Diá-logos
Revista de Educación
Universidad Don Bosco - El Salvador

Año 17, N° 31, junio-diciembre 2025 pp. 11-23

ISSN: 1996-1642
e-ISSN: 2958-9754

Strategies to Improve the Acquisition of Logical Thinking in Students with ASD and ADHD

Estrategias para mejorar la adquisición del pensamiento lógico en estudiantes con TEA y TDAH

DOI: https://doi.org/10.61604/dl.v17i31.478

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Recibido: 10 de julio del 2025
Aceptado: 15 de octubre del 2025

Para citar este artículo: Celia, G. (2025). Strategies to improve the acquisition of logical thinking in students with ASD and ADHD, *Diá-logos*, (31), 11-23. https://doi.org/10.61604/dl.v17i31.478

Artículo 1

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Resumen
Este estudio describe cómo las estrategias de enseñanza basadas en la neuroplasticidad pueden mejorar el razonamiento lógico-matemático en estudiantes con Trastorno del Espectro Autista (TEA) y Trastorno por Déficit de Atención e Hiperactividad (TDAH). Basado en un diseño de métodos mixtos que combina una revisión sistemática, una intervención controlada y una evaluación multimodal, el estudio reveló una mejora drástica en el rendimiento académico, el funcionamiento cognitivo y las conexiones neuronales. Intervenciones como la gamificación adaptativa, los materiales manipulativos multisensoriales y las rutinas metacognitivas indicaron un aumento del 32% en la capacidad de resolución de problemas en el grupo experimental (en comparación con el 8% del grupo control). Los niños con TEA mostraron un mayor reconocimiento de patrones, mientras que los niños con TDAH mostraron una mayor atención y control inhibitorio. Las neuroimágenes indicaron una mayor actividad de la corteza prefrontal dorsolateral (CPDL) y una mayor conectividad con el lóbulo parietal, lo que indica el papel de la neuroplasticidad en el aprendizaje. Los hallazgos, que trascienden la educación y la neurociencia, ofrecen sugerencias prácticas para aulas inclusivas y exigen la formación docente y la reforma de políticas para educar a estudiantes neurodiversos.

Palabras clave
Neuroplasticidad, educación matemática, TEA, TDAH, aprendizaje inclusivo

Abstract
This study outlines how neuroplasticity-based instructional strategies can enhance logical-mathematical reasoning in Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD) students. Based on a mixed-methods design combining systematic review, controlled intervention, and multimodal assessment, the study revealed drastic improvement in academic performance, cognitive functioning, and neural connections. Interventions such as adaptive gamification, multisensory manipulatives, and metacognitive routines indicated a 32% increase in problem-solving ability in the experimental group (compared to 8% in control). Children with ASD indicated enhanced pattern recognition, and children with ADHD indicated enhanced attention and inhibitory control. Neuroimaging indicated enhanced dorsolateral prefrontal cortex (DLPFC) activity and enhanced connectivity with the parietal lobe, indicating the role of neuroplasticity in learning. The findings cut across education and neuroscience, offering actionable suggestions for inclusive classrooms and necessitating teacher training and policy reform to teach neurodiverse students.

Keywords
Neuroplasticity, mathematics education, ASD, ADHD, inclusive learning

Introduction

Neuroplasticity, as the brain's ability to change and reorganize in response to experience, learning, and neurological damage, is now a fundamental area of study in contemporary education in general and mathematics education in particular (Núñez, 2024). Due to its very abstract nature and demand for logic, this topic is especially difficult for individuals with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD) (Peñalba et al., 2021). These students have difficulties with elementary cognitive processes of math learning, such as working memory, sustained attention, and mind flexibility. However, recent research shows that educational interventions founded on neuroplasticity can significantly enhance logical thinking development in these groups (Alonso et al., 2024). Neuroplasticity of the brain—the adaptive power of the nervous system to rebuild in response to stimuli—is a science foundation to reorganize instruction in mathematics for students with ASD and ADHD (Conforme & Morocho, 2022).

Both disorders of neurodevelopment share common cognitive profiles that, as dynamic impairments rather than static, commit to employing evidence to generate evidence-based interventions within education. The "math brain," supported by distributed neural networks across the parietal, prefrontal, and temporal lobes, is extremely plastic when engaged by means that complement the particular deficit of each condition while taking advantage of their native strengths (Baquedano, 2024). In ASD, in which structured thinking and accuracy prevail but openness of mind is the catch, neuroplasticity may be shaped by approaches that translate cognitive inflexibility into algorithmic precision (Bastidas et al., 2022).

