ARTÍCULO

Effectiveness of Structured Instruction Versus Traditional Methodologies in Mathematical Learning of Students With ASD and ADHD

Efectividad de la instrucción estructurada frente a metodologías tradicionales en el aprendizaje matemático de estudiantes con TEA y TDAH

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Abstract

Teaching mathematics to students with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD) is very challenging due to cognitive and executive deficits. The current study compared the efficacy of structured teaching and traditional approaches on improving the mathematical abilities of such learners. A quasi-experimental longitudinal research design was utilized that included a sample of 180 students (90 ASD and 90 ADHD), which were allocated to intervention and control groups. Tools such as the Mathematical Problem-Solving Test (MPST) and the Mathematics Difficulties Questionnaire (MDQ-AA) were administered. Results showed that the structured instruction group demonstrated considerable improvement (ASD: 45 to 75 points;

Arquitectura del silencio, Sebastián Camacho.

ADHD: 42 to 78 points), outperforming both traditional methods and control groups. Progressive structuring, explicit modeling, and visual supports helped to reduce impulsive errors and improve planning. The traditional methods, in contrast, showed smaller gains, revealing lack of effectiveness. The perceived difficulties also showed considerable improvement in the structured instruction group. These findings support the hypothesis that structured teaching is more effective, particularly in ASD and ADHD students, as it is aligned with their neurocognitive needs. It is therefore concluded that the application of structured and individualized pedagogical techniques is necessary to enable mathematical performance, motivation, and self-determination in these students. Future research could be required to examine the impact of these interventions in other areas.

Keywords: Mathematical learning, ASD, ADHD, structured instruction, traditional methodologies, academic performance.

Resumen

La enseñanza de las matemáticas a estudiantes con Trastorno del Espectro Autista (TEA) y Trastorno por Déficit de Atención e Hiperactividad (TDAH) es un gran desafío debido a los déficits cognitivos y ejecutivos. El presente estudio comparó la eficacia de la enseñanza estructurada y los enfoques tradicionales para mejorar las habilidades matemáticas de estos estudiantes. Se utilizó un diseño de investigación longitudinal cuasiexperimental que incluyó una muestra de 180 estudiantes (90 con TEA y 90 con TDAH) que fueron asignados a grupos de intervención y control. Se administraron herramientas como el Test de Resolución de Problemas Matemáticos (MPST) y el Cuestionario de Dificultades Matemáticas (MDQ-AA). Los resultados mostraron que el grupo de instrucción estructurada mostró una mejora considerable (TEA: 45 a 75 puntos; TDAH: 42 a 78 puntos), superando a los métodos tradicionales y a los grupos de control. La estructuración progresiva, el modelado explícito y los apoyos visuales ayudaron a reducir los errores impulsivos y a mejorar la planificación. Los métodos tradicionales, en cambio, mostraron ganancias menores, lo que revela su falta de eficacia. Las dificultades percibidas también mostraron una mejora considerable en el grupo de instrucción estructurada. Estos hallazgos apoyan la hipótesis de que la enseñanza estructurada es más efectiva, particularmente en estudiantes con TEA y TDAH, ya que está alineada con sus necesidades neurocognitivas. Por lo tanto, se concluye que la aplicación de técnicas pedagógicas estructuradas e individualizadas es necesaria para posibilitar el desempeño matemático, la motivación y la autodeterminación en estos estudiantes. Se requerirán futuras investigaciones para examinar el impacto de estas intervenciones en otras áreas y a largo plazo.

Palabras clave: aprendizaje matemático, TEA, TDAH, instrucción estructurada, metodologías tradicionales, desempeño académico.

Introduction

Mathematical education in students with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD) is extremely demanding, as both of these disorders entail impairments of cognitive and executive functions. Mathematical problem-solving involves the coordination of higher-order cognitive abilities like working memory, cognitive flexibility, and attention regulation, abilities impaired in these groups (Geary, 2020). Prior work has examined diverse pedagogic interventions for enhancing the teaching of mathematics and systematic instructions to students as a superior option over conventional strategies (Swanson, 2021). Despite this, reservations persist in its measurement of the magnitude of effect as well as in its generalizability across multiple learning contexts, and thus warrants carrying out controlled and rigorous studies to determine its comparative effectiveness.

