designers might label as "cheating," but
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14 which the user sees as a survival strategy against irrelevant friction. Faced with arbitrary time
15
16 constraints or engaging elements that don't serve a purpose, the impulse to “cheat” (P2)
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18 reappears as a rejection of gamified barriers. Our participants are not playing the game the
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20 designer intended; instead, they are engaging in gaming the system to defeat the interface and
21
22 preserve their energy and sanity (Baker et al., 2008).
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29 The McDonald's aesthetic does more than annoy our participants; it degrades trust. When an
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31 expert learner encounters a juvenile interface, the psychological contract is broken (Pearce &
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33 Rousseau, 1998). The interface signals that the institution views the learner as a child to be
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35 entertained rather than a professional to be informed. P11 (Dyslexic traits) explicitly identifies
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37 this tension, arguing that a one-size-fits-all approach, often disguised by broad, accessible, 'fun'
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39 visuals, “comes across as very patronising" to the intellectual learner who wants deeper detail.
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45 This echoes P7's (ASD) unifying theory of the Happy Meal. P7's brain, which "thrives on
46
47 precision, pattern, and purpose," is insulted by the lack of nutrition. The friction here is
48
49 profound: the user is seeking conceptual mastery, but the system offers sensory novelty. P1
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51 (ADHD) reinforces this rejection of "fluff" with brutal efficiency, stating a desire to simply
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53 "click through videos or slides" when the content is too slow. Crucially, this visual noise levies a
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55 heavy tax on what P6 (ADHD) describes as "mental bandwidth." P6 noted that when balancing
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3 the "chaos" of professional life, the cognitive resources required to process irrelevant design
4 elements are simply unavailable. The equivalent bright colours do not signal anything worth
5 engaging with for these users; **we suggest that they represent a depletion of finite energy**
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7 (Hamada, 2008). When design prioritises style over clarity, it effectively taxes the
8 neurodivergent user for the privilege of learning, filling their limited bandwidth with junk data
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10 (as junk food) before the actual learning has even begun.
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19 Ultimately, P7's description of e-learning as "McDonald's" reveals a critical disconnect between
20 the rhetorical promise of Education 5.0, which claims to be human-centric and value-driven, and
21 the reality of its industrial implementation. The neurodivergent learner serves as the canary in the
22 coal mine here, detecting this nutritional deficit first. While a neurotypical learner might
23 passively tolerate the 'empty calories' of a superficial module, the neurodivergent learner
24 physically and cognitively rejects the shallowness. Far from being a symptom of a disorder, this
25 friction signals a critical misalignment: a deep-thinking mind colliding with an architecture of
26 superficiality.
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41 **Theme 3: The Neurodivergent Learner as the Canary in the Coal Mine**

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43 Our final theme synthesises the individual frustrations of agency (Theme 1) and the rejection of
44 superficiality (Theme 2) into a broader systemic critique. Throughout the data, participants
45 described their interactions with e-learning not merely as difficult, but as exhausting. This is a
46 constant process of translating a hostile format into a usable one.
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3 We assert that the neurodivergent learner serves as the canary in the coal mine for digital
4 education. In mining, the canary's hypersensitivity to toxic gases signalled danger long before
5 miners perceived it. Similarly, our participants' heightened sensitivity to friction, ambiguity, and
6 superficiality exposes structural flaws in e-learning design that neurotypical learners may tolerate
7 or ignore, but which fundamentally degrade the learning experience for all (Le Cunff et al., 2025;
8 Theelen et al., 2022).

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19 The medical model of disability often frames neurodivergent sensitivity such as monotropism or
20 sensory processing differences, as a deficit to be accommodated (Murray et al., 2005). However,
21 our data reframes this sensitivity as a diagnostic asset. The canary does not struggle because it is
22 weak; it struggles because it is the first to detect that the environment is uninhabitable.

