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Cognitive load and neurodiversity in online education: a preliminary framework for educational research and policy

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This theoretical paper presents the development and analysis of an inclusive educational framework designed to manage cognitive load for neurodivergent students in online learning environments. Drawing from cognitive load theory and neurodiversity studies, the framework is based on existing literature, empirical work conducted by the authors, and iterative feedback from a participatory research advisory board. Taking a neurodiversity-informed perspective that focuses on interventions addressing challenges common across a range of conditions, it identifies six critical areas that might impact cognitive load in online learning for neurodivergent students: format, environment, delivery, instruction, support, and research (FEDIS+R). To assess the external factors influencing the potential implementation of the framework and its place within the broader landscape of inclusive education, a PESTEL (Political, Economic, Social, Technological, Environmental, and Legal) analysis was conducted. The analysis highlights challenges such as resource disparities, institutional commitment to inclusion, and legal requirements for accessibility, which may affect the adoption of the framework. Given the evolving nature of both cognitive load theory and neurodiversity studies, future research directions are suggested to evaluate its effectiveness across diverse educational contexts. This paper contributes to the growing body of knowledge on neurodiversity in education and offers practical recommendations for educators and policymakers seeking to create inclusive online learning environments.

KEYWORDS

online learner, neurodiversity, inclusive education, ADHD, autism, dyslexia, cognitive load

1 Introduction

Thirty years ago, the Salamanca Declaration marked a turning point in the global movement toward inclusive education, advocating for the fundamental right to access quality education regardless of diverse needs and abilities (Ainscow et al., 2019; United Nations, 1994). Published in 1978, the Warnock committee's report on Special Educational Needs (SEN) further emphasized the importance of both recognition and support of the unique learning needs of all students (Warnock, 1978). Those frameworks, in alignment with the World Health Organization's vision of inclusive education and the UNESCO goals of education, have since

inspired several initiatives and policy changes worldwide (Lindsay et al., 2020).

The emergence of the neurodiversity paradigm has further supported the goals of inclusive education. Neurodiversity, a term coined in the late 1990s, refers to the natural variation in human brain functioning, encompassing attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), dyslexia, and other neurological differences (Armstrong, 2010). Neurodivergent people, whose brain functions differ from what is considered typical neurodevelopmental and cognitive functioning, are estimated to account for 15–20% of the global population (Doyle, 2020; Jurgens, 2020). The concept of neurodiversity challenges the notion that neurological differences should be viewed as deficits or disorders (Rosqvist et al., 2020). Instead, neurodiversity advocates for a strengths-based approach to understanding neurocognitive differences, recognising that these variations can lead to unique skills, talents, and perspectives (Armstrong, 2010; Rosqvist et al., 2020). As neurodevelopmental conditions are the largest category of qualifying disabilities in education (Hubble and Bolton, 2021), this shift has been instrumental in promoting inclusive education practices and fostering mixed-ability classrooms, where the diverse needs and abilities of all students are valued and supported (Rentenbach et al., 2017), and extensive research has been conducted to investigate strategies for supporting neurodiversity in education (Clouder et al., 2020). Studies called to attention the importance of providing accommodations, such as extended time on tests and alternative assessment methods, to ensure that neurodivergent students have equal opportunities to demonstrate their knowledge and abilities (Lovett and Nelson, 2021). Additionally, research has emphasized the need for educators to receive training in understanding and supporting neurodiversity, enabling them to create inclusive classroom environments (Griffin and Pollak, 2009). The use of evidence-based interventions such as cognitive-behavioral therapy has also been found to be effective in supporting the academic, social, and emotional development of neurodivergent students (Fleury et al., 2014).

However, neurodivergent students still face distinct barriers in educational environments that can impact their learning experience. Variations in executive functioning (EF), which include differences in working memory, cognitive flexibility, and inhibitory control can affect how students engage with multiple learning platforms, organize materials, and maintain attention during lectures (Diamond, 2013). These neurocognitive variations are well-documented across neurodevelopmental conditions, with ADHD associated with challenges in response inhibition and working memory, ASD characterized by differences in cognitive flexibility and planning, and dyslexia connected to working memory and processing speed difficulties (Barkley, 2012; Hill, 2004; Smith-Spark et al., 2016). Language processing differences, including varying interpretations of figurative language, can influence how neurodivergent students engage with discussions and written instructions (Williams et al., 2008). Social interactions can shape participation in class discussions and group work, where traditional turn-taking structures and interpretation of non-verbal cues may not align with their preferred communication styles (White et al., 2016). These patterns align with theoretical frameworks such as Barkley's theory of EF as an extended phenotype, which explains how EF differences might impact self-regulation and learning (Barkley, 2012). In addition, the social model of disability suggests that these challenges often arise from environmental and institutional barriers rather than inherent deficits, with traditional educational systems frequently failing to accommodate neurodiversity (Chapman, 2020; Oliver and Barnes, 2012; Woods, 2017). The significant increase in the adoption of online learning platforms over the past decades, which has been accelerated by the COVID-19 pandemic (Dhawan, 2020), has presented new challenges for supporting neurodivergent students (Becker et al., 2020; He et al., 2021; Young and Clerke, 2024). The unique characteristics of online learning environments, such as the reliance on digital communication and the absence of face-to-face interactions, may pose additional barriers for neurodivergent students (Ballantine et al., 2023; Le Cunff et al., 2022; Smith, 2023). As such, there is a pressing need for research further investigating strategies and best practices for supporting neurodiversity and ensuring that all students have access to inclusive and equitable learning opportunities in online education. Understanding these barriers is crucial for transforming educational systems to create genuinely inclusive learning environments that value neurodiversity rather than expecting students to conform to neurotypical norms.

