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Breaking barriers in education: leveraging 3E approach and technology to foster inclusion for SEN students

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Advances in embodied design highlight the interconnection between the brain, body, and environment in shaping learning experiences, emphasizing the potential of multimodal perception in enriched sociomaterial and technological contexts. Despite growing evidence in this area, traditional educational systems remain anchored in transmissive and cognitivist models, perpetuating barriers to equitable learning, particularly for students with special educational needs (SEN), such as Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), and Specific Learning Disabilities (SLD). In response to these challenges, post-cognitivist frameworks, including embodied, enactive, and environmentally scaffolded cognition (3E) as well as SpEED (Special Education Embodied Design), provide essential foundations for rethinking inclusive educational design. This perspective article explores the role of active teaching methodologies and innovative technologies in shaping a holistic framework to support inclusive learning design. This framework leverages immersive technologies, mobile applications, and artificial intelligence to scaffold multimodal learning experiences that meet the diverse needs of students with SEN. Through a proof-of-concept based on illustrative cases, this article presents a theoretical contribution to guide the design of inclusive and technology-supported learning environments aligned with the 3E approach, fostering engagement, equity, and personalized learning for students with SEN.

KEYWORDS

3E approach, special educational needs, inclusive education, active methodologies, digital technologies, embodied design

Introduction

In the 21st century, formal education faces a structural anachronism: pedagogical methodologies and cognitive theories from the 20th century, shaped by 19th-century assumptions, continue to be applied in classrooms. This misalignment not only hinders pedagogical progress but also weakens the ontological and epistemological foundations of teaching and learning (Videla and Veloz, 2023). Traditional approaches, grounded in dualistic and reductionist conceptions of cognition, which view the brain as a separate entity from the body, have perpetuated a disconnection between brain, body, and environment (Pessoa, 2023). Contemporary neuroscience has refuted these misconceptions, emphasizing that cognition is a dynamic, embodied, and situated system that emerges from mutualistic relationships between the organism and its environment (Parada, 2018). Post-cognitivist perspectives, notably the 4E approach —embodied, enacted, embedded, and extended— (Newen et al., 2018) and the 3E approach —embodied, enacted, and environmentally scaffolded— (Parada et al., 2024), build upon and deepen this view, critically challenging the foundations of neurocentrism in explaining phenomena within ecologically valid contexts.

The paradigm shift from a brain-centered to a holistic model that integrates brain, body, and environment has profound implications for education, particularly in developing pedagogical design principles that address the increasing diversity of the classroom (Parada et al., 2024; Videla et al., 2025). Inclusive design methodologies must not only consider cognitive diversity but also integrate technologies and resources capable of scaffolding personalized and accessible learning experiences across varied contexts (Varsik and Vosberg, 2024). This concept is grounded in the notion that context modulates individuals' actions and cognitive functioning, and individuals, in turn, shape their interactions with the context through dynamic brain–body-environment couplings constituted by transient physiological and environmental mechanisms (Hassinger-Das et al., 2021). Educational environments based on environmental scaffolding practices can enhance learning opportunities for sensory-diverse individuals by incorporating suggestive technologies and contexts (Parada et al., 2024).

Technologies offer opportunities for educators to create environments that face persistent barriers in traditional educational settings that can be challenging for students with conditions such as Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), and Specific Learning Difficulties (SLD). In particular, Virtual Reality (VR) and Augmented Reality (AR) offer safe, controlled simulated environments that allow users to practice social and emotional skills in realistic scenarios (Liu et al., 2017). Mobile applications like Octostudio encourage children and adolescents to create interactive projects grounded in their interests, cultural contexts, and personal experiences (Scratch Foundation, 2024). AI-driven chatbots provide personalized assistance, flexibility, and accessibility, adapting to diverse interests and needs anytime and anywhere (Labadze et al., 2023). Likewise, the generation of audiovisual content with AI is enhancing students' motivation and interest in conventional content (Jauhiainen and Garagorry, 2024). These technologies must be embedded within enactive design principles, utilizing active methodologies that facilitate effective environmental scaffolding through diversified resources that promote perceptual multimodality and progressive adaptation based on personal experience (Varga, 2019).