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31 P7 (ASD) describes how his cognitive architecture acts as an involuntary quality assurance
32 mechanism:

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38 "Having a pattern recognition brain is frustrating. When I find faults in learning
39 programmes, my brain will stall until I can satisfy its sense of justice. Adding an 'I found
40 a problem!' text box to feedback would be a dream come true."

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46 Here, the content is not too complex, but P7 will "stall" because the design is flawed. When P7
47 encounters a Happy Meal interface (as detailed in Theme 2). **We interpret this stalling not as a**
48 **failure to learn, but as a rational rejection of low-quality pedagogy and as a signal that the air in**
49 **the mine is toxic.** This diagnostic burden, however, comes at a high metabolic cost. While the
50 neurodivergent learner detects the faults, the effort required to navigate them is significant. P10
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(ADHD/ASD) articulates the invisible labour required to function in these environments (Milton, 2012):

"I spend a lot of time trying to make sense of things that do not make sense to me. That constant effort takes energy... It is not just about making things easier in general it is about making them possible for everyone."

P10's testimony reveals that the 'toxic gas' in the coal mine consists of implicit ambiguity. For a neurotypical learner, a vague interface or poorly worded instruction might cause a momentary pause. For P10, it triggers a "constant effort" of cognitive translation. This drains the "mental bandwidth" (P6, ADHD) that should be reserved for learning. The canary faints not because of a lack of capability, but because the metabolic cost of "making sense" of a broken system leads to cognitive burnout (Raymaker et al., 2020).

A striking sub-theme emerged regarding the contrast between digital rigidity and human flexibility. P5 (ADHD traits) provided a powerful counter-narrative by describing a supportive human manager:

"She makes allowances for me... just to let it flow my way, not do the form and things like that".

We argue that this interaction exposes the regression inherent in many Education 5.0 implementations. While the technology promises personalisation (Vasilaki & Mavrogianni, 2025), it often delivers rigid standardisation. P5's human manager provided adaptive, nonlinear

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3 support; the e-learning systems described by P1, P2, and P3 did not. In the human ecosystem, the
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5 environment adjusts to the canary; in the digital ecosystem, the environment is immutable, and
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7 the learner is left to suffocate or "cheat" (P2) to survive. This suggests that current e-learning
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9 design is effectively de-humanising the pedagogical process, removing the very flexibility that
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11 neurodivergent learners rely on to thrive (Selwyn, 2021).
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17 The canary metaphor ultimately points toward a conclusion of Universal Design rather than
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19 individual accommodation. P8 (ADHD) noted that educators and designers "don't know it's a
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21 problem" if they lack awareness of how it affects learning ability, stating that "there needs to be
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23 an awareness of the problem for there to be a solution." P10 explicitly connects this awareness to
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25 the collective good of the entire mine:
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31 "What is clear is that the adjustments that support neurodivergent learners often benefit
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33 neurotypical learners too. Clarity, flexibility and emotional safety help everyone".
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38 This serves as the foundational argument for our paper. The friction experienced by P1 (locked
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40 videos), the "revulsion" felt by P7 (superficial gamification), and the fatigue described by P6
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42 (bandwidth depletion) are not niche issues. They are amplified signals of poor instructional
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44 design that affect the entire learner population.
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49 By designing an environment safe for the canary, one rich in agency, deep in substance, and
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51 flexible in structure, we do not merely accommodate disability; we remediate the toxic elements
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53 of the industrial education model. As Burgstahler and Russo-Gleicher (2015) argue, this shift
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3 toward Universal Design creates a cleaner, clearer cognitive atmosphere for every learner. By
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5 removing the pollutants of ambiguity and rigidity, we move beyond simple accessibility
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7 compliance to create a cognitively coherent environment where the focus shifts from navigating
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9 the system to mastering the content. Ultimately, the canary will signal danger, and it illuminates
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11 the only viable path toward a more sustainable, human-centric pedagogy.
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16 Discussion