Cognitive load refers to the amount of mental effort required to process and retain new information (Sweller, 1988). It is a crucial factor in determining students' acceptance of educational content, their overall well-being, and their academic performance (Sweller et al., 2019). Cognitive load theory distinguishes between two main types of cognitive load: intrinsic and extraneous (Sweller et al., 2019). Intrinsic cognitive load represents the inherent difficulty of the learning material and the natural complexity of the task at hand (Paas and van Merriënboer, 2020). Extraneous cognitive load, in contrast, stems from the way information is presented and how learning activities are designed—it is the unnecessary mental effort imposed by poor instructional design or distracting elements in the learning environment (Mayer and Moreno, 2003). While intrinsic cognitive load is considered necessary for learning, extraneous cognitive load might interfere with learning and should be minimized through careful instructional design (Sweller et al., 2019). Managing cognitive load is particularly important for neurodivergent students, who often show differences in working memory (Habib et al., 2019; Jeffries and Everatt, 2004; Kofler et al., 2020). In ADHD, differences in working memory are associated with difficulties in maintaining and manipulating information, which can negatively impact academic performance (Roodenrys, 2012). Similarly, autistic individuals often demonstrate differences in working memory which can hinder their ability to process and retain complex information (Kercood et al., 2014). Dyslexia is also associated with working memory differences, particularly in the phonological domain (Menghini et al., 2011). While cognitive load in online learning has been extensively studied in neurotypical populations (e.g., Mayer and Moreno, 2003; Paas et al., 2003), research on its impact on neurodivergent students in online learning is limited (Le Cunff et al., 2024a). This gap in research has significant implications for the design and delivery of inclusive online education, as it may lead not only to the development of online learning materials and strategies that do not adequately address the unique needs of neurodivergent students but might also hinder the identification of accessibility issues in software that is already widely used.

Because learning differences associated with neurodiversity affect a variety of cognitive processes that are not all easily observed, online learning can make neurodiversity more difficult to support: without

physical indicators, difficulties can remain "hidden," impeding the implementation of inclusive learning strategies (Matthews, 2009). Understanding the impact of cognitive load on neurodivergent students in online learning environments is crucial for policymakers and practitioners alike as it can inform the development of inclusive online education strategies that cater to the diverse needs of all students. While the importance of cognitive load in educational settings is well-established, particularly in online environments, there is currently no empirically grounded framework that specifically addresses the unique needs of neurodivergent students. This gap has led to fragmented approaches in supporting these students (Bănut and Andronache, 2023; Caskurlu et al., 2021).

To address this gap, this article builds upon a body of research, including the authors' prior empirical work, to develop an applied framework that addresses the challenges of managing cognitive load for neurodivergent students in online learning environments, designed to guide educators and policymakers in creating inclusive online learning environments. We adopt a neurodiversity-informed approach that recognises the overlapping challenges faced by neurodivergent students, including those with ADHD, ASD, dyslexia, and other conditions (Chapman, 2020). While each condition presents unique characteristics, many neurodivergent traits—such as difficulties with information processing, executive functioning, and task completion—are shared across these groups (Armstrong, 2010). Rather than fragmenting interventions for specific diagnoses, this framework aims to identify strategies that can broadly help manage cognitive load for all neurodivergent students in online learning environments.

The framework integrates insights from prior studies into practical recommendations for reducing challenges associated with cognitive load in online learning. It draws on a diverse range of studies, including qualitative, quantitative, and neurophysiological data, to provide a holistic understanding of cognitive load in neurodivergent students. This mixed-methods approach is critical for identifying patterns of cognitive load that might not be captured by a single methodology, allowing the framework to address both cognitive and experiential aspects of neurodivergent students' learning (Dwyer et al., 2023). Additionally, this paper includes a Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) analysis to evaluate the external factors influencing the implementation of this framework in real-world educational contexts. PESTEL analyses have been used in education research to evaluate potential changes to policies (Graham, 2018; Musa and Suryono, 2022; Yasir et al., 2023). By synthesising research findings into a cohesive structure and then evaluating the applicability of the framework, this work not only highlights key challenges in the current educational landscape but also proposes concrete steps for future research and policy development. Ultimately, this preliminary framework serves as both an operational tool and a roadmap for future empirical studies, advancing the growing field of inclusive online education for neurodivergent students.

