Technology in teaching mathematics to students with ASD/ADHD in Ecuador and Spain

La tecnología en la enseñanza matemáticas a estudiantes con TEA/TDAH en Ecuador y España

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Abstract

The study investigates the impact of adaptive technology aids on the learning of mathematics for children between 9 and 14 years old with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD) in Spain and Ecuador. The mixed-method design was employed via a sample of 340 children, 9-14 years old, split evenly across Spain and Ecuador. Students utilized apps including Smartick, Matific, and virtual reality in Spain and Prodigy Math and Google Expeditions in Ecuador for a period of six months. There were significant gains on outcome measures of mathematical skill and intrinsic motivation in all groups, with effect sizes in Spain (d=2.12–2.19) larger than those in Ecuador (d=1.54–1.61). Mediators were technological infrastructure, teacher training, and institutional support, which were stronger in Spain. Qualitative findings underscored Ecuadoran concerns of low device utilization and connectivity, with additional Spanish rollout without concern also being noted by more resourced educators. The study emphasizes the potential of technology in education for facilitating neurodivergent learning but creates a need for equity of access in the form of teacher training specifically crafted, and policy contextualization for maximum gain.

Keywords: Adaptive technology; Math education; Neurodivergent students; Digital divide; Teacher training.

Resumen

El estudio investiga el impacto de las ayudas tecnológicas adaptativas en el aprendizaje de matemáticas en niños de entre 9 y 14 años con Trastorno del Espectro Autista (TEA) y Trastorno por Déficit de Atención e Hiperactividad (TDAH) en España y Ecuador. Se empleó un diseño de método mixto con una muestra de 340 niños de 9 a 14 años, distribuidos equitativamente entre España y Ecuador. Los estudiantes utilizaron aplicaciones como Smartick, Matific y realidad virtual en España, y Prodigy Math y Google Expeditions en Ecuador durante seis meses. Se observaron mejoras significativas en las medidas de resultado de habilidad matemática y motivación intrínseca en todos los grupos, con tamaños del efecto mayores en España (d=2,12-2,19) que en Ecuador (d=1,54-1,61). Los mediadores fueron la infraestructura tecnológica, la formación docente y el apoyo institucional, que fueron más fuertes en España. Los hallazgos cualitativos destacaron la preocupación de los ecuatorianos por el bajo uso de dispositivos y la baja conectividad, y los educadores con más recursos también observaron una mayor implementación del español sin problemas. El estudio enfatiza el potencial de la tecnología en la educación para facilitar el aprendizaje neurodivergente, pero plantea la necesidad de equidad en el acceso mediante una formación docente específicamente diseñada y la contextualización de políticas para maximizar los beneficios.

Palabras clave: Tecnología adaptativa; Educación matemática; Estudiantes neurodivergentes; Brecha digital; formación docente.

Introduction

The inclusion of technology tools in educating students with special educational needs, i.e., ASD and ADHD diagnosis, has introduced new insight into the education of mathematics - years ago characterized as an abstract science and thus impossible to educate students with various learning abilities. However, not all technologies are created equal in their revolutionary potential, nor are their virtues guaranteed. Their effectiveness relies on many factors: instrument adaptation to student profiles, teacher training in inclusive practices, using technology, sociocultural and technological educational practice environments, and policy durability in their support (Chaves et al., 2024).

The scientific literature has recorded the exponential growth of digital technologies for educational applications over the last decade. Prodigy Math Game, ST Math, or Khan Academy Kids are some software that employs AI-powered personalization engines in a bid to individualize math practice for each student based on their pace and learning style (Gutiérrez Ruiz et al., 2020; Izquierdo, 2020; López & Valenzuela, 2015). These trends have particularly been encouraging for kids with ASD/ADHD as they can provide real-time feedback, satisfaction, and low-stress social environments (Hijós & Cosculluela, 2022; Lima et al., 2023). For virtual reality, studies like those of Conejeros-Solar et al. (2018) show that immersive virtual environments not only interest students with ADHD but also allow the generalization of math capability to real-world contexts and move beyond the typical restriction of such a diagnosis.