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19 This study explored neurodivergent adults' asynchronous e-learning experiences in higher and
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21 lifelong education. The findings suggest that neurodivergent learners expose systemic
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23 weaknesses in industrialised instructional design, functioning as early diagnostic indicators
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25 rather than simply recipients of accessibility accommodations. These insights resonate with
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27 earlier research highlighting how unclear structure, forced linearity, and overstimulating
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29 interfaces elevate cognitive and emotional load in digital learning (Durgungoz & Durgungoz,
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31 2025; Seufert et al., 2023).
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37 Consistent with Le Cunff et al. (2024, 2025), participants described heightened sensitivity to
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39 design friction, while the rejection of superficial or 'seductive' interface elements reflects long-
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41 standing concerns within multimedia learning literature (Fiorella & Mayer, 2022; Harp &
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43 Mayer, 1998). Collectively, these findings echo Milton's (2012) argument that design
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45 mismatches, rather than learner deficits, constitute the primary barriers to meaningful
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47 engagement. Building on this broader context, the discussion now addresses the three research
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49 questions in turn.
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RQ1: Instructional-design features as barriers or enablers

Digital learning is hindered by features that limit learner autonomy and increase cognitive load, such as locked sequencing, forced linearity, non-skippable media, ambiguous instructions, and overstimulating visuals, which reduce attention and processing efficiency. Conversely, enablers like modular navigation, pacing control, clear signposting, and simple interfaces boost agency and clarity. Thus, inclusion depends on the control given to the learner, not just the use of technology.

RQ2: Influence on motivational load and cognitive sustainability

Restrictive or superficial design caused significant Affective Load, frustration, boredom, and emotional dysregulation, depleting working-memory and reducing persistence. Denying control over time and sequence created Agency-related Load and cognitive entrapment, undermining motivation. The McDonald's Metaphor illustrates how superficially 'engaging' interfaces eroded trust, replacing germane processing with noise. Clarity, predictability, and autonomy supported sustained cognitive effort; their absence actively compromised cognitive sustainability.

RQ3: Strategies used to manage design-related demands

To overcome design friction, participants developed extensive compensatory strategies: scanning, accelerating content, bypassing locked elements (pedagogical repair), chunking information, self-coaching, and independent searches. Some relied on human mediation when digital systems were too rigid. These necessary strategies highlight the additional cognitive

labour neurodivergent learners undertake in environments not designed for their processing needs.

By synthesising the Canary in the Coal Mine metaphor with the principles of Education 5.0 (Vieira et al., 2023), we propose three critical shifts in how digital learning must be conceptualised.

1: The Re-Theorisation of Friction: From User Deficit to Affective Load

Our findings challenge the traditional application of Cognitive Load Theory (CLT) in asynchronous environments. Classic CLT focuses on managing intrinsic and extraneous load to facilitate germane load (Paas et al., 2003; Sweller et al., 2011). However, our analysis of Agency as Access suggests that for neurodivergent learners, a fourth dimension is critical: Affective Load (Kalyuga & Plass, 2025; Skulmowski & Xu, 2022).

When learners are denied temporal autonomy, specifically the ability to regulate the velocity of information, the system creates a state of cognitive entrapment. The resulting frustration is not merely an emotional byproduct; it is a dominant cognitive force that consumes working memory and changes self-regulatory behaviour (Barrouillet et al., 2011; Hofmann et al., 2008). This conceptualisation aligns with, yet distinctively refines, emerging cognitive-affective models of learning. While scholars such as Kalyuga and Plass (2025) have established that emotional states directly influence working memory allocation, our findings specifically isolate *agency deprivation* as the generative mechanism of this load. Unlike general test anxiety or situational interest, the Affective Load described here is structural; it emerges directly from the friction between the learner's regulatory needs and the system's rigidity. By thwarting the fundamental