2 Framework development

Developing a framework that addresses the specific challenges neurodivergent students face in managing cognitive load in online learning environments requires the integration of theoretical and empirical insights. Existing applied frameworks, such as Zimmerman's framework for academic self-regulation (Zimmerman, 2002), focus on how students regulate their learning but do not consider the specific barriers neurodivergent students encounter in online education. Similarly, Laurillard's conversational framework (Laurillard, 2002) supports adaptive teaching processes but does not account for how neurodivergent students might experience excessive cognitive load during online learning. The Emerging Technologies Framework (Millea et al., 2005) explores technology's role in education but does not address how cognitive load impacts neurodivergent students specifically. These gaps highlight the need for a new applied framework that integrates both theoretical and empirical insights, specifically geared toward managing cognitive load in online education for neurodivergent students.

The development of this framework was guided by integrating key insights from cognitive load and neurodiversity research, with a particular emphasis on adapting these models to the needs of neurodivergent students in online education. Cognitive load theory provided the foundational understanding of how cognitive load impacts learning (Sweller, 1988; Sweller et al., 2019), while our systematic review revealed underexplored patterns in the relationship between neurodiversity and cognitive load in online learning (Le Cunff et al., 2024a). Additionally, our own empirical research identified specific barriers faced by neurodivergent students, such as inaccurate transcripts, inaccessible content presentation, and unclear curricula, that can lead to difficulties in regulating cognitive load (Le Cunff et al., 2024b, 2024c, 2024d). These findings directly shaped the development of the framework by identifying key areas where neurodivergent students encounter the most significant challenges, allowing us to suggest strategies aimed at managing cognitive load in online learning for these students.

Each component of the framework was developed to address specific aspects of the learning process that might contribute to cognitive load for neurodivergent students. To ensure methodological rigor, we followed Kern's six-step framework development process (Kern et al., 1998), which is widely recognized in educational research for designing applied frameworks. This process involves defining the problem, identifying necessary components based on empirical evidence, and iterative testing and refinement (Figure 1). The framework was developed in collaboration with a Research Advisory Board (RAB) consisting of neurodivergent students, who contributed throughout the iterative development process. Their input was integrated at various stages to ensure that the framework effectively addresses the challenges neurodivergent students face in online education. The RAB members also co-authored this manuscript, reflecting their active role in shaping the framework.

To assess the framework's applicability in real-world educational settings, we structured the discussion section around a short PESTEL analysis, which evaluates the Political, Economic, Social, Technological, Environmental, and Legal factors that could influence the framework's implementation (Graham, 2018; Musa and Suryono, 2022; Yasir et al., 2023). First, we reviewed current political policies related to neurodiversity and inclusion in education, identifying legislative support and potential barriers to implementing neurodivergent-specific strategies. Next, we assessed the economic implications, considering the costs of adopting the framework and the availability of funding for neurodivergent students. We then examined social factors, such as attitudes toward neurodiversity and the demand for inclusive education practices. The analysis also included a

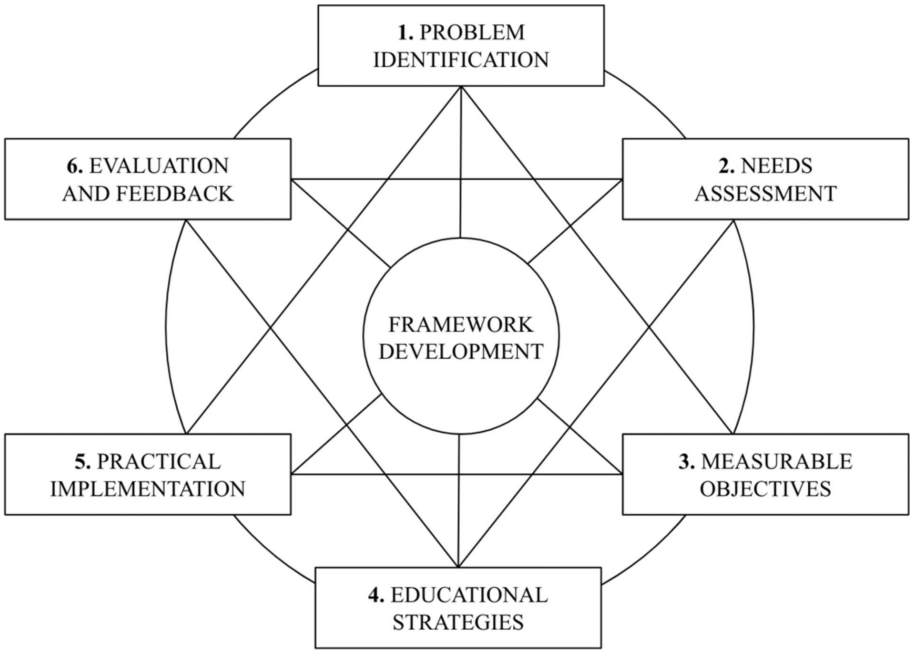

FIGURE 1
Visual representation of Kern's six-step framework development process.