Methodologically, more recent studies have employed quasi-experimental designs and mixed methods for determining the effectiveness of such technologies (Torres Díaz, 2024). For example, Díaz (2024) conducted a long-term intervention in Spain with students with ASD and learned basic geometry using a virtual reality application. Results showed statistically significant results in spatial comprehension and problem-solving compared to a control group that learned using traditional methods. Similarly, within the Latin American context, Fernandes et al., (2023) piloted an AI-based system in Ecuadorian public schools and reported gains in the mathematical fluency and motivation of students with ADHD, although these were moderated by access to devices at unplanned moments and patchy connectivity.

Aspects that lead to improved outcomes include: personalized learning based on the student's pace and cognitive style, immediate feedback that encourages self-correction, reduced social anxiety through controlled digital environments, and interactive visualization capabilities for developing logical-spatial thinking.

Optimism for such innovations, however, needs to be tempered by a critical assessment. As Goncalves & do Rocio Cordeiro (2024) alert, the indiscriminate use of educational technologies can have the consequence of reinforcing pre-existing inequalities if the conditions of implementation are not considered. In nations such as Ecuador, where technological infrastructure differs greatly from one region to another, technological exclusion of vulnerable students is a risk. Likewise, a purely technologically driven response without deep pedagogical consideration risks superficial practice that cannot address the real needs of ASD/ADHD students, whose highly individualized interventions and structured learning supports demand deep consideration (Torres & Téllez, 2020).

The problem underlying here, then, is not so much the presence or absence of technology but rather that complicated intertwinement of tool features, the educational system, politics of in-

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clusion, and teacher behaviour. Knowing how these differently coalesced in two poles, as in Spain and Ecuador, enables us not just to access and application differentials regarding technologies, but also to know the manner in which teaching methodologies, societal inclusion assumptions, along with physical conditions, shape technology infusion effect.

Ecuador-Spain technological gap is complex. Spain's more developed school technology infrastructure comes in the way of national policies like the Escuela 2.0 Plan and Digitalization and Digital Competences Plan 2021-2025, which have promoted the presence of devices and connectivity within school environments. On the other hand, Ecuador, although it has plans like the National Educational Connectivity Plan, still lags in rural internet connectivity, obsolete equipment, and a lack of teacher training in digital literacy (Ecuadorian Ministry of Education, 2023). This lack of balance in infrastructure has a direct influence on the capacity to incorporate future technologies like artificial intelligence or virtual reality at schools, lowering the diversity of strategies that can be provided to students with special educational needs.

Conversely, regulatory and cultural disparities are a problem as well. Spain has evolved integrative stable laws, like the Organic Law of Education (LOE) and its recent reform through LOMLOE, that establish solid principles to face diversity with curricular adaptations and personalized resources. Ecuador, despite having adopted education inclusion in the Constitution and Organic Law of Intercultural Education (LOEI), is faced with additional challenges of effective implementation due to budget constraints, territorial inequalities, and the lack of systematic specialized teacher training.

Spain has an internet penetration rate of over 93% in urban areas and over 85% in rural areas (INE, 2023), while in Ecuador, according to INEC (2023), only 68% of households have stable internet access, with only 35% of connectivity in rural areas. Furthermore, in Spain, 87% of teachers received training in digital skills in the past three years, compared to only 42% in Ecuador. These figures contextualize the real possibilities of technological implementation in each country. This infrastructural, legislative, and instructional practices disparity means that the impact of adaptive technologies on learning mathematics for students with ASD/ADHD cannot be equal in Ecuador and Spain. The need, therefore, for a comparative study that controls not only for learning outcomes, but also for implementation process and educational stakeholders' attitudes becomes apparent.

The gap in research that this study addresses is that no systematic comparison of new learning technology uptake and success with neurodivergent learners across environments of differing levels of technological development has been conducted. While there are many case studies from highly industrialized countries and some solutions from Latin American environments, comparative studies that not only identify "what works" but "under what conditions it works" are lacking. This is central to creating context-sensitive and responsive inclusive education policy that does not reproduce automatically models from elsewhere.

The working hypothesis under which this study operates presupposes that the use of adaptive technology in maths education improves the learning of students with ASD/ADHD but is dependent on access to technology, the quality of teacher training in schools, and prior inclusion policy in all countries. Secondary hypotheses are also developed: (a) that teacher professional development in the use of inclusive technologies positively influences their impact, (b) that AI-based personalized mechanisms within platforms are more effective than platforms that merely digitize

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traditional content, and (c) that students' beliefs about relevance of tools and accessibility significantly influence their motivation and performance.