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3 psychological need for autonomy (Ryan & Deci, 2000), the interface triggers a regulatory crisis
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5 (Pintrich, 2003) where the effort required to manage emotional frustration cannibalises the
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7 cognitive resources intended for schema acquisition (Seufert et al., 2023). Thus, Affective Load
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9 is not simply an emotional reaction *to* the content, but a cognitive tax levied *by* the design. Our
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11 data suggests that compliance features, such as locked navigation and forced linearity, are
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13 paradoxically anti-learning features. They artificially lower the ceiling of engagement to ensure
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15 the floor of attendance. For the neurodivergent professional, access is synonymous with agency
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17 (CAST, 2018, 2024). Without the power to skip, scan, and accelerate the interface itself becomes
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19 the primary barrier to learning.
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26 This consideration reframes the act of cheating not as academic dishonesty, but as pedagogical
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28 repair. When a user bypasses a locked navigation bar, they are not evading learning; they are
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30 manually adjusting the interface to match their cognitive processing speed. The system's rigidity
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32 forces the learner to expend energy fighting the platform rather than absorbing the content
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34 (Abrams et al., 2024; Ljuslinder et al., 2020).
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38 2: The Commodification of Engagement: McDonaldization as a Breach of Trust

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42 The McDonald's Metaphor provides a scathing critique of the trend toward gamification. When
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44 viewed through the lens of Ritzer's (2021) McDonaldization, we see that the 'bright colours'
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46 rejected by our participants are not pedagogical choices, but industrial ones designed for
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48 *Efficiency* (quick consumption) and *Calculability* (tracking clicks).
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3 However, the implication extends beyond poor design; it represents a violation of the
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5 psychological contract. By prioritising sensory novelty over conceptual depth, the system signals
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7 that it does not trust the learner with complexity. This creates a profound epistemic mismatch.
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10 The neurodivergent professional approaches the environment seeking depth, precision, and
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12 schematic construction, qualities aligned with Education 5.0. Instead, they encounter a 'Happy
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14 Meal pedagogy' that offers high-stimulation but low-nutrition. The rejection of these elements is
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16 not a failure of attention; it is a refusal to accept a transaction that trades professional dignity for
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18 gamified compliance. This finding has profound implications for Learning & Development
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20 strategy: it suggests that the seductive details (Harp & Mayer, 1998) intended to motivate the
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22 average user are actively toxic to the motivated, neurodivergent expert.
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28 Crucially, this also highlights a failure of trust. The infantilised design signals to the learner that
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30 the institution views them as a passive consumer of information rather than an active constructor
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32 of knowledge (Freire, 2013; Freire & Freire, 2004). For the neurodivergent professional, whose
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34 cognitive style often relies on pattern recognition and bottom-up processing, this superficiality
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36 renders the content untrustworthy.
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41 As illustrated in Figure 1, this friction introduces a critical theoretical shift. While the standard
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43 CLT model balances intrinsic, extraneous, and germane load within working memory limits, the
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45 neurodivergent experience reveals that Affective Load (frustration and agency friction) competes
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47 for these same resources. In rigid asynchronous environments, this fourth dimension expands to
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49 displace Germane Load, effectively blocking schema acquisition regardless of the learner's
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51 capability.
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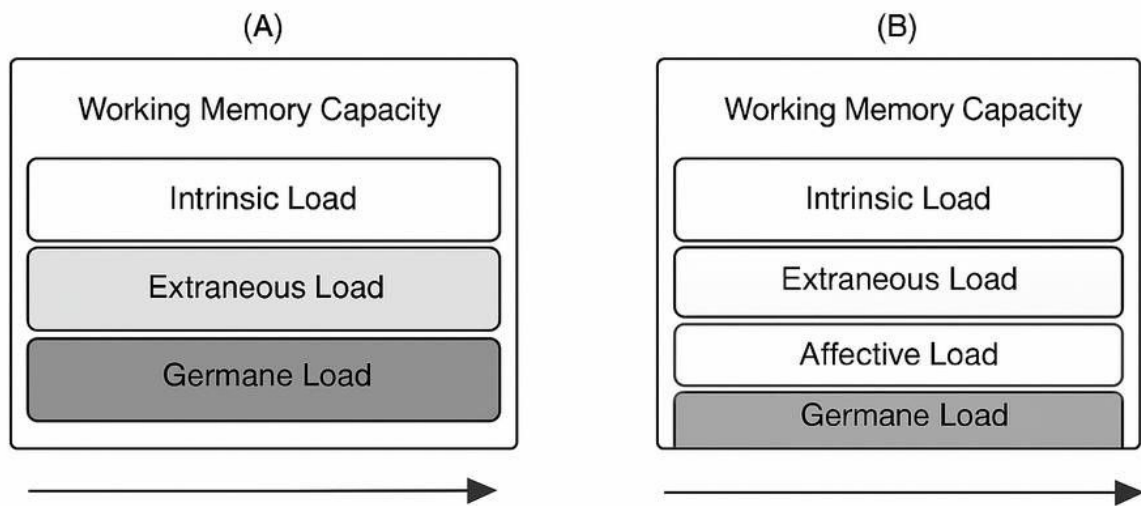