discussion of current technological capabilities in education, determining whether existing digital tools could support the framework's recommendations. Environmental factors were also considered, particularly the shift to remote learning during the COVID-19 pandemic, which has had significant effects on neurodivergent students in online education (Adnan and Anwar, 2020). Finally, we evaluated legal barriers by reviewing accessibility and inclusion laws that impact education. By evaluating these external factors, we aim to provide practical recommendations for educators and policymakers that are adaptable across a variety of educational contexts.

It is important to note that this paper synthesises findings from previously published research. As such, detailed methodological aspects, such as participant inclusion/exclusion criteria, control variables, study designs, and ethical approvals, are thoroughly described in the original studies referenced throughout the framework's development.

3 Preliminary framework for educational research and policy

Based on the insights gained from our systematic review and empirical studies, and following the steps of Kern's development process, we identified six key areas that impact cognitive load for neurodivergent students in online learning environments: format, environment, delivery, instruction, support, and research (FEDIS+R). These six areas provide a structured approach for educators and policymakers to design online learning environments that minimize extraneous cognitive load and promote inclusive practices for neurodivergent students. Figure 2 illustrates the framework, highlighting how each of these areas can be addressed to support neurodivergent students and reduce the cognitive barriers they face in online education.

3.1 Format

Providing content in written format such as transcripts and captions may help in reducing cognitive load for some neurodivergent students in online learning environments. Captions might be helpful for neurodivergent students when used as part of recorded lectures where they can pause, slow down, or speed up the video, making the content more functionally adaptable to their unique needs (Horlin et al., 2024). For dyslexic students, such recordings enhanced with captioning and transcripts can reduce the cognitive load of taking notes during live lectures, reducing the risk of falling behind (Nightingale et al., 2019). Autistic students can also benefit from text being provided in addition to audio visual media as they can experience difficulties in auditory processing that make speech difficult to separate from background noise (Kent et al., 2018). While transcripts and captions have been found to be beneficial to a wide range of students, including neurotypical students (Clossen, 2014), the effectiveness of different formats can vary significantly among students and there can be a complex interplay between engagement and accessibility, where formats that increase engagement might simultaneously impose higher cognitive load (Dahlstrom-Hakki et al., 2020). For instance, research has shown that captions can actually increase cognitive load for some students with ADHD due to the redundancy effect (Brown et al., 2016). Inaccurate transcripts and poorly synchronized captions have also been found to increase perceived cognitive load in online learning for neurodivergent students (Le Cunff et al., 2024b). Therefore, educators should consider providing flexible format

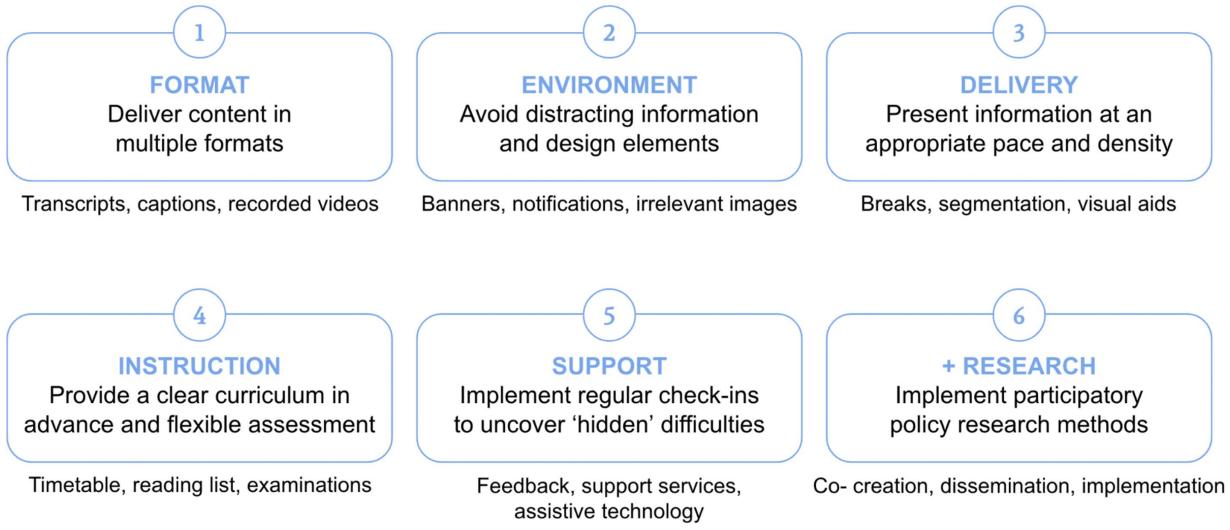

FIGURE 2
FEDIS+R framework to manage cognitive load in online learning for neurodiverse classrooms.