The general objective of the research is to contrast the impact of adaptive technology tools on the learning of mathematics in students with ASD/ADHD in Ecuador and Spain. For this purpose, the following specific aims are set: (1) recognize and categorize principal digital platforms used in both nations to learn maths by neurodivergent students; (2) determine students' academic performance and participation through the use of the platforms; (3) investigate mediating variables of technology adoption and impact (context variables like infrastructure, policy, and pedagogy); and (4) provide evidence-based recommendations for improving equity in access and learning outcomes through innovative technologies.

This research represents a significant contribution to the study of inclusive mathematics teaching through technology, addressing not only the effectiveness of the tools but also the socio-technical conditions necessary for their effective implementation in markedly dissimilar contexts.

Method

The research went on within an intensive mixed-methods research design, i.e., a sequential explanatory model combining a quasi-experimental design with non-equivalent groups and qualitative accompaniment. The methodological design was appropriate to cover the dual aim of estimating the impact of adaptive technological tools on mathematics learning for students with ASD and ADHD, and explaining these results through teachers' everyday experiences and perceptions who implemented the intervention. The research took place between January 2024 and February 2025 in two geographical and socio-educational contexts: Spain and Ecuador.

Ethical procedures were in line with norms in the Declaration of Helsinki (2013) and had been approved by institutional review boards in both countries. Informed consent was obtained from all the parents or legal guardians before inclusion, and assent from the students themselves was obtained in an age-appropriate format. Participants were informed of their right to withdraw at any time without penalty. Confidentiality was ensured at all expense: all the information collected was anonymized, coded, and stored safely, and no identifying details were published or communicated.

The target population was students aged 9-14 years old who were clinically diagnosed with Autism Spectrum Disorder or Attention Deficit Hyperactivity Disorder according to DSM-5 criteria. The total sample was composed of 340 participants, half in each country. Ecuador provided 80 ASD students and 90 ADHD students; Spain provided 85 students in each diagnostic category. Participants were selected through non-probabilistic convenience sampling, with preference given to institutions that had already integrated adaptive technology into their curricula. This was an important consideration because it provided the most convenient means of lending ecological validity to the study and accessing settings with a minimum level of technological infrastructure necessary for the implementation of the intervention. Moreover, this sampling technique was necessary due to ethical and practical constraints in accessing officially diagnosed neurodivergent students in mainstream school environments.

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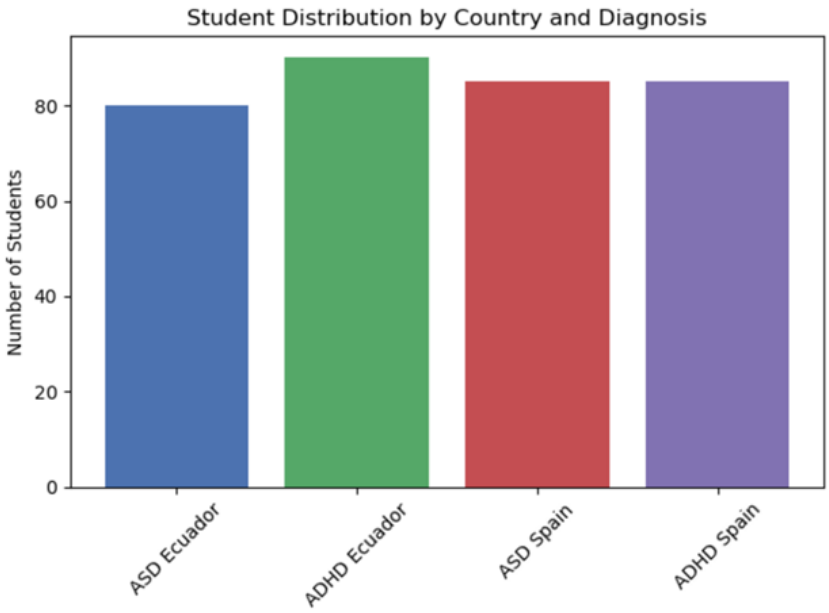
Figure 1.
Student distribution



Stricter inclusion and exclusion criteria were applied to determine sample homogeneity. The students formally diagnosed, partially literate, and had over 80% school attendance throughout the intervention period were considered.