Figure 1: The Displacement of Germane Load in Neurodivergent Learners (Author's own). (A) The Standard Cognitive Load Model assumes a balanced distribution where Extraneous Load is minimised to maximise Germane Load (learning). (B) The 'Canary' Model, derived from participant data, illustrates how high Extraneous Load (superficial design) combined with significant Affective Load (agency friction) exceeds Working Memory Capacity. This results in the 'crowding out' of Germane Load, rendering deep learning impossible regardless of learner capability. Ultimately, the 'Happy Meal' interface breaks the psychological contract, treating the professional learner as a passive consumer rather than an intellectual partner.

3: The Paradox of Inclusive Design: The Minority Tax

This study uncovers a troubling paradox regarding the future production of accessible learning. If the current industrial model prohibits the time, depth, and nuance required for Universal Design, we run the risk of creating a two-tier system where authentic accessibility becomes the sole province of neurodivergent designers.

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3 In a high-velocity corporate environment, neuro-normative designers are often constrained by the
4 very efficiency metrics we critique. Lacking the lived experience of cognitive friction and denied
5 the institutional time to develop empathy-driven materials, they may be systemically unable to
6 deviate from the template. Consequently, the labour of repairing these broken environments falls
7 disproportionately upon the minority group. This constitutes a form of systemic exploitation,
8 where the neurodivergent individual is expected to act as both the victim of the design and the
9 architect of its solution (Rosales et al., 2023).
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21 This creates a specific variety of the Double Empathy Problem (Milton, 2012). The burden is
22 placed on the neurodivergent canary not only to detect the toxic gas but also to redesign the
23 mine. At the same time, the neuro-normative majority continues to operate within the constraints
24 of the status quo. Unless the metrics of success change from speed of delivery to depth of
25 understanding, the weight of educational reform will remain an unpaid tax levied on the
26 neurodivergent community.
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38 **From Accommodation to Canary Diagnostics**