options that allow students to choose the presentation mode that best suits their individual learning needs. By ensuring that captions and transcripts are error-free and matching with the audio content, educators can help neurodivergent students focus on the lecture material without the added cognitive load of deciphering the content.

3.2 Environment

To reduce extraneous load, online learning platforms should avoid including unnecessary visual elements such as banners, advertisements, or irrelevant images (Clark and Mayer, 2023; Oviatt, 2006). These distracting elements can divide students' attention between the primary content and irrelevant stimuli, leading to cognitive overload (Mayer and Fiorella, 2014). Similarly, cluttered interfaces with too many navigation options or overwhelming amounts of text can increase extraneous load, particularly for neurodivergent students who may struggle with information processing (Chen et al., 2011; Le Cunff et al., 2024d). Conversely, research suggests that increasing intrinsic load by designing learning tasks that require a high level of focal-task engagement may decrease extraneous load by reducing peripheral processing of task-irrelevant information (Sörqvist et al., 2016). Educators should also be mindful of how they present announcements and notifications within online learning environments. While timely communication is essential for student engagement and success, poorly timed or excessive notifications can disrupt the learning process and increase extraneous load (Arnold et al., 2023; Ohly and Bastin, 2023; Okoshi et al., 2017; Wang, 2022). To minimize extraneous load, announcements should be concise, relevant, and strategically placed within the learning platform (Humphrey Jr et al., 2021; Lai et al., 2020). By designing online learning environments that minimize distracting elements and optimize the presentation of intrinsically relevant information, educators can help manage cognitive load for all students, including those who are neurodivergent.

3.3 Delivery

Educators should strive to deliver information at an appropriate pace, with sufficient breaks to support understanding and avoid cognitive overload. Presenting content too quickly or too densely can increase perceived cognitive load, particularly for neurodivergent students who may require more time and mental effort to process information (Le Cunff et al., 2024b). This aligns with research suggesting that the pace and density of information presentation can significantly impact cognitive load and learning outcomes (Chang et al., 2012; Costley et al., 2021; Mo et al., 2022). To address this issue, educators can use the segmenting principle, which involves breaking down complex information into smaller, more manageable chunks (Ibrahim et al., 2011; Mayer and Pilegard, 2005). By presenting content in shorter segments with clear timeframes and breaks between each segment, educators can help students process information more effectively and reduce cognitive load (Liu, 2024). Incorporating visual aids, such as diagrams, images, and videos, can also help reduce cognitive load by presenting information in multiple modalities (Mayer and Pilegard, 2005). This may be particularly beneficial for neurodivergent students who may struggle with auditory or visual processing (Le Cunff et al., 2024b). By using visual aids to complement verbal explanations, educators can help neurodivergent students better understand and retain information without experiencing excessive cognitive load (Mayer and Fiorella, 2014).

3.4 Instruction

Neurodivergent students can experience increased perceived cognitive load due to unclear expectations and lack of guidance on assignments and assessments (Le Cunff et al., 2024b). To address this issue, educators should provide a clear curriculum in advance of online lectures, along with detailed instructions, rubrics, and examples for assignments and assessments (Gronseth et al., 2021; Rao et al., 2015). Ideally, educators should clearly communicate which parts of

the curriculum are mandatory for exams and provide guidance on where to start when assigning reading materials (Le Cunff et al., 2024b). This approach can help neurodivergent students better understand what is expected of them and reduce the cognitive load required to navigate ambiguous tasks. Offering flexible deadlines and submission formats might further help neurodivergent students in managing their cognitive load and demonstrating their knowledge in ways that align with their strengths and preferences (Cai and Richdale, 2016; Zeedyk et al., 2019). Finally, providing clear, concrete, and unambiguous instructions is essential when working with neurodivergent students, as they may struggle with interpreting figurative language or deciphering unclear directions (Gurbuz et al., 2019; Toor et al., 2016). By breaking down complex tasks into manageable steps and offering explicit guidance, educators can provide more inclusive instruction that both reduces extraneous load and accommodates the unique needs of neurodivergent students.