The intervention was a controlled six-month enactment of adaptive learning platforms in maths lessons. In Spain, the interventions used were Smartick®, Matific®, and VR simulations on VRMath2; and in Ecuador, Prodigy Math® and Google Expeditions®. The interventions were selected using systematic review based on psychometric validity, curriculum adaptability, usability, and cultural responsiveness.

45-minute individual sessions on the platforms were utilized by students three times weekly, monitored by their maths teachers and researcher. Objective performance measures like tasks attempted, accuracy, time taken, and moving through levels of difficulty were automatically recorded on servers of the platforms, which assured data integrity and minimized observer bias.
Mathematical skills were measured with the Basic Mathematical Competency Test (PCM-B, Cronbach's $\alpha = 0.91$) at pre-test and post-test under standard conditions. Intrinsic motivation was measured with the School Motivation Scale in Mathematics (EMEM; $\alpha = 0.87$) and student-reported use of technology with a modified Technological User Experience Questionnaire (CET-U; $\alpha = 0.89$), an adaptation of the System Usability Scale.

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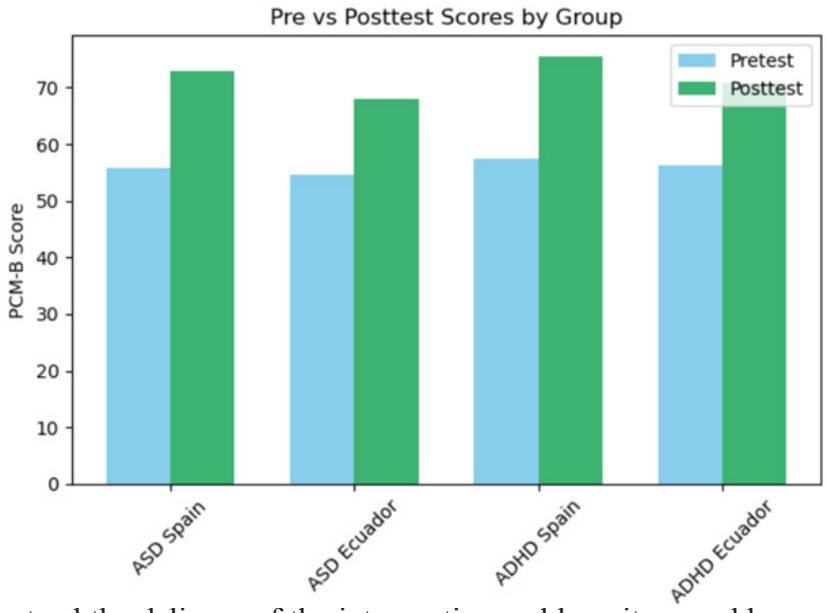
Figure 2.
PCM-B score



To understand the delivery of the intervention and how it was addressed in the two countries, qualitative data were obtained with the use of a semi-structured interview guide for teachers (content validity index = 0.92). This aspect was useful in examining the experiential and contextual determinants that influenced the uptake and effects of the technology tools. Specifically, teacher knowledge helped to identify barriers (e.g., infrastructural issues), enabling conditions (e.g., professional development), and emergent practices (e.g., improvisation or peer support), presenting a detailed picture of intervention success—or failure—across settings.

Quantitative analysis began with Kolmogorov-Smirnov tests for normality, followed by repeated-measures ANOVA to compare pre- and post-test scores within and between groups. Multiple linear regression analyses tested the moderating roles of motivation and technology perception, and Chi-square tests examined differences between categorical variables. Statistical computations were made with SPSS version 27 at a $p < 0.05$ significance level.

For qualitative analysis, inductive thematic analysis was utilized through NVivo 14. Systematic coding of emergent themes was conducted, but more richness is recommended to better understand how geographic and socioeconomic conditions (i.e., internet access, urban or rural living, institutional support) served as mediators of students' participation and performance. Discussing in detail how these structural contexts influenced the students' learning pathway would make the qualitative component stronger.

