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WIP: Examining the Experiences of Neurodivergent Learners in STEM Fields in Their Transition to and Engagement with Online Learning

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I am currently a senior at Clemson University, majoring in Biology and pursuing a pre-medical track with plans to apply to medical school. I have personally experienced the challenges associated with transitioning to online learning. This research is particularly meaningful to me, as I understand the significant impact such transitions can have on neurodivergent learners. However, I am committed to leading this study objectively, ensuring that my personal experiences do not introduce bias. I will follow all ethical guidelines and research protocols established by Clemson University to maintain academic integrity and ensure the validity of the findings.

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Examining the Experiences of Neurodivergent Learners in STEM Fields in Their Transition to and Engagement with Online Learning

Abstract

The purpose of this Work-In-Progress (WIP) research paper is to investigate the experiences of neurodivergent learners in STEM fields as they transition to online education, addressing a critical gap in understanding how digital learning environments can meet diverse cognitive needs. Neurodivergent learners, defined in this study as individuals with neurological differences such as autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), and dyslexia, often encounter systemic barriers in traditional educational settings. These barriers include sensory overload, rigid standardized instruction, and restricted peer engagement, all of which can impact information processing and social integration. The abrupt shift to online learning during the COVID-19 pandemic intensified these challenges while also introducing opportunities for greater accessibility, flexibility, and tailored learning experiences. Building on the context of pandemic-induced educational shifts, this work contributes to a comprehensive study examining neurodiversity within engineering and computing disciplines at a large southeastern R1 (very high research activity) institution. The research team employs a rigorous mixed-methods approach to analyze these dynamics. Undergraduate researchers initiated this collaborative project in Summer 2023 by conducting a pilot survey of students, staff, faculty, and administrators, which offered baseline insights into neurodivergent learners' experiences relative to their neurotypical peers. The pilot findings guided evidence-based revisions, and a refined survey was deployed in Fall 2024. From that survey's respondents, STEM majors who identify as neurodivergent were invited to participate in interviews about their experiences transitioning to online learning during and after the COVID-19 pandemic. Institutional Review Board (IRB) approval was secured for this work-in-progress study, and participant interviews are underway at the time of writing. In these interviews, participants describe their experiences with remote learning, emphasizing the challenges encountered and adaptive strategies employed throughout the transition from in-person to online education. Aligned with the broader research purpose of addressing diverse cognitive needs, core data collection themes include cognitive load management, peer engagement facilitation, technological barrier mitigation, self-regulation strategies, motivational support mechanisms, and human-computer interaction dynamics. Additionally, this study explores emergent themes that arise during ongoing thematic analysis. The paper presents preliminary findings from interviews with neurodivergent STEM learners, providing insights into their transition to online learning and subsequent engagement with digital education platforms. By identifying challenges and adaptive strategies, this work aims to inform the design of inclusive digital learning environments that address diverse learner needs and advance equity in STEM education.

Introduction

The COVID-19 pandemic catalyzed an unprecedented shift to online education, reshaping interactions within academic environments. This abrupt transition disrupted established learning structures and illuminated longstanding challenges for certain student populations. In particular, neurodivergent learners—individuals with neurological differences such as autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), and dyslexia—faced unique and complex obstacles during this shift. Systemic barriers in traditional classroom settings, including difficulties with standardized instruction, sensory overload, and limited peer engagement, have historically challenged these students. The rapid move to digital platforms further magnified these issues, as familiar supports fell away and new demands emerged. At the same time, the transition introduced novel opportunities such as asynchronous learning options and customizable lecture pacing—features that research suggests may better accommodate diverse cognitive needs. Thus, while the pandemic-induced migration to online learning posed new hardships, it also opened possibilities for more adaptive learning experiences. Against this backdrop, the purpose of this research is to understand and advocate for students who often face greater academic struggles. Neurodivergent learners frequently must exert additional effort to achieve outcomes comparable to their neurotypical peers, as they confront systemic hardships in both society and academia. Recognizing these realities, this study aims not only to highlight the resilience and challenges of these individuals but also to contribute to meaningful improvements in online STEM education. Online education remains a context of both promise and peril for neurodivergent students: it offers flexibility and personalized tools that can accommodate individual learning styles, but it can also exacerbate barriers such as technological complexity, social isolation, and suboptimal platform design. These complexities underscore the need to closely examine the lived experiences of neurodivergent STEM learners during the online transition. By exploring the dual nature of online learning for these students, this research identifies strategies and considerations that can inform equitable practices and drive the ongoing transformation of digital learning environments. Furthermore, the sudden pivot to online education during the COVID-19 pandemic exposed deeper inequities affecting neurodivergent learners. Participants in this study report challenges like cognitive overload, technological barriers, and reduced peer interaction as particularly pronounced in the online setting. Conversely, they also point to helpful features such as lecture playback and asynchronous participation, which afforded increased flexibility and learner control. Preliminary findings emphasize the value of accessible technologies, inclusive instructional design, and active community-building practices. These elements are critical in addressing gaps for neurodivergent learners and ensuring that digital education environments evolve to meet the needs of all students.