3.5 Support

Implementing regular check-ins, providing timely and good quality feedback, and ensuring access to support services can help address the hidden nature of cognitive load in online learning for some neurodivergent students. Research suggests that university neurodivergent students may use compensatory strategies to maintain academic performance despite experiencing higher cognitive load, which might remain undetected in online learning environments (Le Cunff et al., 2024d). To provide inclusive and equitable education, practitioners might consider incorporating regular check-ins and providing opportunities for feedback, which could help identify when and where neurodivergent students are struggling and offer targeted support to manage their cognitive load. Furthermore, ensuring that neurodivergent students have access to support services, such as disability services, counseling, and assistive technologies, is crucial for helping them manage their cognitive load and succeed in online learning (Andersen and Jensen, 2018; Cai and Richdale, 2016; Zeedyk et al., 2019). Providing support services to neurodivergent students is essential, but equally important is fostering a psychologically safe environment that encourages them to access and make use of these services (Hamilton and Petty, 2023). Psychological safety refers to the belief that one can express oneself without fear of negative consequences, and it plays a significant role in neurodivergent students' willingness to seek help and engage with support systems (Edmondson, 1999; Hamilton and Petty, 2023). To foster psychological safety for neurodivergent students, educators should strive to create inclusive environments that promote open communication, validate students' experiences, and offer accommodations without judgment (Accardo et al., 2024; Sarrett, 2018; Zeedyk et al., 2019). By implementing these strategies, educators could better identify and address the unique challenges faced by neurodivergent students, ensuring that they have the necessary resources and accommodations to manage their cognitive load effectively.

3.6 Research

Recent research has highlighted the importance of participatory policy research methods in ensuring that the lived experiences and perspectives of neurodivergent students are central to the development of inclusive education policies and practices (Chown et al., 2017; Parsons et al., 2020). Given the hidden nature of cognitive load in online learning for some neurodivergent students (Le Cunff et al., 2024d), it is crucial that policymakers engage directly with neurodivergent students as co-creators of research to better understand their unique challenges and develop effective solutions (Rosqvist et al., 2019; Gillespie-Lynch et al., 2017). Participatory research methods, such as co-design workshops, focus groups, and advisory boards, can provide valuable insights into the experiences of neurodivergent students and help identify areas where support and accommodations are needed (Le Cunff et al., 2023; Nicolaidis et al., 2019; Pellicano et al., 2018). By involving neurodivergent students as active participants in the research process, researchers, policymakers, and practitioners can ensure that their decisions are grounded in the real-world experiences of those most affected by their policies, leading to more effective and equitable outcomes for all students (Fletcher-Watson et al., 2019; Le Cunff et al., 2024e; Parsons et al., 2020; Sonuga-Barke et al., 2024). Furthermore, this approach can help foster a sense of agency and empowerment among neurodivergent students, promoting self-advocacy and reducing the stigma associated with neurodiversity in education (den Houting et al., 2021; Gillespie-Lynch et al., 2017).

The FEDIS+R framework takes a neurodiversity-informed perspective, focusing on interventions that address the neurodivergent traits common to a range of conditions (Armstrong, 2010; Chapman, 2020; Clouder et al., 2020). For example, providing clear, structured instructional materials, reducing distractions, and offering multiple ways to engage with content are strategies that can benefit all neurodivergent students, regardless of specific diagnosis. By focusing on universally accessible design principles, this educational framework seeks to create an inclusive learning environment that supports all students.

4 Discussion

The rapid growth of online learning has presented both opportunities and challenges for supporting neurodivergent students in higher education. The following discussion based on a short PESTEL analysis provides a preliminary evaluation of the broader political, economic, social, technological, environmental, and legal factors that might impact the implementation of the FEDIS+R framework, as well as potential avenues for future research.

First, the political landscape plays a significant role in shaping policies that affect neurodivergent students. Legislation and educational guidelines aimed at supporting neurodiversity and inclusion vary across regions, which influences the ability of institutions to implement the FEDIS+R framework. For example, in some countries, governments have introduced policies that promote inclusive education practices, ensuring that neurodivergent students have access to appropriate resources and accommodations (Parsons et al., 2020). However, in regions where such policies are absent or underdeveloped, the lack of legislative support can hinder the adoption of inclusive frameworks (Chown et al., 2017). The success of the FEDIS+R framework depends on political will and the enactment of policies that prioritize the needs of neurodivergent students. Future research could explore how shifts in government priorities and

political support for inclusive education initiatives impact the implementation of cognitive load management strategies in online learning environments.