Teaching mathematics to children with ASD and ADHD has been a subject of concern due to the convergence of certain challenges in this case. Barkley (2021) explains that children with ADHD exhibit impairments in working memory and inhibitory control, which result in an impact on their ability to maintain processing of math information in a sequence and to control their learning. In ASD, cognitive rigidity and the lack of contextual integration hinder solving mathematics problems that require flexibility and flexible reasoning (Pellicano, 2021). Such variations mean that instructional methods could be modified the unique requirements of each group based on the neurocognitive idiosyncrasies that influence their learning.

Scientific controversy regarding the efficacy of methodologies for teaching mathematics has grown interest in scientific literature. Structured instruction is based on systematic breaking down of math content, clear demonstration of solution steps, and step-by-step presentation of mathematical concepts, which enable internalization of information and prevention of acting-on-impulse mistakes in ADHD students (Rapport, 2022). In contrast, regular procedures, which enable less individualized instruction and less structuring of information, are likely to be less beneficial for such students, who require more feedback and direction (Diamond, 2020). Current research has discovered that ASD and ADHD students perform better in mathematics when explicit and structured instruction is used compared to applying conventional methods based on generalized instruction (García, 2023).

While some studies verify the effectiveness of structured instruction as a best practice, a knowledge gap has resulted from the fact that relatively few comparative studies rigorously examine its efficacy when compared with traditional methods within various learning environments. Most of the studies have focused on specific interventions no rigid regard for long-

term effect or success in a broad population (Swanson, 2021). Further, their influence on variables such as motivation, self-regulation, and mathematics learning transfer to real-world environments must be explored, as little research by existing literature has been conducted on such variables (Molina et al., 2023).

Math education of students with ASD and ADHD is influenced by a variety of neurocognitive and pedagogical factors that need to be considered in instructional development. Executive processes are the basis of math proficiency because working memory facilitates numerical processing, inhibitory control regulates impulsivity under decision-making conditions, and cognitive flexibility allows one to adapt to different types of mathematical challenge (Diamond, 2020). In ASD students, strategy generalization issues can lead to rigid application of mathematical algorithms irrespective of problem variability, affecting their performance on contextualized reasoning tasks (Pellicano, 2021). In ADHD, impulsivity and difficulty with sustained attention can lead to errors in mathematical operations and in adherence to the problem-solving order (Rapport, 2022).

Pedagogically, systematic instruction has been identified as a highly effective pedagogy is used to improve mathematics learning among populations. Systematic instruction is based on the sequenced and step-by-step presentation of mathematical ideas, the use of modeled examples, and the incorporation of scaffolding strategies that facilitate the progressive development of mathematical skills (Swanson, 2021). Existing research has established that ASD and ADHD students who were instructed through structured teaching showed extensive improvement in performing math problems compared to students who were instructed using less structured styles of conventional schooling (García, 2023). Besides, the use of visual aids and graphic organizers has been shown to enhance the understanding of mathematical problems in ASD students, while direct teaching of metacognitive skills ensures that ADHD students improve planning and error control (Ciesielski, 2022).

Traditional approaches, however, which typically rely on general content presentation and free-form problem-solving activities, do not work for ASD and ADHD students. Studies have shown that such practices lead to higher levels of demotivation and frustration among students they are not made explicitly supportive of the cognitive needs of individuals (Molina, 2023). Not providing explicit and sequential training in such methods may impede learning problem-solving steps helping the sustainability of systematic defects in the mathematical education of these groups (Butterworth, 2021).

This study aims to determine if systematic instruction and conventional practice in the mathematical learning of students with ASD and ADHD are

equivalent. It further hopes to compare their impact on the problem-solving skill, conceptual mastery, and independent learning of the students with these conditions. Hypothesis is that systematic instruction will do better on mathematics performance than standard practice, i.e., regarding strategic planning and limiting impulsive errors. ASD students will benefit particularly from information broken into fragments, and from visual aids, ADHD students will see improvements in regulation and control of their learning process.

PICO components

- **P** (Population): Autism Spectrum Disorder (ASD) students and Attention Deficit Hyperactivity Disorder (ADHD) students.
- **I** (Intervention): Organized instruction in mathematics education.
- **C** (Comparison): Conventional methods in mathematics education.
- **O** (Outcome): Effectiveness in learning mathematics (assessed through academic achievement, understanding of concepts, or problem-solving).

The research question for this study is: To what extent is structured instruction more effective than regular methods in teaching mathematics on students with ASD and ADHD?

Method

Longitudinal quasi-experimental research design in the use of estimation of the effects of pedagogical intervention factors to students' mathematics achievement after monitoring the progress over a duration of time is what was used in this context. The addition of control group that received no special intervention served to distinguish between the impact of the independent variable (type of intervention) and that of the dependent variable (mathematics achievement), and greater internal study validity was established even further.