Background and Literature Review

Neurodiversity reflects the natural variation in cognitive functioning within the human population, encompassing conditions such as autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), dyslexia, and other neurological differences. This framework shifts the perspective from viewing these conditions as deficits to recognizing them as valuable aspects of human diversity. Within science, technology, engineering, and mathematics (STEM) disciplines, neurodiversity emphasizes inclusive practices that accommodate diverse cognitive styles and learning needs. Research demonstrates that neurodivergent learners contribute unique strengths to STEM fields, including innovative problem-solving, exceptional attention to detail, and advanced pattern recognition capabilities [1]. Despite these strengths, neurodivergent students encounter barriers in conventional educational settings. These include sensory overload, challenges with time management, and limited access to tailored accommodations, often leading to frustration, isolation, and academic underperformance. For instance, the sensory demands of large lecture halls or the unstructured nature of group work can overwhelm students with ASD or ADHD [2]. These challenges highlight long-standing structural barriers in STEM education that predate the shift to online learning. Notably, these persistent issues exemplify academic ableism in higher education [3], wherein institutional norms privilege neurotypical students and marginalize those with different learning needs. Disability justice frameworks posit that meaningful inclusion requires dismantling such systemic barriers and redesigning educational practices to center diverse bodies and minds [4].

Before the shift to digital platforms, neurodivergent students faced substantial difficulties in traditional, in-person STEM courses. Cognitive load was a persistent issue, as lectures often involved high-speed delivery of complex material without adequate opportunities for reflection or individualized pacing [5]. Group projects, a common component of STEM curricula, often lacked structured guidelines that could support neurodivergent learners, leading to additional stress and difficulty in peer collaboration [6]. Standardized assessments favored neurotypical modes of problem-solving, creating additional hurdles for students who process information differently. Given these pre-existing challenges, online learning presented new opportunities and exacerbated barriers for neurodivergent learners. Digital platforms introduced features such as asynchronous modules, playback functionalities, and customizable user interfaces, all designed to address diverse cognitive needs. However, they also introduced new stressors, including increased cognitive load from navigating multiple digital tools, technological limitations, and diminished peer engagement. This study contextualizes how these shifts impacted neurodivergent learners in STEM.

Cognitive load represents a significant issue in digital learning environments, as online courses require students to manage multiple digital tools and navigate complex interfaces. For neurodivergent learners who may already experience challenges with information processing, these demands are taxing. Research emphasizes the necessity of reducing extraneous cognitive load in multimedia learning, reinforcing the argument that designed online courses can affect neurodivergent students [7].

Self-regulation and motivation emerge as common struggles in online settings, where the absence of structured schedules and immediate supervision increases reliance on intrinsic motivation and self-management skills. Neurodivergent learners often experience difficulties maintaining focus and managing time without external support. Further analysis outlines self-regulation strategies that can enhance learning outcomes. This suggests scaffolding techniques—such as structured deadlines and guided feedback—are crucial for supporting neurodivergent learners in online STEM courses [8].

Reduced peer engagement in online education further compounds challenges for neurodivergent learners, as fewer opportunities for collaboration and interaction hinder the development of essential social and professional skills. Virtual learning environments often lack the informal peer interactions in physical classrooms, exacerbating feelings of isolation. Dillenbourg et al. [9] highlighted the weight of collaborative tools in virtual education, yet many online platforms cannot incorporate features that support neurodivergent learners in building peer connections.

Many digital platforms cannot assimilate accessibility features, such as text-to-speech functionality, customizable layouts, or simplified navigation. These design limitations exacerbate learning barriers for neurodivergent students and highlight the urgent need for inclusive design principles in educational technology. Nielsen [10] discusses usability engineering principles, which align with findings that neurodivergent learners benefit from platforms prioritizing adaptive interfaces, intuitive navigation, and personalized learning controls. These deficiencies are evident in STEM education, where complex course material demands high levels of digital engagement.