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41 Finally, the Canary in the Coal Mine metaphor reframes the role of neurodiversity in design.
42 Historically, accessibility has been treated as a retroactive patch for a minority derived from a
43 Medical Model approach focused on accommodation (Areheart, 2008). Our findings demand a
44 shift toward systemic remediation within the Social Model. The toxins detected by our
45 participants, ambiguity, enforced passivity, and shallowness, are detrimental to all learners, but
46 they are debilitating to the neurodivergent. The contrast between the flexibility of human
47 managers and the rigidity of digital platforms highlights a regression in the digital
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3 transformation. We have inadvertently built systems that are less adaptable than the humans they
4 replaced, effectively de-humanising the learning process in the name of scale (Selwyn, 2021).
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10 Therefore, designing for the canary is not an act of charity; it is a quality assurance mechanism.
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12 A system that allows a learner to speed up, skip fluff, or choose a deep-dive path is not a special
13 system; it is a robust, flexible learning environment. By solving for the edges, we raise the
14 quality of the centre. In the era of Education 5.0, the measure of a system's success is not how
15 well it enforces compliance, but how gracefully it yields control to the learner (Meyer et al.,
16 2014). The friction felt by the neurodivergent mind is the first warning signal that the system is
17 prioritising industrial delivery over human development.
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28 As with all interpretivist case studies, the findings of this research reflect the experiences of a
29 specific group of neurodivergent adults within defined digital-learning contexts. The study relied
30 on self-reported neurodivergence and voluntary participation, which may privilege those
31 confident in articulating their learning experiences. **Furthermore, while our cross-case analysis
32 indicated thematic consistency across the cohort, the sample size inherent to this interpretivist
33 design precludes a granular comparative analysis of how specific variables, such as age, gender,
34 or specific neurotype, might differentially modulate the intensity of affective load.** While the
35 combination of interviews and an asynchronous option supported inclusivity, it also limited
36 opportunities for prolonged engagement or observational data. Finally, the focus on
37 asynchronous e-learning offers depth but does not capture the full complexity of blended or
38 synchronous environments. These boundaries provide important context for interpreting the
39 findings and open several avenues for further inquiry.
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3 Future research in inclusive, human-centred digital learning should focus on several areas. One
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5 direction is to advance personalisation models, allowing individuals to actively control pacing,
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7 navigation, cognitive load, and content depth. Another crucial avenue is exploratory and
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9 participatory research that positions neurodivergent adults as co-designers (canaries in the coal
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11 mine) to optimise early designs and generate new insights into design equity. Finally,
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13 longitudinal studies are required to examine how learners' cognitive, emotional, and
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15 motivational experiences evolve over time. Recognising this cumulative cognitive tax is an
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17 essential step toward the systemic remediation outlined in the conclusion that follows. Together,
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19 these directions would advance a human-centred research agenda that treats neurodivergent
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21 learners not as a niche population but as critical informants for systemic design improvement.
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27 Practical Recommendations for Instructional Designers and L&D teams

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31 This study shows that many challenges neurodivergent learners face in asynchronous e-learning
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33 stem from avoidable design friction rather than learner deficit. Restrictive sequencing, unclear
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35 instructions, overstimulating visuals, and shallow 'engagement' features created unnecessary
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37 cognitive and emotional load, forcing learners to expend energy managing the platform instead
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39 of processing content. In contrast, designs offering clarity, flexibility and conceptual depth
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41 supported autonomy, reduced frustration, and improved cognitive sustainability.
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45 Table 3 summarises the key issues identified by participants and presents concise, evidence-
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47 aligned adjustments. The unifying principle is adaptive autonomy: providing meaningful choice
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49 in pacing, sequencing, and modality while maintaining a clear, predictable structure. These
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51 adjustments require no specialist neurodiversity expertise; they are simply features of well-
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53 designed learning environments that respect adult learners' cognitive diversity. Designing with
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these changes in mind strengthens learning for everyone. Designing inclusively improves the ecosystem for the whole mine, shifting practice from reactive accommodation to proactive, inclusive design.