Building upon the preceding discussion, it becomes essential to critically assess whether Universal Design for Learning (UDL), rooted in cognitivist and neurocentrist paradigms, is capable of providing an expanded and renewed framework to guide inclusive educational practices. This proof-of-concept article addresses this challenge by proposing an inclusive design framework grounded in the principles of the 3E cognitive approach and Embodied Design for Special Education (SpEED) (Tancredi et al., 2021; Abrahamson et al., 2023). SpEED advocates for a reconfiguration of inclusive pedagogical design, emphasizing the diversity of students' sensorimotor actions and perceptual experiences. It calls for a redefinition of accessibility and equity in educational resources through the deployment of technologies attuned to the phylogenetic and ontogenetic trajectories of students with Special Educational Needs (SEN). Moreover, informed by the 3E framework, this proposal incorporates active learning methodologies, such as project-based learning and gamification, mediated by technologies including virtual reality (VR), augmented reality (AR), artificial intelligence (AI), and mobile applications, with the aim of enhancing learning processes among diverse student populations (Wellner and Levin, 2023). Finally, the article presents empirical case studies that embody theoretical reflections on the feasibility of designing educational experiences capable of constructing a holistic and flexible framework for understanding cognition in students with SEN — cognition understood as embodied and distributed across dynamic sociomaterial and technological environments conceptualized as epistemic niches.

Special educational needs: rethinking the educational role of inclusion

Special educational needs (SEN) must be understood within the framework of inclusive education, one that moves beyond a clinical approach focused on diagnoses, and instead recognizes diversity as an inherent aspect of the educational process (Cerna et al., 2021). SEN can be either permanent or temporary, depending on their duration and complexity. Permanent needs are associated with disabilities such as visual, auditory, or intellectual impairments and require sustained support. In contrast, temporary needs are specific learning difficulties that call for short-term support and differentiated pedagogical strategies (Ministerio de Educación de Chile, 2015). International organizations such as UNESCO (2022) and the OECD (2018) have highlighted that students with SEN, particularly those with permanent needs, continue to face significant barriers in accessing quality education, primarily due to rigid pedagogical models and insufficient support approaches. These traditional models are often grounded in cognitivist paradigms that reinforce dualistic ontological assumptions, such as mind–body and organism-environment splits, fragmenting cognitive activity into isolated sensations that passively gather information from the external world.

As a result, such pedagogical models tend to adopt a transmissive and instrumental teaching approach, reducing educational support to didactic and technological resources that do not necessarily align with the interests and capacities of students with SEN. In this context, an educational redesign becomes essential, one that incorporates holistic approaches to understanding cognitive activity and disability within a relational ontological framework (Toro et al., 2020). Such an approach emphasizes personalized teaching methodologies that highlight the potential of diversity as situated and meaningful in each student's lived experience (European Agency for Special Needs and Inclusive Education, 2025). Thus, addressing special educational needs involves not only adapting resources, but also transforming structures and relationships, recognizing the plurality of ways of being and learning among all students. Specific learning Difficulties (SLD), Attention Deficit Hyperactivity Disorder (ADHD), and Autism

Spectrum Disorder (ASD) are neurodevelopmental disorders that significantly impact educational and social performance. Each of these disorders has its own distinct set of symptoms and challenges.

According to the DSM-5, SLD, which affects between 5 and 15% of children and is often diagnosed in childhood but sometimes identified in adulthood, involves persistent impairments in areas such as reading, writing, or mathematics, with dyslexia being the most prevalent (McDonough et al., 2017). ADHD, which affects approximately 5% of children, is a chronic condition with significant persistence into adulthood and is characterized by persistent difficulties with attention, impulsivity, and hyperactivity (Danielson et al., 2018). ASD, which is estimated to affect 1 in 36 children, is a heterogeneous spectrum characterized by social communication disturbances and restricted interests and can manifest with considerable variability in cognitive and sensory disabilities (American Psychiatric Association, 2013). Research in neuroscience has identified structural and functional brain differences in individuals with SLD (Prasad et al., 2020), ADHD (Ortega et al., 2020), and ASD, (Kausel et al., 2024) and in particular in ASD, research is helping to understand the complexity and diversity of the symptomatology (Soto-Icaza et al., 2024).