Neurodivergent learners benefit from educational strategies such as information chunking, visual aids, and intuitive navigation pathways [11]. Studies on self-regulation and motivation highlight scaffolding techniques, including regular feedback, goal-setting tools, and structured schedules, as effective methods for supporting focus, time management, and engagement [12]. Research in human-computer interaction further emphasizes the value of user-centered design in educational technology. Platforms that prioritize accessibility, usability, and adaptability empower neurodivergent learners to engage with content more effectively. Features such as adjustable text size, customizable color schemes, and built-in reminders mitigate common barriers and improve the learning experience [13]. These principles are especially critical in STEM education, where the complexity of course material and reliance on digital platforms necessitate deliberate attention to accessibility.

This study aims to examine the experiences of neurodivergent STEM learners in online education by documenting the challenges they encounter, identifying effective adaptive strategies they employ, and advocating for inclusive policy and pedagogical changes. By understanding the barriers and supports that shape their learning experiences, this research seeks to inform the evolution of more accessible and equitable digital learning environments.

Methodology

This study employed a multi-phase, mixed-methods research design to examine the experiences of neurodivergent STEM learners transitioning to and engaging with online education. The investigation began with a pilot survey in Summer 2023 targeting a broad cohort of stakeholders (students, faculty, staff, and administrators) at the institution. The pilot survey was designed to identify systemic challenges that neurodivergent learners face compared to their neurotypical peers. Insights from the pilot informed the development of a refined survey instrument that was deployed in Fall 2024. Revisions to the survey focused on inclusivity and specificity, ensuring that questions captured the nuanced experiences of neurodivergent individuals within STEM disciplines.

The research team narrowed the participant pool in this phase to college students enrolled in STEM majors, sharpening the study's focus on higher education learning environments. High school students and individuals from non-STEM disciplines were excluded to maintain this emphasis. No additional criteria regarding online or hybrid course enrollment during the pandemic were applied, thereby preserving a consistent participant pool based solely on neurodivergent identity and STEM affiliation.

With survey data collected, the study progressed to a qualitative phase centered on semi-structured interviews. Survey findings guided the development of the interview protocol, allowing for a targeted exploration of specific online learning challenges and adaptive strategies that emerged from the survey. The team recruited interview participants from among the survey respondents who had indicated neurodivergent identity and were willing to be contacted. To maximize diversity within the interview sample, recruitment efforts extended through multiple channels: institutional email invitations, outreach via student disability services and neurodiversity student organizations, and targeted flyers. This approach helped ensure representation across various STEM fields and demographic backgrounds.

Prior to data collection, Institutional Review Board approval was obtained, and all ethical procedures were observed. Participation was voluntary, and informed consent was collected. Recruitment materials emphasized the voluntary nature of the study and outlined the objectives, procedures, and confidentiality safeguards. Given the potentially sensitive nature of discussing educational challenges, all interviews were conducted via Zoom in a setting comfortable for the participant. Conducting interviews online not only mirrored the context of interest but also facilitated accurate recording and transcription. The research team transcribed all interviews verbatim and reviewed the transcripts for accuracy, strengthening data integrity. To support participant well-being, the team provided each interviewee with a "Mental Health and Well-Being Resources" document containing links to university counseling services, crisis hotlines, and peer support networks. This ensured that participants had access to support should any discussion topics cause distress.

The researchers conducted a comprehensive thematic analysis of the interview data, following the principles of reflexive thematic analysis. Through multiple close readings of transcripts, the research team inductively identified patterns and themes in the experiences described. Five core thematic areas aligned with the research objectives emerged: cognitive load and information processing, peer engagement and social interaction, technological barriers and adaptive strategies, self-regulation and motivation, and human-computer interaction and accessibility. These themes provided an organizing framework to investigate how participants managed the demands of online learning. During coding, the team remained open to additional insights, and indeed a few emergent themes surfaced beyond the initial scope (for example, personal environmental adjustments and STEM-specific challenges, discussed later).

Throughout analysis, the team grounded their interpretation in participants' own words, allowing their narratives to drive understanding of the data. The following Results section presents the preliminary findings organized by the major themes identified. Each theme is illustrated with direct participant quotations and contextualized with explanatory detail. This work-in-progress focuses on these themes to shed light on the supports and barriers neurodivergent STEM learners encountered in the shift to online learning.

Results

This study reveals the multifaceted challenges and effective strategies reported by neurodivergent STEM learners during their transition to online education. The findings are organized by key themes that emerged from the interviews. Within each thematic area, the research team presents participants' experiences in their own words and summarizes common patterns.