Results

Analysis of results allowed for the determination of specific and meaningful impacts of the utilization of adaptive technology tools on Spanish and Ecuadorian students with ASD and ADHD in learning mathematics. Pretest results of the PCM-B test indicated that entry levels of mathematical skill were analogous for the groups of both countries. Specifically, Ecuadorian students with ASD scored 54.6 (SD = 8.3) in the pretest and Spanish students 55.9 (SD = 7.9). Ecuadorian students with ADHD scored 56.2 (SD = 9.1) and Spanish students 57.5 (SD = 8.7). ANOVA analy-

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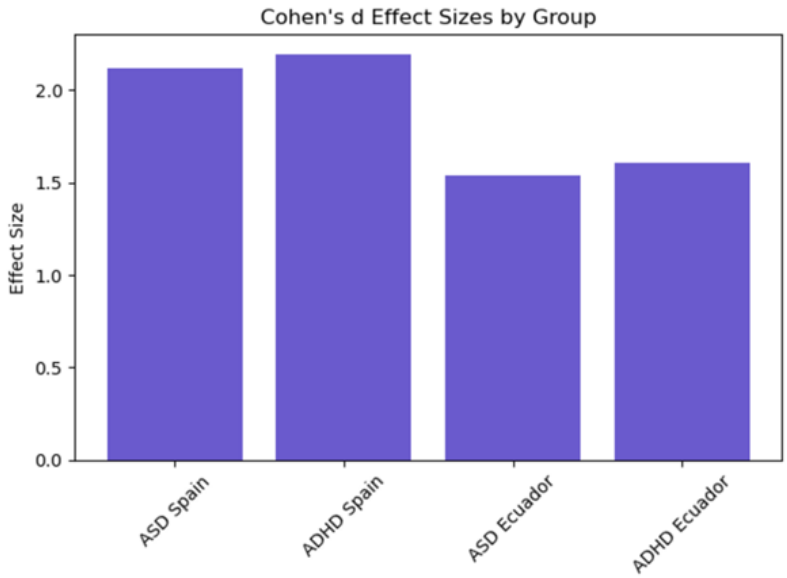
sis was statistically non-significant in country differences at baseline ($F(3,336) = 1.27$, $p = 0.283$), showing sample homogeneity.

At post-test, six months of intervention had resulted in math performance gains in all groups, with some variation by diagnosis and country. The ASD students achieved a score of 72.8 (SD = 7.5) in Spain and 68.1 (SD = 8.2) in Ecuador. The ADHD students scored 75.4 (SD = 6.9) in Spain and 70.7 (SD = 7.6) in Ecuador. Repeated-measures analysis revealed a main effect of time ($F(1,336) = 412.89$, $p < 0.001$, $\eta^2 = 0.55$) and a time and country interaction ($F(1,336) = 9.34$, $p = 0.002$, $\eta^2 = 0.03$), indicating that geographic setting partially mediated the intervention effect.

Effect sizes (Cohen's d) on improvement were large: $d = 2.12$ for Spanish children with ASD and $d = 2.19$ for children with ADHD. Effect sizes in Ecuador were also large, $d = 1.54$ for ASD and $d = 1.61$ for ADHD. This agrees with the perception that although adaptive technologies assisted in the two countries, their total effect was greater in the Spanish context because of possibly infrastructural and training factors.

Figure 3.

Cohen's effect size



Spanish ADHD students´ performance on individual tasks also showed important patterns. On high-complexity problem-solving tasks, 78.8% of Spanish ADHD students were high-competent and 62.4% of Ecuadorian students were high-competent, while for ASD students, 72.3% in Spain were high-competent and 65.5% in Ecuador were high-competent. Multiple linear regression showed intrinsic motivation ($\beta = 0.37$, $p < 0.001$) and perceived technological usability ($\beta = 0.29$, $p = 0.003$) predicted post-intervention performance significantly. Gender and age were not shown to be significant predictors.