3E approach: beyond neurocentrism and cognitivism in inclusive design

The transition from a dualist epistemology to a relational ontology allows for an understanding of cognition as a holistic and emergent phenomenon, intrinsically intertwined with the brain, body, and environment (Criscuolo et al., 2022). This cognitive shift has not only epistemological and theoretical implications, expanding current frameworks of cognition in inclusive education, such as the neurocentrism and cognitivism underlying Universal Design for Learning (UDL), but also practical consequences for pedagogical design in tailoring strategies and resources. In particular, it highlights the relational role of human agency in interacting with materials and technologies based on support needs (CAST, 2018). Unlike the UDL approach, which guides pedagogical design based on the functioning of "parts of the brain" to justify diversified strategies, a holistic perspective that integrates brain, body, and environment fosters a more dynamic, embodied, and relational understanding of educational inclusion. In this sense, reducing diversity to rigid neurocognitive models that dictate multiple forms of representation, expression, and engagement (Rose and Lapinski, 2011) is problematic, as much of the contemporary evidence on the brain urges caution in its direct application to classroom practice. While UDL recognizes and values the diversity of learning, it does not fully address the potential of teaching, particularly in terms of designing dynamic educational environments that incorporate active methodologies aimed at cultivating diverse, culturally embedded forms of learning (Rodríguez Herrero and Herrán-Gascón, 2020; Videla et al., 2024).

The classical neuroscience paradigm, which assigns specific functions to discrete brain regions, has been widely challenged by contemporary approaches emphasizing brain interconnectivity and functional dynamics (Fuchs, 2017; Cisek, 2021). In this vein, Pessoa (2023) proposes the entangled brain model, in which cognition and emotion emerge from the distributed interaction of large-scale networks rather than being localized in rigid, independent modules. This approach breaks away from reductionist views, such as the exclusive association of the amygdala with fear or the prefrontal cortex with rational control, highlighting the emergent nature of neural activity. "The relations among sensory/perceptual/motor streams give rise to emergent structure greater than the sum of its parts" (Abrahamson et al., 2023, p. 13). By recognizing that brain function is highly contextual and depends on dynamic coalitions, this model strongly resonates with perspectives that integrate the brain, body, and environment (Parada and Rossi, 2020). These perspectives, known as post-cognitivist, 4E (embodied, enactive, embedded, and extended) or 3E (embodied, enactive, and environmentally scaffolded), are making significant contributions to transdisciplinary scientific development. They offer a renewed framework for rethinking teaching and learning in light of the complexity and dynamic nature of cognition (Penny, 2017; Gallagher, 2023; Aguayo et al., 2023; Videla and Veloz, 2023).

A key concept within the 3E framework is *environmental scaffolding*, which goes beyond mere cognitive extension to highlight how culturally and physically designed niches facilitate, support, regulate and enhance agency (Videla et al., 2025). These epistemic niches redistribute cognitive load, shape agency, and foster accumulated knowledge across generations, offering a broader understanding of how students learn through diverse materials, technologies, and contexts. This approach has significant implications for designing educational supports that address student diversity and their context, through methodologies and educational resources that leverage technologies to expand each student's learning opportunities. This entails practical engagements with diverse material and technological forms, enabling multimodal perceptions that interactively involve the visual, haptic, and auditory systems, among others, providing alternative pathways that support personalized learning (Fincher-Kiefer, 2019).