Technological Barriers;

Platforms and course organization: Participants reported substantial technological barriers, particularly involving the online platforms used for coursework. In the early stages of the pandemic, many instructors and students had to adapt to tools like Canvas, Zoom, and Microsoft Teams with little preparation. Several students noted that these platforms often lacked essential features or that existing features were underutilized. For instance, one participant pointed out that Microsoft Teams initially did not support breakout rooms or real-time hand-raising functions, hindering interactive engagement. Moreover, instructors' inconsistent use of learning management systems (LMS) led to accessibility issues. Variability in course organization within the LMS made it difficult for students to locate assignments and resources, adding unnecessary cognitive load. In one interview, a student remarked, "So many of my instructors do things in completely different ways… each semester, you're also learning how to use their version of Canvas and where everything's saved." This inconsistency exacerbated the cognitive effort required to navigate each course. Routine tasks such as scanning and uploading documents posed additional challenges, contributing to frustration and decreased efficiency. Furthermore, discrepancies in instructors' proficiency with digital tools resulted in uneven course delivery experiences, sometimes disrupting the learning process. Participants emphasized that when instructors were not adept with the platform's features, the burden often fell on students to adapt to each instructor's system, creating a recurring hurdle each term.

Social Isolation and Peer Engagement;

Lack of informal interaction: Another key theme that emerged was social isolation and diminished peer engagement in virtual learning environments. Participants noted that online classes provided far fewer opportunities for casual interaction than in-person classes. "The last thing I want to do is an online group project," one participant bluntly stated, highlighting a common reluctance to engage in virtual collaboration without established peer connections. In traditional classrooms, neurodivergent students might benefit from organic interactions (e.g., chatting before class or study groups forming naturally). In contrast, online breakout rooms often lacked those organic dynamics. Students described breakout room sessions as awkward and largely silent, with peers hesitant to speak up, making collaboration difficult and often unproductive.

Communication challenges: The absence of in-person nonverbal cues further compounded the issue for those who rely on visual or contextual information to communicate. Delays in response times over chat, peers keeping their cameras off during group work, and minimal instructor guidance in breakout discussions all reduced the richness of interaction. Many participants experienced a deepening sense of disconnection and exclusion in the online setting. They felt it was easy to become "out of sight, out of mind." One student shared that without body language or immediate feedback, "you can't tell if anyone is understanding you or if they care… it feels like talking into a void." This social disconnect not only affected their motivation but also their ability to learn through peer discussion and teamwork.

Self-Regulation and Motivation;

Challenges with time management: Participants described significant self-regulation and motivational struggles in the online learning environment. While asynchronous learning and recorded lectures provided flexibility, they also removed the external structures that many students relied on. Without the routine of attending classes in person, some neurodivergent learners found it harder to maintain focus and manage their time. Procrastination became a common hurdle. Several participants admitted to experiencing stress due to last-minute efforts to complete assignments. They noted that being at home, an environment associated with relaxation or leisure, further hindered their ability to switch into “work mode.” “The transition to remote learning meant I had to rely almost entirely on my own motivation,” one student explained, “and that was a challenge when my bedroom is also my classroom.” Indeed, one student confessed, “I usually don’t really pay much attention [to recorded lectures]… it’s kind of hard to care when it’s on your computer instead of you going there in person,” illustrating the decline in engagement and motivation when face-to-face accountability was removed.

Lack of external accountability: Many participants emphasized that the lack of structured schedules and immediate feedback in online courses undermined their focus. In a physical class, simply being present in a learning-centric environment or having a professor notice your absence can provide subtle accountability. Online, especially with asynchronous components, those checks were gone. As one interviewee put it, “Deadlines are my biggest motivator at this point. Without regular class meetings, it was too easy to let things slide until a due date loomed.” This quote underlines how critical clear deadlines and periodic check-ins were for sustaining engagement. Students who struggled with executive functioning found that online learning required a level of self-discipline that was difficult to muster consistently.

Effective Strategies;

Structured scheduling and tools: A common thread was the creation of structure in a structure-light environment. Many neurodivergent students became adept at self-scheduling. They leveraged tools such as Google Calendar or scheduling apps to organize their tasks and set their own interim deadlines. By visualizing their week and allocating time blocks to each course or project, they imposed order on the flexibility of online learning. Some used the Pomodoro Technique (working in focused intervals with short breaks) to maintain concentration. One participant mentioned using a timer app to enforce 25-minute study sessions followed by 5-minute breaks, helping to manage focus and prevent burnout. These personalized time-management techniques were often learned through trial and error and by seeking advice from disability services or mentors.

Leveraging lecture recordings and playback: Neurodivergent learners also took unique advantage of recorded lectures and playback features. Several students commented that having lecture videos available to pause and rewind was a “game changer” for comprehension. They could review complex material at their own pace, something not possible in a live classroom. One participant shared that they routinely watched recordings at a slightly slower speed when a topic was difficult, and conversely, sped up portions that were review for efficiency. The ability to add captions or use transcripts (when provided) also catered to different processing preferences. However, students noted a caution: overusing playback speed adjustments (e.g., always watching at 2x speed) sometimes led to reduced understanding, highlighting the importance of balance in digital learning strategies. In general, the availability of recorded content allowed students to tailor the learning experience to their needs, which many cited as a significant benefit of online learning.