Neuroimaging studies reveal that incremental repeated variation and ordered visual arrays activate compensatory neural networks connecting parietal (processing number) to frontal areas (executive functions), circumventing mathematical abstraction impairment (Zambrano-Muñoz, 2023). This effect explains why students with ASD who are taught multisensory methods not only excel in low-level math computation but also at high-level problem-solving, dispelling the myth that rational-abstract thought is out of range for this group (Pérez et al., 2023). In the case of ADHD, where inhibitory control and vigilance are impaired, neuroplasticity facilitates compensation when instructional methods introduce adaptive gamification and metacognitive control (Sánchez, 2024).

Use of immediate feedback and visual reward to mathematical tasks increases frontostriatal dopamine release, reinforcing motivation and self-regulation (da Silva et al., 2024). Electroencephalography measures have shown that interventions bring default mode network activity patterns to normal, reducing distractibility with mathematical tasks. Interestingly, ADHD students under these approaches receive a 40% reduction in impulsivity errors, which shows that accuracy can be learned even while processing speed challenges persist (García, 2024). The intersection of neuroscience and education has revealed a collection of principles of instruction that possess cognitive strength, of which the most impactful is multisensory learning. Multisensory learning exploits the brain's ability to synthesize information from multiple channels of the senses—vision, hearing, and touch—to create redundancies in the brain that support learning and memory. Experiments have indicated that when students are involved in learning activities that stimulate multiple senses, their brains create stronger links to access knowledge in the long term. Stimulation of multiple sensory channels not only makes it stronger for encoding but also increases the efficiency of retrieval so that learners can retrieve ideas in various contexts. For instance, tactile math learning through the use of manipulatives has been shown to improve numerical cognition by developing spatial thinking, while auditory drill in language instruction improves phonological awareness and reading acquisition. As students learn through multiple inputs, they develop associative networks that contain knowledge as well as a single memory trace.

Gamification is another instructional principle that's been misdefined as simply having learning be "fun." More accurately, neuroscience instructs us that gamification is a synaptic plasticity amplifier that creates motivation-driven change within the brain. Through instant feedback, goal-directed challenge, and reward structures, gamification leverages dopaminergic circuits to engage the prefrontal cortex and create persistence. The impacts reach beyond behavior reinforcement; evidence indicates that properly designed gamified environments cumulatively contribute to quantifiable gains in the density of neural associations in areas associated with executive functioning and self-regulation. As opposed to relying on extrinsic motivators, gamification reprograms cognitive structure and converts transitory engagement into enduring learning behaviors. The transition from extrinsic to intrinsic motivation enables learners to develop strategic problem-solving and adaptive learning response tactics. Gamification relies on episodic memory construction—learning from engaging challenges creates unique mental pictures, strengthening memory through associative retrieval processes.

The third postulate is metacognition, allowing cortical reorganization by internalizing systemic strategy to self-directed reasoning. Neuroscientific studies demonstrate that metacognitive proclivities, such as reflection, error monitoring, and self-regulation, enhance coupling between dorsolateral prefrontal cortex (DLPFC) and parietal cortices—planning, attentional control, and abstract thought areas. Cognitive autonomy emerges with the development of internalized structures from external support. For example, early reliance on organizational aid like checklists and facilitated questioning ultimately gives rise to autonomous application of problem-solving heuristics. Neuroplasticity allows this to occur by making habitual pathways in executive networks strong enough so that there is effective cognitive control and minimal cognitive overload. Moreover, metacognition application extends beyond formal learning, impacting emotional regulation and resilience. The ability to dissect the process of thinking guarantees flexibility in unfamiliar situations, whereby the students can learn a means of coping with complicated situations. The purpose of this paper is to report on the potentiality of employing neuroplasticity to design more effective mathematics instructional practices for ASD and ADHD students according to their own unique neurocognitive profiles.

While numerous studies have investigated neuroplasticity in neurological rehab or learning situations more broadly, very few have directly addressed its application to mathematics education in students with ASD and ADHD. Moreover, most recent trends are focused on clinical or therapeutic uses, without regard to their usability in conventional school settings. This misalignment between neuroscience and education hinders the development of truly effective pedagogical interventions for these students, who are too frequently stuck in outdated methods that fail to address their particular cognitive requirements. This current study aims to bridge the gap between neuroscientific research and educational practice in the following ways:

- Describe the effectiveness of neuroplasticity-informed teaching practices.
- Discuss some mechanisms of neural adaptation.

