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The divergent reckoner the creative thinking of a child with ASD in solving mathematical problems in the multiplicative conceptual field

Abstract: We identified aspects of the creative thinking of a ten-year-old ASD child when solving mathematical problems in the multiplicative field in interactive groups from the perspective of dialogic learning. This is a qualitative exploratory study in which the strategies used and solutions produced in order to respond to closed and open problems were analyzed. We concluded that the ASD child was able to create original, flexible, plausible strategies anchored in mathematical arguments, which was possible due to the presentation of unique internal aspects and aspects related to social interactions. The way in which he behaved in interactions, the mediation of adults and the differentiated cognitive style were drivers of creativity.

Keywords: Creative Thinking in Mathematics. Autism Spectrum Disorder. Dialogic Learning. Inclusive Mathematics Education.

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Article

El calculador divergente: signos de creatividad en un niño autista durante la resolución de problemas matemáticos

Resumen: Identificamos aspectos del pensamiento creativo de un niño con TEA de diez años al resolver problemas matemáticos en el campo multiplicativo en grupos interactivos desde la perspectiva del aprendizaje dialógico. Se trata de un estudio exploratorio cualitativo en el que se analizaron las estrategias utilizadas y las soluciones producidas para dar respuesta a problemas matemáticos cerrados y abiertos. Concluimos que el niño con TEA fue capaz de crear estrategias originales, flexibles, plausibles y ancladas en argumentos matemáticos, lo cual fue posible porque presentó aspectos internos únicos y aspectos relacionados con las interacciones sociales. Su forma de comportarse en las interacciones, la mediación de los adultos y su estilo cognitivo diferenciado fueron impulsores de la creatividad.

Palabras clave: Pensamiento Creativo en Matemáticas. Trastorno del Espectro Autista. Aprendizaje Dialógico. Educación Matemática Inclusiva.

O calculista divergente: o pensamento criativo de uma criança com transtorno do espectro autista na resolução de problemas matemáticos do campo multiplicativo

Resumo: Foram identificados aspectos do pensamento criativo de uma criança TEA, com dez anos de idade, ao solucionar problemas matemáticos do campo multiplicativo em grupos interativos realizados em uma classe de ensino regular, sob a perspectiva da Aprendizagem Dialógica. Trata-se de um estudo qualitativo do tipo exploratório, no qual foram analisadas as estratégias utilizadas e as soluções produzidas em busca de responder a problemas matemáticos fechados e abertos. Concluiu-se que a criança TEA foi capaz de criar estratégias originais, flexíveis, plausíveis e ancoradas em argumentos matemáticos, o que foi possível devido a aspectos únicos internos e aspectos relacionados às interações sociais. O modo como se comportou nas interações, a mediação dos adultos e o estilo cognitivo diferenciado foram propulsores da criatividade.

Palavras-chave: Pensamento Criativo em Matemática. Transtorno do Espectro Autista.

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Aprendizagem Dialógica. Educação Matemática Inclusiva.

1 Introduction

In Brazil, 35% of the target audience for special education (PAEE) are people on the autistic spectrum (Brazil, 2024), and the growing number of students with this disorder in classrooms is clear, since 95% of PAEE are enrolled in regular classes (Brazil, 2024). However, little progress has been made in ensuring that these students have their right to a good quality education guaranteed. This points to the need to implement inclusive school practices that overcome deficient, ableist and biological views about those who do not present typical development.

Although, throughout history, there have been advances in what is understood and expected of people with Autism Spectrum Disorder (ASD), and even though it is increasingly common to find children with ASD in regular classrooms, it is clear that the lack of preparation of teachers and the lack of knowledge about the peculiarities of this disorder have created a limited perspective regarding the potential of these people. In addition to the lack of preparation of teachers to deal with autistic children, there is a lack of studies that makes it difficult for these professionals to access information about ASD (Santos, 2008).

This article seeks to counter this limiting perspective by arguing and showing evidence that these children can and should be encouraged to develop higher-order abilities, such as creative thinking. However, it is clear that some conditions regarding the organization of classroom interactions, providing opportunities for argumentation and exchange of ideas, and valuing each person's strategies are important factors for the expression of creativity to occur when a child with ASD solves mathematical problems in the multiplicative conceptual field in interaction with peers with typical development.

With this focus, this text highlights partial results of a study that had as its research subject an ASD student enrolled in the 5th grade of Elementary School[1]. Aspects of the creative thinking of the ASD child that emerge when developing strategies and using solutions to respond to closed and open mathematical problems are analyzed. Student records, data generated in observations and recorded and transcribed dialogues composed the corpus of the data analyzed through content analysis.