Environmental Adjustments: Creating dedicated workspaces: Many neurodivergent learners found that working in the same space where they relax or sleep made it difficult to switch into an academic mindset. To counteract this, they established dedicated study areas. For students living at home or in dorms, this sometimes meant a specific corner of their room designated for classes, or going to a quiet location like a library or campus study room when possible. “Working in my bedroom was hard, so I had to go to the library or a space that’s not where I relax to actually focus,” one participant reflected. Changing the environment signaled a mental transition to “school mode,” which improved concentration. Those who couldn’t leave their room often tried rearranging the setup—such as facing a desk toward a wall or window rather than the bed, to create a psychological separation between work and leisure space.

Minimizing distractions: Participants also adopted tactics to reduce sensory and digital distractions. Some mentioned using noise-cancelling headphones or specific types of background music (like white noise or instrumental music) to drown out household noises. On the digital front, students would close non-essential tabs, put their phone in another room, or use apps that block social media during study periods. Setting clear rules for themselves, like “no YouTube on the side unless it’s class-related,” helped maintain focus. A couple of students noted that they became more attuned to their sensory needs; for example, one student realized that a cluttered desk made them anxious, so they tidied up and kept only relevant materials at hand during classes.

STEM-Specific Challenges and Recommendations;

Participants noted that certain challenges were amplified in STEM courses due to the nature of the content and typical teaching methods in these fields. They also offered recommendations, from their perspective, on addressing these issues.

Cognitive load in dense material: STEM courses are often content-heavy, with dense lectures and complex problem sets. In the online context, some instructors attempted to cover the same quantity of material without pauses or interactive questions, leading to even greater cognitive load on students. Participants described feeling overwhelmed by back-to-back slides or long coding demonstrations on screen. Without the usual class pacing (where an instructor might read the room and slow down, or where students could quickly ask a clarifying question), many just fell behind during live sessions. One participant illustrated this overload by noting that on a typical course site “there’s like a million tabs… only like three of them you need. It’s definitely overloading.” This comment, while about the course website, metaphorically captures how excess information and options can overwhelm learners—an issue that extends to course content presentation as well.

Faculty training and awareness: A significant point raised was the variability in how well instructors adapted STEM teaching for online formats. Some professors were praised for creativity (such as sending lab kits to students’ homes or using virtual whiteboards for problem-solving sessions). However, others simply lectured for hours or relied on automated grading of assignments without feedback. Participants felt that many professors “don’t know how to make things accessible” unless they receive guidance. One student emphasized the need for faculty training in inclusive online teaching, noting that instructors might not be aware of the compounded difficulties their neurodivergent students face. For example, providing multiple examples, breaking lectures into smaller chunks, or using visual aids can benefit everyone, but especially those who struggle with abstraction or sustained attention. When professors did these things, students noticed a positive difference.

By adopting structured support systems, including progress tracking tools, clear deadlines, regular feedback, and guided study frameworks, educational institutions can help address these challenges. And by integrating innovative strategies tailored to the technical demands of STEM education, institutions can foster inclusive, effective learning environments for all students.

Discussion

Participants in this study underscored that current online learning platforms and practices often lack the flexibility to accommodate diverse cognitive needs. The findings highlight a tension between the rigidity of many online systems and the varied requirements of neurodivergent learners. Many of the challenges described reflect a broader issue: educational technologies and pedagogies frequently assume a one-size-fits-all student, thereby inadvertently disadvantaging those who diverge from the neurotypical norm.

One recurring issue centered on the design of learning management systems and automated tools. Several students mentioned how features like automated grading or rigid quiz timers penalized them for minor quirks (e.g., input formatting issues) rather than truly assessing their understanding. This reflects a deficit-based approach embedded in some digital platforms, wherein the burden is on the student to conform to the system’s demands. Such an approach is rooted in ableist norms of academia [3], prioritizing standardization and efficiency over accessibility and individual differences. The need for institutions to re-examine digital learning policies through the lens of universal design principles [10] is evident. If platforms allowed more adaptable response inputs or if instructors could easily override automated settings to accommodate students (for example, by granting flexible deadlines or alternative submission formats), many neurodivergent learners would face fewer unnecessary obstacles.