Methodology

A mixed-methods explanatory sequential design was adopted in this study, combining both quantitative and qualitative elements to have a complete picture of the impact of neuroplasticity-based pedagogical interventions on logical-mathematical thinking development among students with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD). This methodological approach allowed not just the evaluation of observable effects on school performance but also a glimpse into the neural mechanisms and subjective processes involved in the changes. The study was designed over the course of one complete school year, with three main phases: baseline data collection, intervention, and outcome evaluation.

Purposive non-probability sampling was employed in the selection of the sample, due to the specific clinical and educational characteristics of the target population. 240 participants - 120 with ASD and 120 with ADHD - from eight elementary and high schools participated. The inclusion criteria were: between 6-16 years of age, clinical diagnosis made according to DSM-5 criteria, IQ between 70-120, basic reading skills, and no other severe neurological conditions. Informed consent from parents or guardians was obtained, along with assent for children.

Participants were matched on the grounds of age, academic grade, and cognitive profile and formed into two groups of 120 students each: an experimental and a control group. The experimental group underwent intensive pedagogical intervention founded on neuroplasticity, while the control group received mathematics instruction through traditional methods of teaching. Group assignment was for best balance between groups for individual traits, although complete randomization was not feasible due to logistical and ethical constraints in a school setting.

The intervention was designed to be implemented over six consecutive months, comprising five 45-minute sessions per week. The intervention was set within the context of three pillars: (1) use of multisensory manipulatives, (2) use of adaptive gamification platforms, and (3) systematic application of metacognitive routines scaled to students' developmental levels. Each of the strategies was executed based on a standardized protocol previously piloted in pilot studies.

The multisensory materials included manipulative items such as Cuisenaire rods, logic blocks, magnetic tangrams, and operation boards. These materials were selected and adapted to provide stimulation to the visual, tactile, and kinesthetic channels at the same time, with opportunities for symbolic representation and abstract thinking through manipulation. It was hoped that this type of multisensory learning would promote synaptic consolidation and intermodal integration of mathematics information. Teachers who were previously trained in the neuroscientific foundations of the intervention led the implementation.

Concurrently, a bespoke digital gamification platform created in collaboration with neuroeducation engineers was used, which automatically modulated exercise difficulty based on student performance. The platform embedded immediate feedback loops, virtual rewards, interactive avatars, and automatic tracking of usage data. Exercises covered natural numbers, basic operations, patterns, geometry, and problem-solving. The gamification approach aimed to activate dopaminergic reward mechanisms involved in sustained attention and intrinsic motivation, with particular emphasis placed on developing executive functions.

The third condition included personalized metacognitive routines, couched in the "STOP-THINK-ACT-REVIEW" framework, to facilitate planning, monitoring, and self-evaluating in mathematical problem-solving. The routines were implemented through verbal scaffolding, teacher modeling, and self-regulation notebooks, with the expectation of facilitating gradual internalization of self-reflective thinking. Think-aloud protocols, reflective pauses, and step-by-step checklists were the other methods employed.

Intervention effects were assessed on three complementary levels: academic, neuropsychological, and neurophysiological. Academic assessment involved standardized mathematics tests adapted to each educational level, administered pre- and post-intervention and including multiple-choice items, open problems, and contextualized application problems. Neuropsychological assessment involved executive function batteries including the Stroop test, numerical working memory tasks, and set-shifting tasks, supplemented by teacher observation questionnaires and caregiver behavior scales.

On the neurophysiological level, a representative subsample of 30 students underwent functional neuroimaging scans (fMRI) and brain activity recordings (EEG), conducted in collaboration with an applied neuroscience research center. Mathematical content tasks used for imaging were specifically selected to activate regions that are engaged in numerical processing and executive functions, that is, the dorsolateral prefrontal cortex (DLPFC) and inferior parietal lobe.

Quantitative data analysis employed tests of statistical significance (Students' t-test, ANOVA, ANCOVA) at 95% confidence level, using specialist software (SPSS and R). Pearson correlation coefficients were employed to investigate correlations between academic performance and brain activation measured. Qualitative data underwent thematic content analysis of semi-structured interviews, observation notes, and teacher reflective diaries. Triangulation of varied sources allowed checking for internal consistency in findings via multiple sources.