Table 3: Practical Inclusive Design Adjustments (Author's own, 2025)

Design Issue Identified by Participants	Recommended Adjustment	Inclusion Benefit (for ND and NT Learners)
Locked navigation, forced linear sequencing, non-skippable media	Provide modular navigation, chapter markers, skippable/rewindable media	Restores agency and pacing control; reduces affective load and frustration; supports self-regulation
Long, slow, or time-bound content	Offer time-estimate ranges, variable content speed, alternative concise or deepdive pathways	Supports cognitive diversity; reduces shame/self-blame; increases motivation and persistence
Overstimulating or gamified interfaces	Use clean, minimal layouts; ensure visuals serve instructional purpose	Reduces extraneous load; improves focus and processing efficiency; preserves trust
Ambiguous instructions, unclear expectations	Add explicit signposting, micro-instructions, and previews	Lowers cognitive friction; reduces need for interpretive guesswork; supports working memory
Restrictions on learning strategies	Enable adaptive autonomy: scanning, text search, adjustable playback, transcripts	Prevents cognitive entrapment; respects legitimate strategies; increases usability
Compliance-driven time requirements	Replace time-on-task with short mastery checks	Aligns with learning outcomes; reduces emotional and cognitive load
Superficial or gimmicky content	Prioritise conceptual depth and meaningful examples; optional advanced content	Enhances relevance; supports deep learning; maintains trust

No quick way to report errors	Add a “Report an issue” button and update notifications	Prevents cognitive stalling; supports smoother learning
One-size-fits-all design	Provide structured autonomy and multimodal access	Supports personalisation; reduces cognitive load
High self-regulation burden	Offer progress cues, clear structure, optional checklists	Supports motivation and sustained effort

Conclusion

This study challenges the prevailing orthodoxy of instructional design, which too often operationalises accessibility as a retroactive checklist rather than a foundational pedagogical principle. By centring the lived experience of neurodivergent professionals, we have exposed the hidden costs of the industrialised e-learning model: a system that trades cognitive sustainability for administrative efficiency.

The findings re-theorise the relationship between learner and interface. We argue that for the neurodivergent learner, agency is not a preference but a prerequisite for access. When design denies this agency through locked navigation or forced linearity, it generates a unique form of Affective Load - a cognitive entrapment that displaces the mental resources required for learning. Furthermore, the rejection of superficial gamification (the McDonaldization of content) signals a profound epistemic mismatch between the deep-diving learner and the shallow-processing system.

As neurodivergent researchers, we acknowledge a shared positionality with our participants. This insider perspective allowed us to recognise the subtle signals of friction, the “stalling” described

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3 by P7 and the ‘invisible labour’ articulated by P10, not as behavioural deficits, but as rational
4 responses to a hostile architecture. Our own lived experience confirms that the “cheating”
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6 described in this study is, in reality, a necessary act of pedagogical repair. This shared double
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8 empathy validates the findings: the fatigue reported is not a failure of the learner, but a failure of
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10 the environment. Ultimately, the neurodivergent learner serves as the diagnostic canary for the
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12 digital education ecosystem. However, the burden of this diagnosis cannot remain a minority tax
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14 levied on the neurodivergent community. The toxins these learners detect, ambiguity, rigidity,
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16 and hollowness, degrade the learning experience for all.
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23 To realise the human-centric promise of Education 5.0, higher education and lifelong learning
24 ecosystems must pivot from an industrial logic of compliance to a logic of cognitive coherence.
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26 This requires a move toward Universal Design for Learning (UDL), where flexibility is the
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28 default rather than the exception. By designing environments that sustain the most sensitive
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30 thinkers, we inevitably create clearer, cleaner, and more cognitively coherent pathways for every
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32 learner. The imperative is clear: we must stop designing for the statistical average and start
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34 planning for the cognitive margins, for it is at the margins that the true viability of the system is
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36 exposed.
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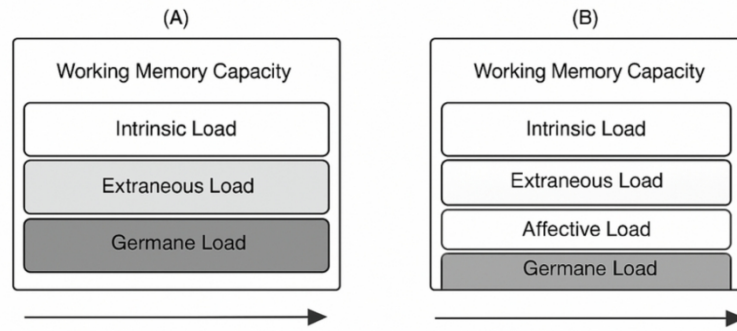
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Participant ID	Neurodivergence (Self-Reported)	Gender	Age (years)	Industry / Sector	Data Collection Method
P1	ADHD	Female	45-54	Aviation/Air Transport	Online Semi-structured Interview
P2	Dyslexia	Male	45-54	Information Technology and Legal Services	Online Semi-structured Interview
P3	Dyslexia	Female	45-54	Health and Social Care	Online Semi-structured Interview
P4	Dyslexia	Female	45-54	Pharmaceutical/Manufacturing	Online Semi-structured Interview
P5	ADHD	Female	45-54	Health and Social Care	Online Semi-structured Interview
P6	ADHD	Female	55+	Professional Services/Consultancy	Online Semi-structured Interview
P7	ASD	Male	45-54	Healthcare (Allied Health – Chiropractic)	Semi-Structured Interview via asynchronous form
P8	ADHD	Female	33-44	Healthcare (Allied Health – Chiropractic)	Online Semi-structured Interview
P9	ADHD	Female	33-44	Education and Events Management	Online Semi-structured Interview
P10	ADHD, ASD, Dyslexia	Female	45-54	Information Technology/Public sector	Online Semi-Structured Interview
P11	Dyslexia	Male	55+	Pharmaceutical/Manufacturing	Online Semi-Structured Interview