Another major theme in the discussion is the impact of cognitive overload on learning outcomes. Consistent with cognitive load theory, Mayer and Moreno [6] demonstrate in their work that reducing extraneous cognitive demands is critical for all students, and especially for neurodivergent learners who might be managing sensory sensitivities or working memory challenges. The participants reported that online courses sometimes increased extraneous load through poor course organization, an overabundance of digital materials, and lack of interactive engagement. One student's observation that a course site had "a million tabs" but only a few useful ones exemplifies how cluttered interfaces can overwhelm users. The implication is that online course design should prioritize clarity and simplicity: streamline navigation, declutter course pages, and use user-friendly multimedia formats. By doing so, educators can alleviate unnecessary cognitive strain on neurodivergent learners, allowing them to devote more mental resources to the actual content learning (germane load).

Self-regulation and motivation emerged as key determinants of success in the online setting, aligning with Zimmerman's theories of self-regulated learning [7]. The data indicate that neurodivergent students thrive when structured scaffolding mechanisms are in place to reinforce goal-setting, time management, and sustained engagement. In the absence of external scheduling (like fixed class times), many struggled, as noted earlier. This finding suggests that integrating structured supports into online courses can benefit these learners. For instance, instructors might break large projects into interim milestones, provide optional weekly checklists, or encourage use of progress-tracking tools. One participant's comment, "I've been really struggling with motivation… deadlines are my biggest motivator at this point," underscores the critical role of external benchmarks for sustaining engagement. Accordingly, instructors could set up more frequent low-stakes deadlines to create a rhythm, rather than leaving everything to a midterm and final exam. While some students independently used calendars and timers, others did not or could not. Thus, course-level scaffolding can ensure no student falls through the cracks due to self-regulation difficulties.

The scarcity of peer engagement in online STEM courses also shaped learners' experiences. In line with Dillenbourg et al.'s emphasis on structured peer interaction for active learning [8], the participants found virtual classrooms isolating and not conducive to teamwork or community. The lack of informal academic discourse hindered group project dynamics and the formation of an academic identity or sense of belonging. This is particularly concerning because a sense of community can buffer against other stressors; without it, many neurodivergent students felt detached from their studies. Addressing this issue requires intentional design of interactive elements: guided discussion forums, structured breakout room tasks, and collaborative problem-solving activities can facilitate meaningful peer interaction. In practice, something as simple as assigning rotating roles in breakout groups or having a standing weekly "study buddy" system could impose just enough structure to get students talking. The discussion indicates that peer engagement is not a trivial add-on but a core component of learning that was diminished in the remote pivot, and it needs to be rebuilt in online formats to support both learning and socio-emotional well-being.

Human-computer interaction (HCI) and platform usability defined a significant portion of participants' experiences. Nielsen's usability principles stress user-centered design [9], yet many STEM learning platforms fell short in providing intuitive navigation and adaptive interfaces. The findings show an urgent need for adopting universal design in digital learning tools. When platforms lack features like adjustable text formatting or integrated text-to-speech, neurodivergent learners are either forced to find third-party workarounds or simply endure suboptimal conditions. This discussion reinforces that accessibility features should not be considered optional or specialized—they should be built-in and standard. Interestingly, those participants who took the initiative to customize their environment and tools demonstrated what is possible when flexibility exists (e.g., using browser extensions to adjust appearance). If platforms offered those customization options by default, it would level the playing field. For example, an LMS could allow each user to choose a “low-distraction” view that hides unused tabs, or enable notifications that are customizable in timing and mode (visual vs. auditory) to help with reminders without being overwhelming.

A key insight from participant narratives was autonomy in online learning success. Many neurodivergent students found that customizable learning experiences—such as the ability to pause, rewind, and adjust playback speed—enhanced comprehension and reduced anxiety. However, others struggled with self-paced formats when courses lacked clear instructional guidance or progress-tracking mechanisms. These findings suggest that a balanced approach to course design—combining flexibility with structured scaffolding—is essential for optimizing learning outcomes for neurodivergent students.

The reliance on digital data collection tools introduced inherent limitations to this study. As participation required reliable internet access and a certain level of digital literacy, students with technology-related barriers or discomfort with virtual communication may have been underrepresented. Future studies should incorporate multimodal research methods, including in-person interviews, observational studies, and hybrid focus groups, to capture a broader range of neurodivergent experiences.

In sum, the discussion highlights that the challenges neurodivergent learners faced are not isolated issues; they connect to broader theoretical and design considerations in education. The experiences of these students illustrate the consequences of designs that assume a narrow range of learner profiles. Conversely, their adaptive strategies and suggestions point towards more inclusive approaches: applying universal design for learning, enhancing teacher training in online pedagogy, simplifying digital interfaces, and fostering genuine community online. By linking these insights to established theories and principles, this work provides a foundation for rethinking online STEM education in a way that better serves neurodiverse populations.