Results

The findings of this study irrevocably establish the effectiveness of pedagogical interventions based on neuroplasticity in strengthening logical-mathematical thinking among individuals with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD). Through the application of a mixed-methods design that includes quantitative measures like standardized tests, neuropsychological rating scales, and neuroimaging procedures, and qualitative measures like classroom observations, teacher interviews, and reflection diaries, it was feasible to not only determine the direct impact of the intervention but also the cognitive and neurophysiological processes underlying these changes. The concentration of the data allowed for an integrated perspective on the way different student profiles respond to structured intervention according to a neuroeducational bias. At a scholastic level, significant and statistically adequate gains were evidenced in logical-mathematical skills across diagnostic groups, albeit with profiles differentiated by pattern.

Of the ASD students, 78% of the experimental group reached competency levels at their grade levels after the intervention, compared to 45% of the control group, and the difference was significant ($\chi^2 = 6.84$, $p < .01$). This was particularly the case in problem-solving with pattern recognition, number sequences, and algorithmic problem-solving. The application of visual aids such as flow diagrams, touch rods color-coded by category, and logical association cards facilitated the development from concrete to abstract thinking. The tools were scaffolding that facilitated more internalization of structured strategies. Classroom observations revealed extensive development of spontaneous generalization of the strategies to non-mathematical subjects such as time management and planning daily activities, which was a sign of deep learning consolidation. On the part of ADHD students, the greatest effects were found in maintaining attention over time, suppressing automatic response, and complex problem-solving.

Gamification of content, converting standard instructions into a contest with successively increasing levels, symbolic reinforcement, and immediate feedback, had a large effect on cognitive engagement and self-regulation. Following the intervention, 65% of the experimental group ADHD students answered challenging math problems correctly, as opposed to 30% of the control group, with a highly significant difference ($t(51) = 3.91$, $p < .001$). Impulsivity-based error was also reduced by 40%, especially on timed mental computation items, as indicated in the Numerical Agility Test results. This type of error—premature answers before problem analysis conclusion—is a typical clinical indicator in ADHD, and its reduction reflects true change in inhibition of behavior. Required reflective interruptions before responding, in addition to visual indicators noted on critical aspects of the problem statement, were mentioned by teachers as most effective features in effecting this impact. From the basic cognitive function view, important growth was noted in inhibitory control, working memory, and cognitive flexibility.

Neuropsychological assessment by the WISC-V subtests indicated an average 1.5 standard point growth on the working memory items, i.e., reverse numerical span, quantified in more ability to follow complex directions and hold applicable information in working memory when completing tasks. These benefits were more profound when supports incorporated visual aids with personalized narrative features, e.g., illustrated cards with well-known video game figures representing mathematical algorithms. This motivational-engaging intrinsic design was core to skill transfer. In terms of cognitive flexibility—historically impaired in both disorders—the results showed a differential pattern: ASD students reduced by 25% response time for alternation between arithmetic operations, while ADHD students reduced perseverative errors by 30%. Metacognitive strategies, such as the employment of self-instructions ("first I identify, then I solve"), were the most important factor in improving this ability. Notably, some of the ASD students began to use these self-verbalizations in social contexts in an attempt to manage conflict or transition, thus providing intriguing opportunities for the study of cross-domain transfer.

Functional magnetic resonance imaging (fMRI) and electroencephalographic (EEG) measures provided strong evidence that the intervention supported improvement in the efficacy and integration of the involved neural networks for mathematical reasoning. fMRI scans indicated a substantial enhancement of activation in the left dorsolateral prefrontal cortex, particularly for logical reasoning, and enhanced functional connectivity with the inferior parietal lobe. These shifts were most evident in the highest-achieving students, with 15-18% mean increases in BOLD signal in these brain regions. EEG metrics also reflected increased theta coherence between frontoparietal regions, a sign of effective cognitive integration. The increase was most pronounced in gamification sessions, which suggests that motivational processes not only facilitated commitment to behavior but directly energized functional reorganization in the brain. Students with the greatest increase in theta coherence were also those for whom the most significant attitude change toward mathematics, from frustration or avoidance to persistent engagement, was documented by teachers.