Environmentally scaffolded with active methodologies: gamification and project based learning

The 3E approach provides a well-grounded framework for inclusive educational design with technologies, particularly in the use of active learning methodologies that promote learning by doing based on personal experiences and diverse sensory engagement. Environmental scaffolding can be social, physical, or digital, reinforcing the co-evolution of organisms and their environments to facilitate and enhance learning through the creation of specialized and inclusive niches (Tanesini, 2022). Bruner (1990), in his cognitive development model, proposes a progression of representations that move from the concrete to the abstract, spanning the enactive, iconic, and symbolic stages through the use of scaffolding. The concept of scaffolding refers to "environmental elements" utilized by a child, either independently or with the help of a tutor, to reconfigure their initial experiences and transition toward higher levels of development (Wood et al., 1976). From a 3E cognition perspective, scaffolding is no longer an external mechanism guiding the learner toward higher developmental levels; rather, it is a dynamic assembly that emerges from recurrent interactions between the agent and their environment (Gallagher, 2018). In contrast to the proposal by Wood and collaborators (1976) proposal, enactive approaches, such as those from Varela et al. (1991), advocate for a relational ontology where agents do not sense-making from external representations; instead, they co-create their own worlds of meaning through embodied and situated practices.

Likewise, environmental scaffolding from the 3E framework not only differs from traditional scaffolding, which provides external support for what the learner has not yet mastered but is also inspired by the notion of reverse scaffolding (Abrahamson and Chase, 2020). This approach incorporates only what the learner has already conceptualized and successfully enacted, thereby fostering agency and consolidating skills through the expansion of their epistemic niche. Active methodologies foster dynamic, student-centered environments, making environmental scaffolding practices essential for the creation of personalized epistemic niches with an embodied and enactive emphasis. Project-Based Learning (PBL) is an active, student-centered learning methodology that engages students in real-world projects over extended periods, operating on the premise that learning is most effective when students are actively involved in challenges tasks that allow them to embody their understanding (Krajcik and Shin, 2014). From this perspective, knowledge is constructed through experience, in environments prepared with materials, tools, and technologies, highlighting the importance of social interaction and collaboration during material engagement processes (Sotomayor et al., 2021). Gamification is an educational approach that incorporates game elements, such as points, levels, rewards, and challenges, into non-game contexts to increase student engagement, motivation, and learning effectiveness. By transforming conventional tasks into dynamic and interactive experiences, gamification provides a structured and dynamic environment that supports, facilitates, regulates, and enhances learning (Seaborn and Fels, 2015).

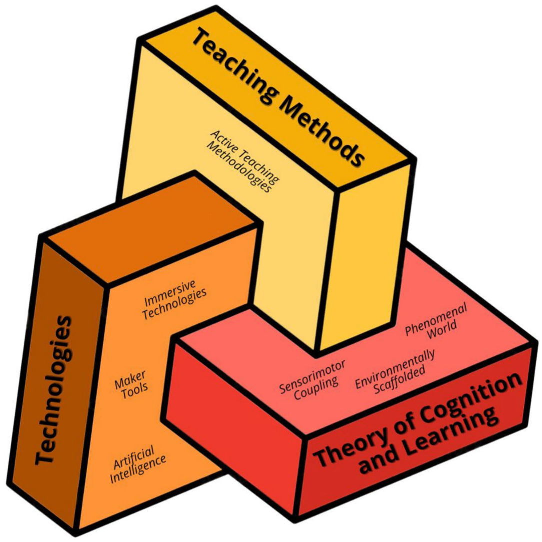

FIGURE 1
Design model of pedagogical practices with technologies based on the 3E cognition framework.

Inclusive design principles with technologies: AR, VR, AI and mobile app

Inclusive educational challenges aimed at facilitating learning for all individuals require the creation of educational environments designed with diverse materials and technologies that allow effective learning for all children (Dolan et al., 2013). Unlike UDL, which is primarily grounded in a neuropsychological framework, we argue that its inclusive scope is limited, as it fails to incorporate active teaching methodologies that place all students at the center of the learning process. Approaches such as SpEED (Special Education Embodied Design) promote a broader and more integrated vision of inclusion by connecting the body and the environment to enrich support needs through the expansion of students' epistemic niches (Abrahamson et al., 2023; Videla et al., 2024). Based on this characterization and considering the educational challenges that technologies can address through the 3E approach, we draw inspiration from a promising framework of SpEED to generate inclusive design principles with technologies (Tancredi et al., 2022).