Practical Implications

To create inclusive online learning environments that support neurodivergent STEM students, several institutional strategies should be prioritized based on the findings:

First, improve course standardization and platform usability to reduce cognitive load. Many participants described the inconsistent organization of digital course materials as a major barrier to learning, requiring significant mental effort to navigate. Instructors should ensure that course content is structured in a clear, logical manner (for example, using a consistent module format each week) and that instructions for assignments are explicit. Wherever possible, departments or programs can adopt template course layouts in the LMS so students encounter a familiar structure across different classes. Faculty training on how to effectively use the LMS is crucial. By standardizing where students can find syllabi, readings, assignments, and lecture recordings, we eliminate one layer of uncertainty. Additionally, simplifying course navigation (hiding unused menu items, labeling sections clearly, etc.) can prevent the “million tabs” overload scenario. In short, usability matters: courses should be designed with an eye towards ease-of-use, which will particularly benefit students who struggle with executive function and organization.

Second, enhance accessibility features within digital platforms. Online learning systems should integrate and promote customizable interfaces and assistive functionalities. As indicated by participants’ experiences, features like adjustable text size, color contrast settings, text-to-speech options, captioned recordings, and playback speed controls are not just conveniences but sometimes necessities. These tools empower neurodivergent learners to engage with content in the mode that best suits them (e.g., listening vs. reading, or slowing down a lecture to take detailed notes). Institutions should work with platform vendors or leverage available settings to ensure such features are active and easily discoverable by students. In some cases, procuring third-party tools or browser extensions and training students in their use may be beneficial. It is also advisable for instructors to explicitly inform students of accessibility options (for instance, pointing out that a video has captions or that transcripts are provided). Collaboration with usability experts and neurodivergent students during platform selection or LMS updates can provide valuable insights into necessary improvements. Ultimately, making the digital environment more flexible will reduce unnecessary barriers.

Third, strengthen peer engagement strategies in online STEM courses. The social isolation reported calls for deliberate facilitation of student interaction. Educators can implement structured yet low-pressure opportunities for collaboration. For example, guided breakout sessions during live classes (with clear tasks or discussion prompts) can encourage participation more effectively than unguided breakouts. Setting up small group discussion forums or study pods that persist throughout the term allows students to build connections. Collaborative learning projects should be scaffolded: instructors might assign initial ice-breaker activities or brief group quizzes to build familiarity before expecting full project teamwork. Moreover, offering multiple modes of interaction can help—some students might engage more via written discussion boards, while others prefer live video discussion. Providing synchronous and asynchronous options ensures students can engage at their own comfort level and pace. The goal is to simulate the community aspect of a classroom: consider virtual "hallway conversations" by leaving Zoom sessions open a few minutes before/after class for casual chat, or using class-wide messaging apps (with guidelines) to let students help each other.

Fourth, implement personalized support structures to assist with self-regulation challenges. Many participants emphasized the difficulty of managing time and sustaining motivation without external accountability. Institutions and instructors can help recreate some of the scaffolding lost in remote learning. This could include periodic check-ins: for instance, instructors or TAs sending a quick mid-week message ("How are you progressing on this week's assignment? Need help?") or using learning analytics to spot disengagement early and reach out. Structuring courses with incremental deadlines (e.g., weekly quizzes, staged project submissions) provides regular milestones that keep students on track. Instructors might incorporate brief self-assessment surveys where students report their own progress or struggles; this not only prompts reflection (a self-regulation strategy) but also alerts the teaching team to those needing assistance. Optional virtual study halls or co-working sessions could be offered, where students can quietly work in a Zoom room and ask questions if needed—mimicking the experience of doing homework in a supervised setting. Additionally, universities should continue and expand training for faculty in inclusive teaching practices and neurodiversity awareness. By equipping educators with strategies to support executive functioning (like posting reminders or providing sample schedules for completing larger tasks), the institution proactively addresses challenges before they escalate.

Fifth, invest in professional development for faculty to build capacity in inclusive online pedagogy. The findings suggest that instructors vary widely in their ability to adapt STEM instruction for neurodiverse learners. Regular workshops or seminars can expose faculty to universal design for learning (UDL) principles and practical techniques for online teaching. For example, training could cover how to make Zoom sessions more interactive, how to caption videos or use transcripts, how to handle accommodations in an online setting, and how to identify signs of student disengagement or distress in virtual environments. Sharing success stories or strategies among faculty (such as an internal forum or resource site for teaching online STEM courses) could diffuse effective practices. It's also valuable to include student voices in these trainings: a panel of neurodivergent students discussing what helped or hindered them can leave a strong impression on instructors designing their courses. The institution should recognize and reward faculty who innovate in inclusive teaching—this creates an incentive to prioritize these efforts. By building a culture of awareness and skill around neurodiversity, universities enable professors to proactively design courses that don't just accommodate neurodivergent learners, but truly empower them.