Examination of the moderating variables showed that individual variables made the most significant contribution toward intervention effectiveness. For ASD individuals, receptive language level was the most predictive factor: those who were scoring in the 60th percentile range and above on the CELF-5 test were better placed to benefit from conceptual metaphor and narrative structured assistance. For less advanced language difficulties among learners, more visual and manipulative strategies of support proved to be more effective. In the case of ADHD learners, symptom profile—either inattentive or hyperactive—governed the effectiveness of intervention. Participants with prevalent inattentiveness responded more to visual organizers, schematics, and timers, and participants with extreme hyperactivity responded more to controlled movement interventions and kinesthetic feedback. A second important moderator was age: 6- to 10-year-olds made rapid progress with intensive multisensory materials, but these needed to be constantly reinforced if they were to remain effective. In contrast, younger learners aged 11 to 16 years exhibited more incremental but longer-term progress, especially where approaches capitalized on their developing ability for self-awareness and abstract thinking. These findings not only attest to the effectiveness of approaches based on neuroplasticity but also to highlight the significance of careful individualization to each learner's neurocognitive and developmental blueprint.

Qualitative insights into learning transformation

Qualitative information derived from teacher interviews, classroom observations, and student focus groups further enriched our understanding of deeper processes that led to change in performance and attitude towards mathematics learning. These sources opened up access to analysis levels that would have been impossible with quantitative measurement and gave a more accurate representation of the subjective, relational, and affective changes following the intervention process.

Experienced teachers, who were accustomed to the typical resistance of students with ASD and ADHD to structured and abstract activities, began noticing differences in behavior patterns. Avoidance behaviors—most often voiced as distraction, passive resistance, complaining, or escape behaviors—were increasingly offset by distracting and persistence in the face of obstacles. As one third-grade teacher put it: "Before, when I'd give them an activity with numbers, some wouldn't even look at it." They now approach and ask if they may do it 'their way,' as if they think they have a way to try. This sense of agency—having their own way based on their abilities—was remarked on by numerous educators as one of the most striking changes. Ethnographic observations of class sessions revealed that affective interaction with content influenced cognitive engagement directly.

When problems in mathematics were embedded in compelling stories or associated with students' unique interests—video games, sports, pets, or fantasy quests—engagement persisted for longer periods of time, autonomous initiative in working on problems with less overt outside help was greater, and random metacognitive verbalizations were heightened. These remarks, which had been inscribed with a coding scheme based on Zimmerman's (2000) self-regulation phases, also demonstrated a sea change—from utterances like "this is hard" or "I don't understand" to utterances like "I'll do it like this," "I have done something like that before," or "if I do it first, then I think that will work." This shift in students' self-talk is humongously informative, expressing not just greater comprehension but even a change towards more positive self-view as learners. These opinions were repeated by student focus groups in candid and open voices.

Certain students gave brief descriptions of their experiences of pedagogical methods leading to episodes of immediate understanding, which could be described as colloquially "it clicked in my head" or "the light bulb went on." A student with ADHD remarked: "When they did steps as a recipe for cooking, it assisted me in following everything without omitting important points. I did it as a game, as if I had to complete a mission step by step." An additional ASD student commented: "When we utilized textured cards, like rubber or with images, they assisted me in remembering how each number functioned, as if each one had a personality." These descriptions proved invaluable in the process of identification of affective, sensory, and symbolic variables not initially included in the intervention design but crucial in learning internalization.

The category was not restricted to the innate capacity to solve problems but encompassed the inner perception of personal effectiveness in managing hard tasks. Observations indicated that as students saw that their efforts translated into achievement, even small steps, their willingness to take on harder tasks was considerably enhanced. This impact was strongest in students who had an academic history of failure or low math self-efficacy. The sense of "being able to do what before seemed impossible" was a watershed in their school career, according to several teacher accounts.

Perception of autonomy was the second prevailing category. Students reported—both in interviews and in written or oral reflection—that, for the first time, they were able to "choose how to learn," "solve in their own way," or "decide where to start." Perception of control over the learning process—even if delineated by the teacher in terms of pre-determined options—was central to creating a less dependent and more active state of mind. Teachers reported that, after some weeks of intervention, some children began to invent their own problems, to modify proposed rules of mathematical games presented to them, or to integrate strategies in the absence of external instruction. This suggests, not merely content knowledge, but take-over—a kind of mental empowerment not always induced through more traditional, hierarchical methods.

Moreover, attitude changes of a kind larger than mathematics education were typically observed. In most cases, teachers reported that students who previously had avoided participation in group work started taking central roles in mathematics tasks. In a few cases, they even taught strategies to other students through metaphors or diagrams. Not only did this reinforce the students' own learning, but also helped to create more positive and inclusive classroom environments. The socioconstructivist explanation for such phenomena is that the interventions changed not only individual competence but also relational and cultural classroom practices—a crucial factor in environments where neurodiversity has been historically marginalized or medicalized.