This framework applies embodied and enactive cognition theory to educational design for sensory-diverse students, considering three dimensions: cognitive theories, technologies as support modalities, and bottom-up design-based research (Abrahamson et al., 2023). In our case, we incorporate a fourth dimension related to teaching methodologies, adopting an active approach that provides environmental scaffolding in various situations and degrees as facilitated by teachers (see Figure 1). Active teaching methodologies foster different levels of environmental scaffolding, promoting the creation of contingent relationships among teachers, media, and students that facilitate, support, regulate, and enhance learning opportunities for diverse students. We hope that this model can help to address the challenges of the implementation of programs that seek to foster inclusion in educational contexts, such as governmental programs like the School Integration Program (PIE - Programa de Integración Escolar) in Chile, which aims to contribute to the continuous improvement of the quality of education, promoting learning in the classroom and the participation of each and every student, especially those with Special Educational Needs (SuperEduca, 2025).

Figure 1 represents the integrated model aimed at supporting inclusive educational design with technologies, active teaching methodologies, and post-cognitivist cognitive and learning theories. The inclusive design principles derived from SpEED (Tancredi et al., 2021) emphasize that (i) the embodiment of learning emerges through the sensorimotor interaction of the body with the environment, (ii) learning begins with prior experiences, practices, processes, and sensorimotor skills, and (iii) teaching must be flexible to students' sensorimotor diversities, as learners may change the way they interact with what they are learning. Building on these general principles, we present specific inclusive design principles for formal educational settings that use immersive XR (Extended Reality) technologies, such as VR and AR in our case, as well as mobile applications and artificial intelligence, within a framework of embodied, enactive, and environmentally scaffolded educational practices.

The following design principles serve as educational guidelines to promote inclusive education with technology, as the purpose of the 3E approach is to develop theory from the bottom up, based on data collected in naturalistic contexts. In other words, empirical evidence is gathered to support, expand, and challenge theoretical claims. These design principles should not be seen as rigid or absolute directives for educators; rather, they offer parallel or alternative pathways to approaches emerging from the specific contexts and experiences in which AR, VR, AI, and mobile applications are used. To illustrate these principles, we present a set of cases developed in our STEAM (Science, Technology, Engineering, Art, and Math) educational innovation laboratory, in collaboration with special education teachers from the School Integration Program (SIP) who implement active methodologies with technologies to promote the inclusion of students with SLD, ADHD, and ASD in their learning environments. The design process of the experiences took about between three and six months and followed the model proposed in Figure 1, involving following steps:

- Teacher training in pedagogical competencies for digital innovation, integrating post-cognitivist learning theories, active teaching methodologies, and mobile, immersive, and AI technologies.
- Support in identifying the needs and interests of inclusive education teaching teams, contributing to the assessment of student cases requiring specific support, such as SLD, ADHD and ASD.
- Guidance in the design and implementation of active learning methodologies, including project-based learning and gamification, applied through various technologies, according to the following cases: (i) Octostudio, a mobile app developed by MIT (Rusk et al., 2024) and AI (Leonardo AI, HeyGen, and EyeJack), specifically designed for students with ADHD; (ii) Augmented Reality (AR) and Virtual Reality (VR) for students with SLD; (iii) AI-powered chatbots for families and educators of children with ASD, enhancing situated and inclusive learning experiences in northern Chile.

Illustrative case 1: use of mobile app and artificial intelligence in educational settings with students with ADHD

This case study highlights the integration of OctoStudio and AI tools to support a 12-year-old student with ADHD in the context of environmental education in a subsidized private school in Coquimbo, Chile. The OctoStudio app served as a dynamic scaffolding tool, allowing adaptive customization of tasks aimed at improving sustained attention, working memory, and creativity through the design of gamified digital narratives. The educational intervention was implemented through project-based learning (PBL) and gamification, contextualized within a socio-environmental issue concerning the pollution of the Culebrón Wetland. By developing a story in which young activists collaborate with native wildlife to restore ecological balance, the student connected ecological knowledge with personal experiences. The visual programming blocks of OctoStudio required sequential organization and planning, strengthening the student's attentional control and executive functioning, while also promoting narrative construction and emotional engagement with the subject matter.