Implementing these recommendations can make online STEM education more accessible and effective for neurodivergent students, and indeed for all students. Many of these practices align with general good teaching: clear organization, multiple engagement methods, timely feedback, and supportive community. The difference is that for neurodivergent learners, these elements are often the deciding factor in whether they can participate on equal footing. Institutions that take these steps will move closer to equity in educational outcomes, ensuring that the shift to digital learning environments does not leave neurodivergent learners behind.

Future Research

While this work provides valuable preliminary insights, further research is necessary to explore the long-term academic and professional outcomes for neurodivergent learners in online STEM education. This study, being a work-in-progress, raises several questions that warrant deeper investigation:

Individual differences within neurodivergent profiles: Future studies should investigate how students with different neurodivergent profiles (e.g., ADHD vs. autism spectrum, or combinations of neurodivergences) interact with various digital learning tools. Do certain platforms or features pose specific challenges to one group more than others? For instance, are students with ADHD more affected by the absence of immediate interaction, whereas autistic students might be more impacted by sensory overload in interfaces? Understanding these nuances can help tailor interventions. Research might use a larger sample to compare experiences across neurodivergent subgroups, looking for patterns in preferences or pain points.

Instructional approaches and learning outcomes: Another avenue is to examine which instructional approaches maximize engagement, retention, and academic performance among neurodivergent students online. This could involve experimental or quasi-experimental studies where certain inclusive strategies are implemented in some course sections but not others, measuring the difference in outcomes for neurodivergent learners (and by extension, all learners). For example, one could test the impact of weekly structured peer discussion sessions on course completion rates for students with known executive functioning challenges. Similarly, exploring adaptive learning technologies (like AI-driven tutoring systems or interactive simulations) – how do neurodivergent students respond to these, and can these tools be tuned to better suit them? Emerging technologies (virtual reality labs, intelligent tutoring) offer exciting opportunities to enhance accessibility and personalization in STEM education. Research should explore how these tools can be leveraged or modified to maximize usability for neurodivergent learners.

Faculty perceptions and institutional barriers: More research is needed to assess faculty attitudes toward neurodiversity in digital education and to identify institutional barriers to implementing inclusive practices. Surveys or interviews with instructors could reveal misconceptions or knowledge gaps that need to be addressed (for example, an instructor might not realize why a student turning off their camera could be related to sensory issues). Additionally, investigating institutional policy—such as how accommodation requests are handled online, or whether there are incentives/disincentives for faculty to modify courses—would highlight structural factors. Understanding faculty experiences during the online transition (what worked for them, what training they felt they lacked) could inform targeted professional development.

Methodological expansion: Expanding research methodologies will be critical to capturing the diverse experiences of neurodivergent students. This study relied on virtual interviews, which may have excluded students with limited internet access or those uncomfortable with video calls. Future studies should incorporate multimodal data collection methods to broaden participation. This could include in-person interviews (when feasible), written diaries or video blog submissions by students documenting their online learning routines, and longitudinal case studies following students over multiple semesters to see how their strategies and needs evolve. Observational research is another rich approach—one could observe recorded class sessions or analyze LMS usage logs (with permission) to see patterns in how neurodivergent students engage (e.g., do they pause videos more often, access materials at different times, etc.). Such data can triangulate self-reported experiences with behavioral evidence.

Long-term outcomes and career trajectories: It is also essential to explore the long-term impact of online learning on neurodivergent students' academic trajectories and career readiness. For example, did the challenges of online learning lead to any shifts in major (did some leave STEM fields or slow down their course load)? Conversely, did any find the online format beneficial enough that they excelled and maybe continued into online graduate programs or remote STEM work? Longitudinal research tracking neurodivergent students' academic performance, retention in STEM majors, graduation rates, and entry into STEM careers will help determine how digital education experiences influence their professional success. This could highlight if certain support during college has downstream effects on maintaining interest and confidence in STEM.

Overall, further research should build on these findings by diving deeper into specific neurodivergent experiences, testing the effectiveness of inclusive interventions, and examining the broader educational journey of neurodivergent students in a post-pandemic landscape. The knowledge gained will not only fill theoretical gaps in the team's understanding of neurodiversity in online learning but will also guide practitioners and policymakers in creating learning environments where all students can thrive.

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