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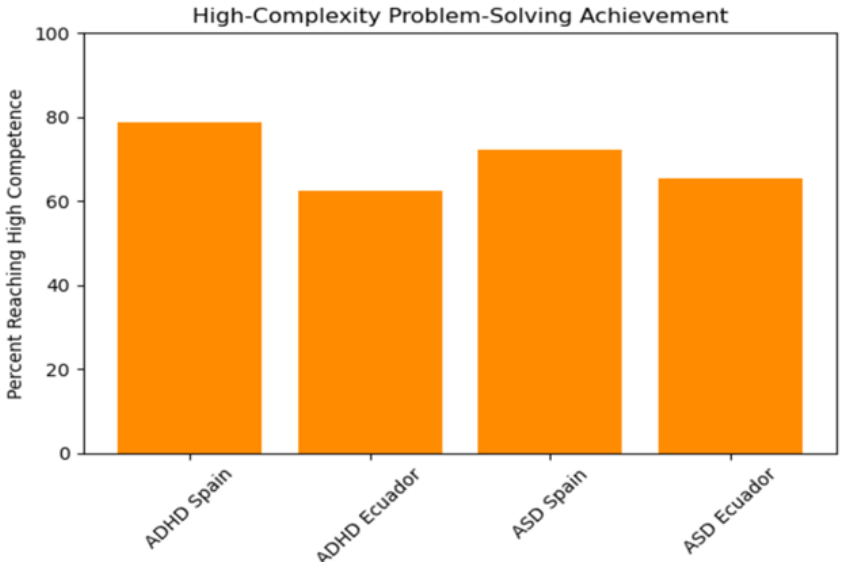
Figure 4.

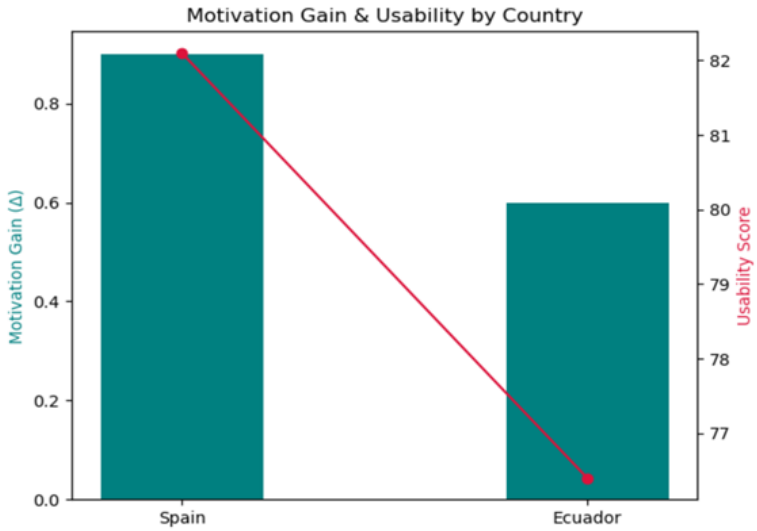
Problem-solving achievement



Intrinsic maths motivation was improved in all groups. Scores increased from a mean of 2.8 (SD = 0.6) to 3.7 (SD = 0.5) in Spain and from 2.7 (SD = 0.7) to 3.3 (SD = 0.6) in Ecuador. Paired-sample t-tests also confirmed these gains (Spain: $t(169) = 16.42$, $p < 0.001$; Ecuador: $t(169) = 13.05$, $p < 0.001$). ANOVA also showed a country-by-diagnosis interaction, with greater motivational gain in Spanish ADHD students.

Figure 5.

Motivation gain and usability



Self-reporting measure on CET-U reported high platform usability ratings: 82.1 (SD = 9.7) in Spain and 76.4 (SD = 11.3) in Ecuador ($t(338) = 4.88$, $p < 0.001$). While diagnostic category overall usability ratings were not significantly different, trends in application preferences existed. ASD children ever favoured such interventions like VRMath2 and Matific, which are distinguished by immersive setting, visual sequence, and lower language complexity. They are in line with their visual processing strength, need for structured low-stimulus interaction, and permit spatial

reasoning, an aspect of cognition in which they possess special abilities.