Economic constraints also play a crucial role in determining how effectively institutions can implement strategies to manage cognitive load for neurodivergent students in online learning. The FEDIS+R framework suggests targeted interventions, such as offering accessible content formats, personalized instructional delivery, and structured support systems, all of which may require significant financial investment. For example, minimising extraneous cognitive load through revised instructional materials and training staff to implement cognitive load management strategies all carry associated costs (Jones et al., 2023). Institutions with limited financial resources may struggle to meet these economic demands, potentially resulting in increased cognitive load for neurodivergent students who lack the necessary support. In contrast, well-funded institutions can provide more robust accommodations and tools, allowing for a more effective implementation of the FEDIS+R framework and thus reducing extraneous cognitive load for students. This financial disparity risks exacerbating inequalities in how neurodivergent students experience online learning. Furthermore, the availability of funding for neurodivergent students themselves, such as scholarships or subsidies for assistive technologies, is critical in providing equitable access to inclusive learning environments (Griful-Freixenet et al., 2017). As such, policymakers might consider establishing dedicated funding streams to help under-resourced institutions adopt such inclusive educational frameworks, ensuring that all students can benefit from reduced extraneous cognitive load and a more accessible online learning experience.

Social attitudes toward neurodiversity also play a key role in shaping how well inclusive educational frameworks can be implemented. Public awareness and acceptance of neurodivergent students' needs are critical in ensuring that inclusive practices are embraced by both educators and the students themselves (Satterfield et al., 2015). In some cases, neurodivergent students face stigma or misunderstanding, which can create additional barriers to their full participation in online learning environments (Rosqvist et al., 2019). By fostering a culture of inclusivity, institutions can promote the successful adoption of frameworks that support cognitive load management for neurodivergent students. Fortunately, despite many remaining challenges, the societal demand for inclusive education is growing, which may drive institutions to adopt frameworks such as FEDIS+R as part of their commitment to equity and diversity in education (Ainscow, 2020; Ferguson, 2008).

Technological advancements present both opportunities and challenges for implementing the FEDIS+R framework. Emerging technologies, such as artificial intelligence (AI), virtual reality (VR), augmented reality (AR) have the potential to create more personalized and accessible online learning environments for neurodivergent students (Hutson, 2022; Zhang et al., 2022). These tools allow for flexible learning experiences that adjust to students' neurocognitive profiles, making online education more inclusive (Kulik and Fletcher, 2016; Xie et al., 2019). Additionally, adaptive technologies such as text-to-speech and speech-to-text tools, can make content more accessible (Erdem, 2017; Lyamuremye et al., 2023). However, the implementation of these technologies comes with challenges, such as concerns about cost, accessibility, and data privacy (Jones et al., 2023). Moreover, offering too many accommodations without clear guidance can overwhelm students and increase cognitive load by forcing them to frequently switch between formats, leading to distraction (Chrysochoou et al., 2021; Cole et al., 2024; Boyd, 2024; Landry, 2021). To mitigate this, practitioners should aim to provide focused and concise information, as well as clear guidance on how to effectively use the available accommodations (Cai and Richdale, 2016). By thoughtfully leveraging emerging technologies as part of instructional design, educators can create more inclusive and equitable online learning experiences for all students, regardless of their neurocognitive differences.

Environmental factors, including the ongoing effects of the COVID-19 pandemic, have significantly reshaped online education, with implications for neurodivergent students. The rapid shift to remote learning highlighted both the potential of online platforms to support flexible education and the challenges of designing inclusive digital environments that minimize cognitive load (Adnan and Anwar, 2020). For many neurodivergent students, the abrupt transition to remote learning increased their cognitive load due to poorly designed digital environments, inaccessible content, and lack of structured support (Le Cunff et al., 2024b). As online learning becomes more entrenched in higher education, institutions must consider how to design flexible yet inclusive learning environments that can adapt to both global shifts and the evolving needs of neurodivergent students. Future research might further explore how environmental factors, such as prolonged isolation and changing work-study arrangements, impact neurodivergent students' cognitive load and well-being.

The legal landscape surrounding accessibility and inclusion in education is critical for ensuring that neurodivergent students receive adequate support. In many regions, laws such as the Equality Act (UK) and the Americans with Disabilities Act (US) require institutions to provide reasonable accommodations for students with disabilities, including those who are neurodivergent. However, the enforcement and interpretation of these laws vary, and gaps in legal protections can limit the ability of some institutions to fully implement inclusive educational frameworks (Chown et al., 2017). Additionally, issues related to privacy and disclosure present significant legal challenges. Many neurodivergent students may be hesitant to disclose their diagnosis due to concerns about stigma or how their personal information will be used, which can hinder their access to necessary accommodations (Brown, 2020; Kerschbaum et al., 2017). Institutions must navigate these complexities while ensuring that students' rights to privacy and confidentiality are protected (Fletcher-Watson et al., 2019). By working closely with legal experts, educators and policymakers can ensure that their implementation of the FEDIS+R framework aligns with local and international legal standards for accessibility, while also respecting students' autonomy and confidentiality regarding their neurodivergent status.