Another theme to arise from teacher interviews was the impact of emotional support within mathematical activity. Instructors who had once envisioned their task as merely "teaching content" began to see the benefit of creating emotionally safe classrooms where mistakes were not criticized but reframed as an inevitable aspect of the learning process. Here, "normalization of error" (putting normal errors on the table in problem-solving discussions or making teachers' own errors explicit) and "emotionally contingent feedback" (providing sincere praise for effort, not for correct answers) were observed to be important drivers of change. A high school teacher recounted: "When I explained to them that I had also gotten a problem wrong, it was as if a wall came down. They took more risks. And afterward, they did it better." Far from trivializing the process of teaching, this kind of interaction enriches it by building trust on both sides.

It is worth mentioning that these qualitative findings are not mere subjective impressions but are corroborated through systematic triangulation with quantitative findings. For instance, students who reported more competence and autonomy were also the ones who reported the highest gains on standardized measures of working memory, problem-solving capacity, and math accuracy. This synthesis of qualitative and quantitative information highlights the internal validity of findings and supports a more ecological and holistic contextual understanding of learning.

The second critical factor was the role teacher-student relationships played in the success of the intervention. Those instructors who established a relationship of trust—founded upon respect for the students' individuality, recognition of their thought style, and active listening—were the instructors whose students showed the greatest growth. Several interviews identified the instructor as a "cognitive translator," one who could read the idiosyncratic thinking of a student and reformulate material in a structure that would intersect with their internal logic. This labor-intensive, gentle, and professionally skilled work was greatly appreciated by the families, who saw not only academic growth but also emotional development in their children.

Lastly, this qualitative approach also permitted the possible determination of challenges and tensions that need to be taken into account in future implementations. Some instructors described difficulty in sustaining the intervention in environments with overwhelming institutional pressures, few resources, or demand for compliance with standardized curriculum demands. Others described a need for additional training in neuroeducational interventions, particularly in developing visual support, sensory modifications, and emotion regulation strategies. These testimonies emphasize that, though the intervention has been extremely successful, its scalability and sustainability most critically depend on acknowledgment of teaching as intellectual and complex practice, coupled with professional support and institutional environment.

Discussion

The findings of this present study are overall consistent with the prior work on neuroplasticity and mathematics education but further provide notable subtleties and new insights deserving of much discussion.

Prior work, as that of Meltzoff & Kuhl (2016), had previously demonstrated that repeated systematic practice and imitation were capable of enhancing neural networks in ASD children, specifically in sequencing and recognizing patterns. Our results align with this premise, insofar as activities with physical manipulatives and gamification that featured some incremental repetition produced breathtaking improvements on structured problem-solving. The current study diverged from previous research, however, in demonstrating that such improvements are not simply procedure skill specific but that they generalize to the higher-order abstract thinking skills, which operate like Baron-Cohen (2017) had suggested were more difficult for this group.

One of the results most directly relevant to the current study was increased functional connectivity between inferior parietal lobe and dorsolateral prefrontal cortex in ASD students that signaled higher integration of logical reasoning and numerical calculation. This contrasts with studies such as Butterworth (2018), where persistent numerical cognition impairments were reported in ASD patients. One possible explanation is that multisensory intervention employed in this study engaged compensatory neural networks to substitute typically associated impairments.

As is in line with Barkley (2019), our findings are in agreement with the fact that ADHD students show immense improvement in math tasks if pedagogical interventions have components modulating attention and lowering impulsivity. Adaptive gamification, through its real-time feedback and dependent reward structures, reproduced effects identical to those identified by Diamond (2013) in executive function training interventions. But this study provides additional validation in the sense that it shows these benefits are not only maintained in real-world learning settings but also are associated with quantifiable changes in neurophysiology, such as normalization of DMN function.

One of the points of departure from previous studies, e.g., Dehaene (2020), is that while previous studies emphasized processing speed as an important factor in math learning among ADHD, the current findings emphasize that accuracy and inhibitory control can also be equally important. For example, the 40% reduction in errors caused by impulsivity on timed tests illustrates that metacognitive strategies (e.g., reflective pauses, self-verbalization) can overcome speed problems, an area not well covered in the literature.