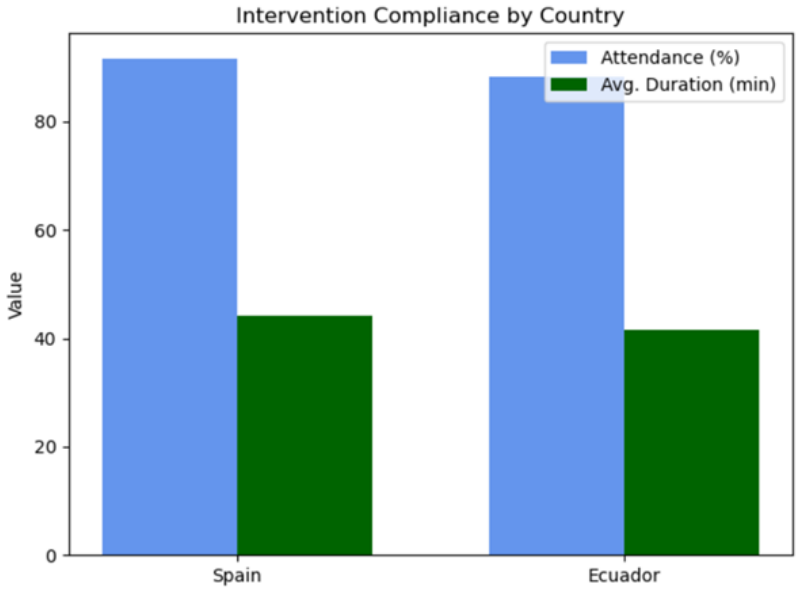
On the other hand, the ADHD students preferred websites like Prodigy Maths and Smartick, both with immediate feedback, quick-fire problems, and gamification in the form of rewards and a progress chart. All of these elements are consistent with their need for immediate reinforcement, novelty, and high interactivity to be constantly interested and on their toes during the sessions. The suggestions thus appear to be quite tailored to the individual motivational and attentional needs of each neurodivergent group.

Log analysis of the sites confirmed proper adherence to the intervention protocol: mean rates of participation were 91.7% in Spain and 88.2% in Ecuador. The mean length of sessions was only slightly longer in Spain (44.2 minutes) than in Ecuador (41.6 minutes). Frequency of use was positively and significantly related to gains on maths ($r = 0.42$, $p < 0.001$), once again confirming the finding that repeated use of the tools predicted more robust outcomes of learning.

Qualitative interview analysis by teachers contributed additional evidence. Spanish teachers underscored the need for stable infrastructure and constant access to high-speed internet and specialist hardware. Ecuadorian teachers, while being supportive of the intervention, indicated restricted access to devices and connectivity problems that necessitated constant improvisation (e.g., having to share the devices or go offline).

Figure 6.

Intervention compliance



Teacher training was also a determining factor. Spanish teachers felt prepared due to relevant and ongoing training. In Ecuador, most of them had initial training, but most believed they needed more technical and pedagogical support to utilize the tools to their maximum capability. Teachers in both environments reported having students more assured, especially when the students were off-task. An Ecuadorian teacher replied: “The ADHD children who became distracted earlier now request more tasks because they want to beat their records.” A Spanish teacher also replied: “ASD students were quieter and more concentrated when they worked out space issues with virtual reality.”

Country variations in infrastructure influenced implementation. Technical staff support

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was 95% Spanish school attendance, versus 57% in Ecuador. The difference supported the documentation of fewer session breaks in Spain (3.2%) versus Ecuador (9.8%). Logs of maintenance yielded an average of 0.8 technical problems per month in Spain, versus 2.4 in Ecuador.

CET-U student responses were also positive, such as “Learning this way is fun,” "I like competing with myself,” and “Maths easier with games.” Ecuadorian students complained about frustration caused by limitations such as "Sometimes the internet is down” or "Not every day are there enough tablets to go around."

No adverse affective or behavioural side effects were noted. Single cases of sensory overload were reported in four cases of VR exposure among ASD students (two for each country), and all of them were treated successfully with personal mentoring.