In tandem, AI applications: Leonardo AI, HeyGen and EyeJack, were utilized to enrich the student's story with hyper-realistic illustrations, animated sequences, and immersive audio-visual elements, offering progressive challenges that supported digital literacy and creative expression. The story, Guardians of El Culebrón, incorporated AI-generated missions from fictional ecological mentors, and brought characters such as Sami and Gaia to life through interactive augmented reality, positioning the student as an environmental storyteller and agent of change. Over 3 weeks, the student co-created an interactive narrative aligned with curriculum goals and ecological awareness, supported by collaboration between the special education team and INNOVA STEAM Lab. Qualitative observations indicated marked improvements in the student's attention span, self-regulation, and engagement, suggesting that such technology-enhanced, interest-driven learning environments are promising for inclusive education. The case exemplifies how AI and mobile apps can scaffold cognitive and emotional engagement in learners with ADHD through meaningful, culturally relevant, and ecologically conscious pedagogical practices (Figure 2).

Illustrative case 2: XR technologies to enhance learning in students with specific learning difficulties

This case study examines the implementation of augmented reality (AR) and virtual reality (VR) as inclusive tools to support students with specific learning difficulties (SLD) in both language and mathematics. Conducted over 3 weeks in a high school in the Coquimbo Region of Chile, the intervention focused on two educational experiences involving 12 students aged 11 to 16. Five students with language SLD explored literary comprehension through AR by interacting with 3D dioramas of key scenes from Julio Cortázar's "La noche boca arriba." Using platforms such as CoSpaces and Merge Cube, the activity scaffolded comprehension through multimodal strategies, including audio narration, collective reading, and the projection of symbolic story elements like the motorcycle accident and Aztec rituals. This immersive, gamified approach distributed the cognitive load and facilitated a tangible connection with the literary content. Students then reflected and presented their dioramas, promoting expressive skills and collaborative learning. The embodied interaction fostered deeper engagement and personalized sense-making, strengthening comprehension and oral communication.

Simultaneously, seven students with math SLD participated in a VR-based geometry module using Meta Quest headsets and Gravity Sketch. This sequence began with 2D calculations of area and perimeter, progressing to the construction of paper-based 3D nets, and ultimately, to the creation of virtual geometric models. The transition from abstract symbols to manipulable digital representations fostered conceptual understanding of volume and surface area through embodied cognition. Activities such as "First Steps with Handtracking" familiarized students with spatial navigation and interaction in virtual environments, while the final modeling tasks empowered them to explore geometric figures from multiple perspectives. The integration of AR and VR technologies provided environmental scaffolding that enhanced attentional control, spatial reasoning, and fine motor coordination. Overall, the immersive experiences led to increased engagement, deeper understanding of concepts, and greater motivation. The findings suggest that extended reality (XR) tools offer valuable pathways for designing accessible, multisensory learning environments that respond to diverse cognitive profiles in inclusive education (Figure 3).

FIGURE 2
Use of the OctoStudio mobile app and AI tools for students with ADHD: This figure illustrates how the OctoStudio mobile app, along with AI tools like Leonardo AI, HeyGen, and EyeJack, helps students with ADHD stay engaged, focused, and enhance their learning experience through interactive technology.

FIGURE 3
Use of AR, VR, and 3D Pen for students with ASD: This figure illustrates how augmented reality (AR), virtual reality (VR), and 3D pens are used to support students with ASD in learning environments, promoting engagement and skill development.