Table 2: Illustrative Analytic Pathway (Excerpt → Code → Theme) (Author's own, 2025)

Stage of coding process	Example
Excerpt P1	“Many systems assume a linear learning style ... I often feel trapped within a predetermined route that restricts my natural learning process.”
Initial code	Forced linearity as cognitive entrapment; frustration due to loss of pacing control
Interpretive Notes	Meaning interpreted as an affective response to restricted learner agency
Mainn Theme	Agency as access



25 Figure 1: The Displacement of Germane Load in Neurodivergent Learners.

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Table 3: Practical Inclusive Design Adjustments (Author's own, 2025)

Design Issue Identified by Participants	Recommended Adjustment	Inclusion Benefit (for ND and NT Learners)
Locked navigation, forced linear sequencing, non-skippable media	Provide modular navigation, chapter markers, skippable/rewindable media	Restores agency and pacing control; reduces affective load and frustration; supports self-regulation
Long, slow, or time-bound content	Offer time-estimate ranges, variable content speed, alternative concise or deepdive pathways	Supports cognitive diversity; reduces shame/self-blame; increases motivation and persistence
Overstimulating or gamified interfaces	Use clean, minimal layouts; ensure visuals serve instructional purpose	Reduces extraneous load; improves focus and processing efficiency; preserves trust
Ambiguous instructions, unclear expectations	Add explicit signposting, micro-instructions, and previews	Lowers cognitive friction; reduces need for interpretive guesswork; supports working memory
Restrictions on learning strategies	Enable adaptive autonomy: scanning, text search, adjustable playback, transcripts	Prevents cognitive entrapment; respects legitimate strategies; increases usability
Compliance-driven time requirements	Replace time-on-task with short mastery checks	Aligns with learning outcomes; reduces emotional and cognitive load
Superficial or gimmicky content	Prioritise conceptual depth and meaningful examples; optional advanced content	Enhances relevance; supports deep learning; maintains trust
No quick way to report errors	Add a "Report an issue" button and update notifications	Prevents cognitive stalling; supports smoother learning

One-size-fits-all design	Provide structured autonomy and multimodal access	Supports personalisation; reduces cognitive load
High self-regulation burden	Offer progress cues, clear structure, optional checklists	Supports motivation and sustained effort

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