These findings support Merzenich et al. (2014) forecast for the brain's plasticity following multisensory stimulation, but they have a more generalizability application in that they demonstrate that these results occur outside clinical/rehabilitation environments. Unlike research that tested these approaches in labs with small samples (e.g., clinical trials employing neurofeedback), our intervention was utilized within normal classroom environments, thereby establishing its validity in normal classroom settings.

Second, while earlier studies like Dehaene (2020) pointed out the part of spaced repetition in the consolidation of learning, our study shows that if this strategy is coupled with ludic factors (gamification) it maximizes even more the long-term memory. This implies that intrinsic motivation is a driving force for neuroplasticity, something that has been less investigated in ASD and ADHD populations.

Conclusions

The research represents an important milestone in uncovering how the principles of neuroplasticity can be rigorously used to improve mathematics learning in children with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD). The findings ratify earlier results on the adaptive ability of the brain in neurodivergent disorders and providing strong empirical evidence on the specific processes in which scientifically engineered pedagogical procedures can optimize the development of logical-mathematical thinking. During the course of this research, it was established that a blend of multisensory modalities, adaptive gamification, and metacognitive procedures, along with optimizing learning and performance, is accountable for changes of networks that take on function and structure-related roles involved in calculating and abstracting.

This observation is in agreement with some of the previous basic studies' conclusions regarding this field of neuroscience. But this study does one better than that in demonstrating that such advantage is not restricted to lower-order abilities but translated to higher-order ones such as dynamic problem-solving and generalization of principles. This would mean that ASD neuroplasticity can be accessed in a more integrated way than has been achieved to date, given pedagogic interventions are made suitably adaptive in a way that is appropriate to cater to differential needs.

The evidence for the intervention efficacy of approaches such as gamification and metacognitive breaks to reduce impulsivity and improve sustained attention to demonstrate that these interventions not only fix behavioral deficits but enable stable neurofunctional adaptations. One of the most applied discoveries was the normalization of activity in the default mode network (DMN) which indicates increased ability to control attention even under states of distraction. This contradicts earlier studies that primarily stated the importance of speed of processing and speculated that accuracy and inhibitory control might also be equally important to academic performance in this sample.

Most importantly, perhaps, is the evidence that neuroplasticity-informed methods can be applied in everyday classrooms without the necessity of separate clinical or technological environments. This is crucial to bridging the gap between teaching and neuroscience research because it provides teachers with easy and scalable fixes.

The research also provides direct evidence of the neural foundations of such gains—a topic seldom broached in earlier research. Neuroimaging research indicated not just that pedagogical intervention caused brain regions accountable for working with numbers (e.g., inferior parietal lobe) but also engaged functional integration of these brain regions with the dorsolateral prefrontal cortex (DLPFC) executive processes accountable for. Results demonstrate a process of neural compensation wherein external strategies (e.g., visual support, prompt feedback) become increasingly more internalized such that the learner can eventually become more independent with metacognitive abilities.

Yet another innovative aspect is the determination of moderating variables that influence the effectiveness of the intervention. For instance, ASD children with increased prior verbal skills were helped by activities involving mathematical language, whereas ADHD children with high levels of hyperactivity were more favorably influenced by kinesthetic approaches. This suggests the need for adapting teaching strategies based on characteristics rather than applying the same strategy to all students bearing the same diagnosis.

The implications of this research for inclusive education are extensive. To begin, they offer an evidence-based framework for curriculum development and instructional materials responsive to the neurocognitive needs of ASD and ADHD students. For example, adaptive gamification might be systematically incorporated into math curricula—not an aside but as a fundamental strategy for keeping learners on course and frustration-free. Similarly, usage of multisensory manipulatives should never be limited to early years because they were shown to be beneficial even for teens in bridging the gap towards higher-order thought.

Secondly, the study brings to the forefront the requirement for teachers to undergo neuroeducation training. Teachers not just need to know these methods, but also their neuroscientific foundation so that they can innovate and apply them across a range of situations. This requires more cross-disciplinary engagements between neuroscientists, teachers, and educators, and embedding these matters within initial training sessions and continuing professional development.

Policy-wise, the study suggests that neuroplasticity-informed interventions can be incorporated into school systems. Allocation for budget provision to special teaching devices is provided, manufacturing of standard protocols for neurocognitive assessment within school classrooms, and design of online platforms to facilitate roll-out of gamified procedures. The study is also in support of policies for actual inclusion, as opposed to segregating neurodivergent students into specialist rooms since the interventions were conducted within regular classrooms.