Illustrative case 3: use of AI chatbots to support caregivers and educators of children with ASD

This case study investigates the use of AI-powered chatbots to support families and educators of children with ASD, focusing on personalized and context-sensitive guidance. Conducted in Vicuña, Chile, in December 2024, the initiative engaged twelve family members, eight mothers and four fathers, through four interactive sessions designed by the HUB EDUCA STEAM team. Using the Poe AI chatbot platform, participants were trained to create tailored digital assistants to support emotional regulation, communication, and

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socio-educational strategies for their children. The chatbots acted as accessible expert tutors, adapting responses to the individual needs of each child based on their sensory profile, emotional state, and family dynamics. Through sessions covering personalization, emotional support, contextual adaptation, and the development of practical materials (e.g., visual schedules and sensory games), families gained tools to make informed, empathetic decisions aligned with their values and environments. The chatbot's adaptability allowed for real-time, meaningful interaction, empowering caregivers to respond with greater confidence and precision to daily challenges.

The implementation of AI chatbots fostered a holistic and inclusive approach by bridging the gap between home and school settings. Participants reported increased autonomy and confidence in supporting their children, as well as improved communication with educational teams. Emotional validation emerged as a central element, with the chatbot strengthening caregivers' roles and acknowledging the complexities of raising a child with ASD. The practical outputs such as pictograms, co-regulation activities, and personalized guidance, enabled consistent educational and emotional support, reducing behavioral crises and enhancing the student's engagement and well-being. Educators also benefited from improved collaboration with families, leveraging chatbot-generated materials in classroom planning. The qualitative findings indicate that AI chatbots are a scalable and inclusive solution for building responsive, culturally relevant support networks for families of children with ASD. This case exemplifies how technology can mediate inclusive educational practices by tailoring interventions to the lived realities of families and collaborative care models between home and school (Figure 4).

Conclusion

In conclusion, this article proposes an inclusive framework grounded in the principles of 3E cognition and illustrated through concrete examples inspired by the SpEED design principles. It highlights how environments enriched with active teaching methodologies and technologies can shape epistemic niches that are relevant and responsive to students with SEN. By integrating immersive technologies such as augmented and virtual reality, specialized mobile applications like Octostudio, and AI-powered tools such as chatbots and image/video generation, the article presents innovative strategies that personalize and diversify educational experiences. This approach not only responds to the demands of contemporary learning environments, but also emphasizes the importance of multimodality,