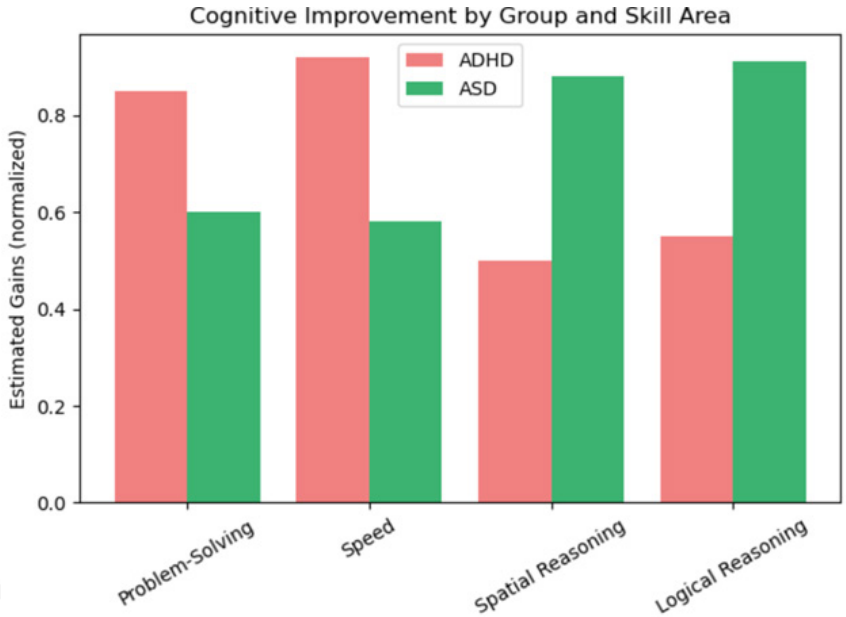
Conclusions

This study evaluated the impact of adaptive technology assists to mathematics education in students with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD) in two diverse learning contexts: Ecuador and Spain. Results of the six-month intervention testified to the beneficial influence of the aids on academic success and intrinsic motivation, confirming prior studies while additionally highlighting context-specific nuances.

Larger effect sizes were observed in Spain for all groups, pointing to the role of structural drivers such as infrastructure, teacher education, and institutional support. Children with ADHD improved significantly on speed and accuracy of problem-solving, while ASD children also improved on spatial thinking and logical thinking, reflecting their cognitive processes.

Figure 7.

Cognitive improvement



Motivation was another point of improvement, as was the case with Spanish students. This result contributes validity to the hypothesis that interactive, personalized, and entertaining technologies have the capacity to increase learner persistence and enjoyment—key variables for maintaining educational gains in the long term.

Notably, application preference also differed by diagnosis: ASD students liked immersive and visually structured tools (e.g., VRMath2), while ADHD students liked fast-paced, gamified

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environments (e.g., Prodigy Maths). These preferences indicate their distinct cognitive and motivational needs and demonstrate the necessity of differentiated tool selection in inclusive education.

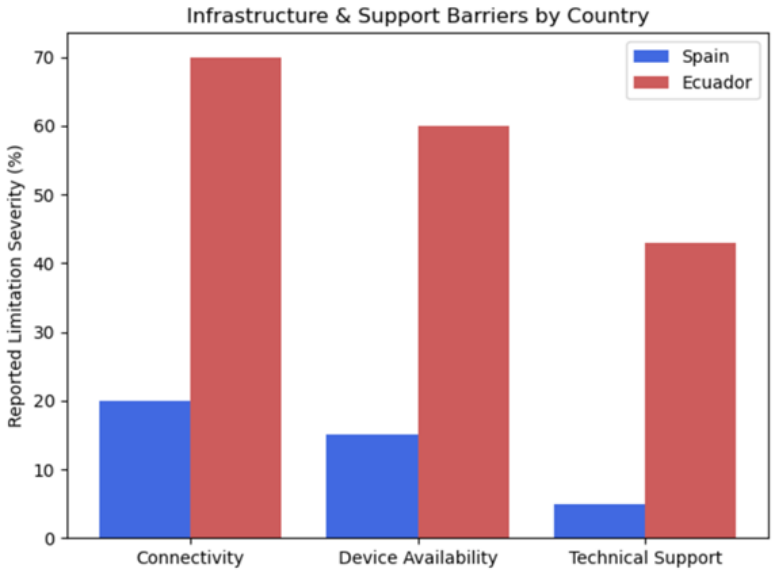
The correlation of frequency of tool usage with learning gain further augments the potential of consistent, structured technology integration. Contextual asymmetries—specifically in Ecuador—such as restricted connectivity and technical support, limited full intervention realization and should be addressed through targeted policy initiative.

Instructors reported increased student engagement and confidence but required more comprehensive training, particularly in under-resourced environments. While the study rated high for internal validity, it was low on longitudinal follow-up and enhanced curricular emphasis—both suggestions for future research. Furthermore, while sensory overload was rare, the fact that it happened at all speaks to the importance of flexibility and moment-to-moment responsiveness in tech-based interventions with neurodivergent learners.

In summary, adaptive technologies were shown to be effective to promote maths learning and motivation for students with ASD and ADHD, but whose success is also dependent on systemic conditions. Facilitation of equitable access, investment in teacher capacity, and alignment of tools to learner profiles are needed to achieve their optimum benefits. Future research needs to have a broader content area covered, longer-term tracking, and has to address the comparative effectiveness of different technological modalities for a range of learner needs.

Figure 8.

Infrastructure and support barriers



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