This analysis highlights the complexity of implementing the FEDIS+R framework in diverse educational settings. Each external factor—whether political, economic, social, technological, environmental, or legal—plays a significant role in shaping the success of this framework. While some institutions may have the resources and support needed to fully adopt inclusive educational frameworks, others may face barriers that require additional attention from policymakers and stakeholders. Addressing these external factors through informed decision-making will be essential for creating inclusive online learning environments that support neurodivergent students effectively.

5 Limitations and future directions

The FEDIS+R Framework was developed through the integration of theoretical and empirical research and designed in collaboration with a Research Advisory Board of neurodivergent students. Using Kern's six-step method, it was conceptualized to address cognitive load challenges in online learning, with a PESTEL analysis to evaluate its applicability in real-world educational contexts. However, it is important to view it as a tentative model that includes the critical need for further research and development. The framework is grounded in the current understanding of cognitive load theory (Sweller et al., 2019) and neurodiversity (Armstrong, 2010; Knoop-van Campen et al., 2020; Le Cunff et al., 2024a), but as research in these areas evolves, so too must the framework. Additionally, while the PESTEL analysis provides a preliminary review of external factors, it is not exhaustive, and other influences, such as cultural differences, may also affect the framework's implementation (Parsons et al., 2020; Griful-Freixenet et al., 2017). The practical application of the FEDIS+R framework may differ significantly between institutions depending on available resources, staff training, and institutional commitment to inclusion (Chown et al., 2017; Fletcher-Watson et al., 2019). Therefore, future research should explore how the framework can be adapted to diverse educational settings and evaluate its effectiveness in reducing cognitive load for neurodivergent students.

While the FEDIS+R framework does not offer condition-specific interventions, we believe that a neurodiversity-informed approach offers a flexible and inclusive way to address the shared cognitive challenges of neurodivergent students (Armstrong, 2010; Chapman, 2020; Mirfin-Veitch et al., 2020). Although our approach aims to provide immediate, broadly applicable strategies that benefit all neurodivergent students (Clouder et al., 2020), future research may explore how tailored interventions for specific conditions such as ADHD or dyslexia can be integrated into a more comprehensive framework.

Overall, advancing inclusive online education for neurodivergent students requires a collaborative effort among researchers, policymakers, and practitioners. Researchers play a critical role in generating evidence-based knowledge about the experiences, challenges, and effective strategies for supporting neurodivergent students in online learning environments (Clouder et al., 2020). Policymakers, in turn, can use this research to inform the development of inclusive education policies and guidelines that prioritize the needs of neurodivergent students and ensure equitable access to online learning opportunities (Chown et al., 2017; Parsons et al., 2020). Practitioners, such as educators, instructional designers, and support staff, can apply research findings and policy guidelines to create inclusive online learning environments that accommodate the diverse needs of neurodivergent students (Griful-Freixenet et al., 2017; Satterfield et al., 2015).

However, effective collaboration among these stakeholders requires open communication, shared goals, and a commitment to participatory research and decision-making processes that involve neurodivergent students as active partners (Rosqvist et al., 2019; Fletcher-Watson et al., 2019). By engaging neurodivergent students in the research process and seeking their input on the design and implementation of online learning environments, researchers, policymakers, and practitioners can ensure that their efforts to manage cognitive load are grounded in the lived experiences and needs of neurodivergent students. Through cross-disciplinary collaboration and the meaningful inclusion of neurodivergent voices, stakeholders can work together to create a more inclusive and equitable future for online education that effectively supports the learning and well-being of all students, regardless of their neurocognitive differences.

6 Conclusion

The FEDIS+R framework offers a preliminary set of recommendations for managing cognitive load in neurodivergent students within online learning environments. By focusing on six key areas—format, environment, delivery, instruction, support, and research—the framework provides educators and policymakers with a structured approach to creating more inclusive and accessible online learning environments. The accompanying PESTEL analysis reveals critical external factors that might influence the successful implementation of the framework. While the framework holds potential, it should be viewed as an evolving model that requires further research to adapt to diverse educational settings and respond to new developments in the understanding of cognitive load and neurodiversity. Future research should explore the framework's application across various educational contexts, examine its long-term effectiveness in reducing cognitive load, and assess its adaptability in response to institutional and cultural change. Moreover, as emerging technologies continue to shape the landscape of online education, it is crucial that researchers, policymakers, and practitioners work together to ensure that these innovations are thoughtfully leveraged to create more inclusive and equitable learning opportunities for all students, regardless of their neurocognitive differences. This requires a commitment to participatory research centred on the voices and experiences of neurodivergent students.

Author contributions

AL: Writing – original draft, Writing – review & editing. BM: Writing – review & editing. CG: Writing – review & editing. EA: Writing – review & editing. RF: Writing – review & editing. VG: Writing – review & editing. ED: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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