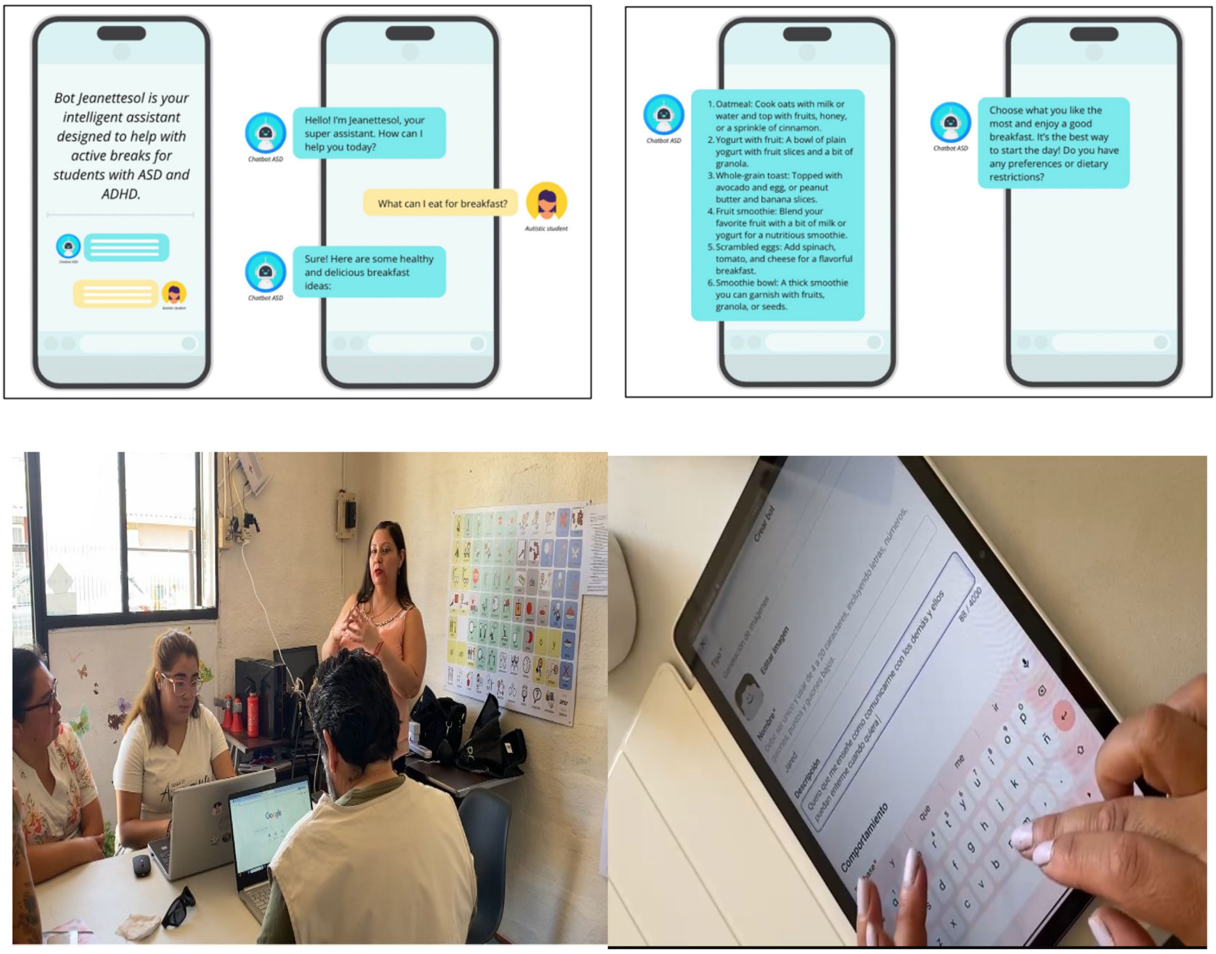

FIGURE 4
Implementation of AI Chatbot with POE for students with ASD: This figure illustrates the use of an AI chatbot integrated with POE (Personality-Oriented Engagement) to assist students with Autism Spectrum Disorder (ASD) by offering personalized interactions and support to family.

material interaction, and environmental scaffolding to enhance learning and promote educational equity for students with SEN.

The article is rooted in the 3E cognition framework, emphasizing the role of environmental scaffolding, where the learning environment is not seen as a static backdrop, but rather as a dynamic and expanding epistemically ecological niche. This perspective enables fluid relationships between students and their learning contexts. It suggests that technologies do not merely structure diverse relationships, but also have the potential to transform the very structures that make such relationships possible. In doing so, it offers an integrative framework of brain, body, and environment that amplifies the contributions of UDL. In this regard, the article provides a theoretical-practical foundation for implementing educational designs that support plurality and diversity in learning, in response to the digital challenges of the 21st century.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by HUB EDUCA STEAM ethical group. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RV: Conceptualization, Investigation, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing. FP: Conceptualization, Investigation, Supervision, Validation, Writing – original draft. MA: Conceptualization, Formal analysis, Investigation, Writing – original draft. PR: Conceptualization, Investigation, Supervision, Validation, Writing – original draft. AS: Investigation, Methodology, Project administration, Writing – original draft. DJ: Conceptualization, Formal analysis, Methodology, Project administration, Writing – original draft. CP: Investigation, Methodology, Project administration, Writing – original draft. AT: Methodology, Project administration, Validation, Writing – original draft. DI: Investigation, Methodology, Project administration, Writing – original draft. MG: Investigation, Methodology, Project administration, Writing – original draft. AV: Investigation, Methodology, Project administration, Writing – original draft. KM: Investigation, Methodology, Project administration, Writing – original draft. MB: Methodology, Project administration, Writing – original draft. LK: Conceptualization, 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.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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