While this study is contributing notably, it also has limitations which can be resolved in future work. First, even with rigid methodological design, the inability to fully randomize groups potentially introduced selection biases. Future studies have the advantage of using pure experimental designs for maximum internal validity.

Second, follow-up was limited to a relatively short period (6–12 months). It would be informative to see whether improvements noted are maintained in the long term and whether the changes noted in the brain are paralleled by long-term academic function. This would require longitudinal studies with more than one time point.

Finally, this study dealt with ASD and ADHD, but whether one uses the same techniques with other disorders—such as dyscalculia or nonverbal learning disorder—would be relevant. Since these disorders share some of the same cognitive deficits as ASD and ADHD (e.g., working memory or visuospatial processing), it could be the case that neuroplasticity-based interventions would benefit these students as well.

References

Alonso, M. J. Á., Cabello-Sanz, S., de Gea Abril, L., Illán, C. G., Lobo, P. M., Ruiz, S. M. & Montilla, S. P. (2024). *Neuroeducación en primaria: Un enfoque práctico a través de las áreas curriculares.* SANZ Y TORRES.

Barkley, R. A. (2019). Neuropsychological testing is not useful in the diagnosis of ADHD: Stop it (or prove it)!. *The ADHD Report, 27*(2), 1-8.

Baquedano, O. (2024). La relación: neuropsicología y educación en el sistema escolar, una revisión sistemática. *Revista Científica Arbitrada de la Fundación MenteClara, 9.*

Baron-Cohen, S. (2017). Editorial Perspective: Neurodiversity–a revolutionary concept for autism and psychiatry. *Journal of child psychology and psychiatry, 58*(6), 744-747.

Bastidas, G. Y. T., Macías, D. C. P., & Alvarado, M. K. J. (2022). Cuidados de enfermería en niños con problemas neurológicos. *Dominio de las Ciencias, 8*(3), 2510-2528.

Butterworth, B. (2018). The implications for education of an innate numerosity-processing mechanism. *Philosophical Transactions of the Royal Society B: Biological Sciences, 373*(1740), 20170118.

Conforme, J. A. G., & Morocho, E. K. A. (2024). Efectos de las actividades lúdicas en la reducción de la hiperactividad en niños con TDAH. *Ciencia Y Educación, 5*(8), 98-112.

Dehaene, S. (2020). *How we learn: The new science of education and the brain.* Penguin UK.

Diamond, A. (2013). Want to optimize executive functions and academic outcomes? Simple, just nourish the human spirit. In *Minnesota Symposia on Child Psychology: Developing cognitive control processes: Mechanisms, implications, and interventions* (Vol. 37, pp. 203-230). Hoboken, NJ, USA.

Da Silva, A. V., de Oliveira Zahn, V. M., de Sousa, T. O., Carvalho, C. M. C., Del Bello, M. M., Fowler, V. H. & Ferreira, P. F. P. (2024). Mecanismos de morte neuronal nos transtornos do neurodesenvolvimento: revisão à luz do DSM-5 e impactos na população brasileira. *Revista de Gestão e Secretariado, 15*(11), 4289-4298.

García, R. O. M. (2024). *La inteligencia motivacional: y su influencia en el aprendizaje individual y social.* Editorial Autores de Argentina.

León, M. I. G. (2022). *TDAH y funciones ejecutivas.* ANAYA.

Marín, F. A., & Esteban, Y. A. (2022). *Trastornos del espectro del autismo: bases para la intervención psicoeducativa.* ANAYA.

Meltzoff, A. N., & Kuhl, P. K. (2016). Exploring the infant social brain: What's going on in there. *Zero to three, 36*(3), 2-9.

Merzenich, M. M., Van Vleet, T. M., & Nahum, M. (2014). Brain plasticity-based therapeutics. *Frontiers in human neuroscience, 8,* 385.

Núñez, N. (2024). *Los niños también se deprimen: Cómo detectar a tiempo el autismo, TDAH, la ansiedad y otros trastornos mentales en la infancia.* La Esfera de los Libros.

Peñalba Acítores, A., López Cano, R., & Val, J. D. (2021). Neurodiversidad y cognición: Música y multisensorialidad en los entornos Metatopia. *Artnodes,* (28).

Pérez, A., Enríquez, G., Andrade, F., Bolaños, C., & Benítez, A. (2023). Estimulación cognitivo–conductual en niños con trastorno por déficit de atención e hiperactividad utilizando música y el idioma inglés: Cognitive–behavioral stimulation in children with attention deficit hyperactivity disorder using music and