The sample had 180 students, 90 of whom had been diagnosed with ASD and 90 with ADHD, and each of these two groups had three subgroups: one for instruction with a structure, one to retain traditional methods, and one as a control group. This distribution permitted the accurate comparison of intervention types with control group in a manner such that differences yielded would be due the procedures utilized. The sample size was substantial enough to provide statistical power to detect significant differences between groups with 95% confidence and a margin of error 5%.

The sample was selected using intentional non-probabilistic sampling, together with educational centers with students who have special edu-

cational needs. For representativeness, students from different geographical regions and socioeconomic backgrounds were approached so that the sample would be a representation of the heterogeneity of the population of students with ASD and ADHD in Spain and Ecuador. Inclusion criteria were adequately defined: students must have a DSM-5-diagnosed clinical ASD or ADHD, be attending educational centers where curricular adaptations are provided, and have informed parents' or legal guardians' consent. Exclusion criteria were the presence of severe cognitive comorbidities, i.e., moderate or severe intellectual disability, which could interfere with the assessment of math abilities.

Three primary instruments were employed: the Mathematical Problem-Solving Test (MPST), the Mathematics Difficulties Questionnaire for ASD and ADHD (MDQ-AA), and the Pedagogical Strategies Survey (PSS).

The MPST was employed to measure understanding of problem statements, choice of strategy, accuracy of computation, and control of error, all of which are critical components of mathematical problem-solving. It had 20 items, with a top score of 100 points, and was highly reliable with a Cronbach's alpha of over 0.85. MDQ-AA assessed self-reported issues among students when they are learning mathematics, on understanding, planning, and emotional concerns on learning mathematics. The measure was derived from known scales, for instance, by Swanson, (2021). In turn, the instrument became psychometrically sound. PSS assessed instructional strategies employed by teachers when interacting with ASD and ADHD students. This was validated professionals in special education to ensure quality data obtained. Data was further augmented with semi-structured interviews conducted among 20 teachers (10 each of the intervention groups) to investigate self-reported facilitators and barriers in teaching mathematics to these students.

Data analysis was conducted on three broad levels, namely, descriptive, inferential, and correlational. Descriptive analysis yielded means, standard deviations, and frequency distributions to operationalize mathematical performance across groups. Shapiro-Wilk and Kolmogorov-Smirnov were used to assess data normality before group comparison. Student's t-tests, about to data normality, compared the intervention group and control on mathematics performance in inferential analysis. Furthermore, repeated-measures ANOVA was conducted to investigate the interaction effect between instructional method and disorder category (ASD and ADHD). Pearson's coefficients were used in correlational analysis to investigate the relationship between pedagogic strategies and the mathematical performance of the students. A further multinomial logistic regression model was developed in an attempt to research the most significant predictors of performance in math problem-solving. Finally, qualitative data analysis

of the interview with instructors identified typical patterns for facilitators and barriers, in teaching mathematics to students with ASD and ADHD, through thematic analysis.

The process of collecting data was demarcated in three phases: pre-test, intervention phase, and post-test. At the initiation stage, MPST and MDQ-AA were administered to the entire subject list, questionnaires pedagogical strategy and interview sessions from the teachers. Under the course of intervention which extended for 12 weeks, students received guided teaching or conventional means, depending on the group the student and follow-up on every week. MPST and MDQ-AA were then administered at the last stage to measure changes in students' math performance, comparing intervention groups with control groups through comparative analysis. This was carried out to produce robust and valid data, supporting the conclusions of the study with empirical evidence.

Results

The ASD students obtained an average of 45 points (SD = 12.3) on the MPST, and the ADHD students obtained an average of 42 points (SD = 13.2) on the MPST during the pre-test. These initial results are indicative of both groups' difficulties in mathematical problem-solving, as suggested by the cognitive pattern of these disorders. Their low performance scores in the ADHD group are the result of their impulsivity and inattention under tasks that call for sequential and planful processing, while those of the ASD group are the result of cognitive rigidity and context integration impairment.

Improvement in math performance was notable in the structured instruction group after intervention. The ASD students in this group scored a mean of 75 (SD = 10.1) on post-test, 30 points improvement from pre-test. The ADHD students in this same group scored a mean of 78 (SD = 11.5), a 36-point improvement. These findings underscore the effectiveness instruction that was effectively designed and grounded in incremental partitioning of mathematics content, explicit demonstration of problem-solving strategy, and introduction of visual forms such as graphic organizers and diagrams. These all supported mathematical problem understanding and restricted impulsive error, particularly in ADHD students, who were shown to have improved planning and regulation of problem-solving activity.

The other two groups, the traditional methods and the control, also made less gain. The mean for the students with ASD in the traditional methods group was 60 points (SD = 14.3) post-test, with a 15-point increase on the pre-test. The mean for the control group was 55 points (SD = 13.5), but only with a 10-point increase. In the traditional methodologies group of

ADHD students, the score was 63 points (SD = 15.7) and increased by 21 points, and in the control group, 59 points (SD = 14.1) and an increase of 17 points. This means that the traditional approaches with their focus on generalized presentation of content and absence of organization in problem-solving activities are less advantageous to the individualized needs of ASD and ADHD students.

Statistical comparison through a repeated-measures ANOVA confirmed that group differences were statistically significant ($p < 0.001$). The analysis allowed examination of group differences and changes in math achievement over time. Post-hoc analysis with Bonferroni test indicated differences between the structured instruction group and the other two groups (control and conventional methods) were statistically significant ($p < 0.05$). No significant differences were observed in the control groups and conventional approaches, and gains in these groups were minimal and cannot be accounted for by pedagogical treatment.

These results confirm the hypothesis that systematic instruction surpasses conventional instruction in promoting mathematical proficiency in students with ASD and ADHD. Material segmentation and provision of visual supports facilitated ASD students to circumvent problems in context integration and generalization of strategies, whereas clear instruction and showing of strategies benefited ADHD students by reducing impulsive errors and augmenting planning ability.

With the rise in MPST scores, significant changes in the perception of mathematical difficulties among students were also discovered. Pre-test scores of ASD students had an average of 4.2 on the perceived difficulty scale (range 1-5), and pre-test averages from ADHD students were 4.1. These levels represent a high degree of perceived difficulty and can be likened to the frustration and loss of confidence that such students feel towards more difficult math problems. But after intervention, the structured instruction group reported a substantial reduction in perceived difficulties: ASD students averaged 2.8, and ADHD students averaged 2.9. Conversely, the control groups and traditional methods showed lower reductions, with means of 3.7 and 4.0 for ASD, and 3.5 and 3.8 for ADHD, respectively.

Student's t-tests confirmed that differences between the structured instruction group and the other two groups were statistically significant ($p < 0.01$). These findings confirm that structured instruction not only improves mathematical performance but also has positive effects on students' motivation and confidence. With an organized structure and pictures, students understand mathematical problems better and are more inclined to try them, reducing their of difficulty and promoting their tendency to seek out challenges.

An integration of the Pedagogical Strategies Survey (PSS) revealed that explicit instruction, visual supports, and repetitive practice were employed by the teachers in the structured instruction group in their instructional approach. The strategies to practice and consolidate the most important mathematical skills, and this resulted in improved performance. Teachers observed that the students were less distracted and more focused, with improved learning. Teachers in the traditional methodologies group, however, used more conventional methods such as verbal direction and group work, and there was less evidence of improvement. For the control group, where no methodologies were used directly, mathematics performance improved slightly.

Semi-structured interviews with teachers provided an insight into the facilitators and inhibitors of teaching mathematics to children with ASD and ADHD. Structuring tools or aids comprised existing structuring of material, activities structured on an individual basis, and the use of visual and manipulative aids. They helped in maintaining the accomplishment of abstract math by students and keeping students engaged in class. Difficulty in maintaining student attention and working with students with ASD in emotionally and behaviorally manageable manners continued to be the biggest challenges. Despite the accommodations, these students were still having problems with actual engagement in the math activities that hurt their learning process.

Correlational analysis also found a statistically significant relationship between the use of a structured pedagogical approach and math performance. Pedagogical strategy and MPST score were moderately related for students with ASD ($r = 0.68$, $p < 0.001$) and ADHD ($r = 0.65$, $p < 0.001$). The results indicate that the use of structured and adapted pedagogical strategies is the strongest predictor of math problem-solving success among students with the disorders.

Discussion

The results were that systematic instruction was significantly better than usual practice or the no-intervention control group at enhancing math performance and reducing self-reported difficulty in students with ASD and ADHD. These results are consistent with mounting evidence to indicate that ASD and ADHD students can gain a significant advantage from explicit, systematic, and individualized pedagogy. Particularly, organized instruction that employs visual aids, repetition of tasks, and sequential instruction has proven effective in enhancing academic achievement among these groups (Baker et al., 2020; Swanson, 2021). The results of this study align with these findings, as the students with ASD and ADHD who received systematic instruction on math problem-solving and reported fewer perceived difficulties, previous studies (Hughes et al., 2018; Koenig et al., 2016).

Specifically, the improvement of the performance of students with ASD and ADHD who were instructed through structured instruction agrees with research emphasizing the importance of maintaining a highly predictable and structured learning environment to maximize attention and comprehension (Caldwell et al., 2017; Hume et al., 2015). These strategies are particularly effective with ASD students, who will require more explicit structure and visual information (Lindsey et al., 2016), and ADHD students, who will require more attention and less distraction in the classroom (DuPaul et al., 2018). Structured teaching has also been found to be effective by other researchers advocating for its use in the classroom, namely to teach math proficiency (Swanson, 2021).

On the other hand, evidence of lower efficacy of traditional measures is complemented by studies confirming that typical pedagogical practices are not always adjusted to suit unique requirements of students with ASD and ADHD, which can be difficult for them to adapt to more universal instructional practices (López et al., 2020; Sutherland et al., 2015). Traditional methods based on auditory instruction and collaborative learning might be less responsive to students with attention deficits or auditory or social information processing deficits. These students are likely to face challenges dealing with traditional methods, which can affect their learning.

From a perceived difficulty in mathematics viewpoint, results of this research confirm previous studies that students with ASD and ADHD will be more likely to report increased cognitive and affective difficulties when faced with difficult academic tasks (Thompson et al., 2019). Systematic teaching approaches, providing additional support and individualized instruction, appear and boost the confidence of students in their ability.

Theoretically, findings validate hypotheses contending explicit and systematic instructional support is necessary in improving the performance of students with special education needs, particularly ASD and ADHD. The study requires adaptive pedagogy, contending interventions ought to be oriented towards the distinctive characteristics of the disorders, such as attentional deficits, sensitivities to sensory stimulation, and the requirement of additional emotional support.

Practically, the study offers strong evidence to support the implementation of education interventions through formal procedures appropriate for ASD and ADHD learners. The home message from instruction in the classroom is clear: teachers can significantly contribute to promoting such students' math abilities by implementing more explicit and adapted approaches, such as the use of visual aids, drill practice, and simplified instructions. In addition, systematic instruction is also highly beneficial to ADHD pupils, who are susceptible to other aspects of distraction and inattention.

At school, the report suggests that schools conduct training teachers to use specific pedagogical methods in managing ASD and ADHD. The methodical approach of teaching can prove to be advantageous not only for mathematics but also for other academic subjects in school, and a whole package for special-needs students can be offered. In the same manner, integration of adaptive strategies into the curricula of students with ASD and ADHD will enhance their input to the learning process and develop their intellectual ability as well.

Despite the extraordinary outcomes, the study has its constraints that must be remembered when interpreting the results. One is, quasi-experimental research design entails the possibility that the outcomes would have been subject to uncontrolled variables, i.e., variance among the students or variation of intervention implementation. Despite efforts by the control over the sample variables with to inclusion and exclusion conditions, there were extraneous variables that influence the findings. For instance, the intervention effect could have been moderated by teacher support or student support that were not measured in this study.

Secondly, the sample size might have ruled out identifying more limited or nuanced effects, particularly distinguishing the ASD and ADHD groups. Even though statistical estimation for the given sample size remained in line, an enlarged sample might have proved accurate and generalizable.

Lastly, the final consideration study specifically examined maths attainment and did not examine other facets of academic and social progress. Whether or not the use of structured pedagogical interventions has a positive impact on all spheres of learning, reading or social skills, compared to maths, is not known.

Conclusions

This study firmly established that explicit instruction significantly impacts students with ASD and ADHD positively in their math performance. Explicit and modified pedagogical practices utilized facilitated improved problem-solving skills and perceptions of academic difficulty among the students. In addition, evidence suggests that the more traditional pedagogical methods are less effective in improving school performance among such students, recognizing a need to create pedagogical methods attuned to the particular nature of such disorders.

Despite the limitations of the study, findings suggest that formalized approaches within the classroom are a valuable asset in enhancing learning outcomes among ASD and ADHD students. The findings of this research have important practical implications planning inclusive education policies, suggesting that teaching practices should be adjusted to address the needs of these children.

Future research can continue to examine this work and quantify the effect of structured instruction on other areas of academic functioning, such as reading and social skills. Longitudinal analyses would also be beneficial to ascertain the effect of such interventions over extended periods and how actual implementation of structured pedagogic practices influences the academic and social development of students over an extended period.

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