2 Theoretical contributions

The research carried out is supported by the following theoretical contributions: assumptions of Inclusive Mathematics Education, learning of ASD subjects, Dialogical Learning and Creativity in Mathematics. These are theoretical fields that helped to analyze and understand aspects present in the mathematical thinking of an ASD subject, allowing them to think divergently and build original, flexible, useful and, therefore, creative strategies and solutions (Carvalho, 2023; Lithner, 2008).

The following examines each of these theoretical contributions, seeking to establish connections between them. The aim is to demonstrate how they contributed to the modeling of this qualitative exploratory study, based on dialogue and the emergence of creativity during the solution of mathematical problems in the multiplicative conceptual field.

2.1 Autism Spectrum Disorder and cognitive development

Much of what is known about ASD individuals is more related to what is learned from the exclusionary culture that characterizes society than to the experiences of living with them.

[1] Study submitted to the Ethics Committee of the State University of Paraná under CAAE 77358623.0.0000.9247, approved by opinion number 6,933,441. It also had support from Capes through a scholarship paid to the first author.

Therefore, when we view them with pity, disbelief in their capabilities, or as people who depend exclusively on medication to be integrated into the school environment, we are reproducing a historical path that has shaped the social view of these people.

Thus, social practices, including those that occur in schools, are permeated by historical and cultural biases that lead us to believe that inclusion of ASD individuals is occurring when, in fact, such practices can contribute to disqualifying their development and social participation. In Figure 1, inspired by Elias and Paulino (2022) and created by Carvalho (2023), it is evident how historical evolution has allowed different perspectives on the role of the ASD subject in society without, however, eliminating exclusionary remnants that are still noticeable today and prevent full inclusion.

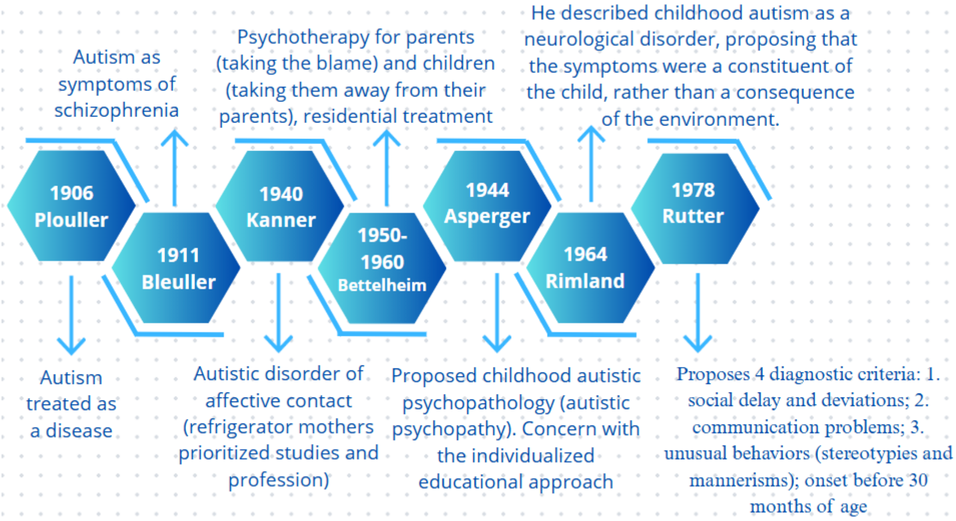

Figure 1: ASD throughout history (Carvalho, 2023, p. 269)

From the *demented* to the *schizophrenic*, from the *schizophrenic* to the *victims of their parents' indifference*, until the 1960s, these people were considered threats to the so-called normal people — they should be separated from society — or victims of their parents' lack of affection — thrown into mental hospitals or boarding schools that would keep them away from their family life. In any case, the prevailing logic during this period was to isolate people with ASD, excluding them physically and symbolically. For decades, “their rights [were] relegated, and they were sent, as children, to mental hospitals in search of containment of their deviant behaviors, being subjected, for this purpose, to torture and degrading treatments” (Carvalho, 2023, p. 268).

Since 1964, when autism began to be recognized as a neurological pathology, these ideas based on isolation have been mitigated by biological concepts. However, even today, despite the ease of access to information, there are mistaken views that defend the segregation of people with ASD, either through exclusion into special classes with few or no classmates, or through the belief that, due to their particularities, they are incapable of learning, making school supposedly ineffective or even dispensable.

Although this understanding represents an advance in relation to how the subject of ASD was socially understood, the biological conception focuses on disability, emphasizing negative aspects that characterize the person with this condition. The Diagnostic and Statistical Manual of Mental Disorders DSM-V, for example, distinguishes autism by the presence of, among other characteristics, impairment in social interaction, language difficulties and restricted interests (APA, 2014).

Based on psychiatry and psychology, this Manual moves autism away from “more philosophical bases, towards organicist perspectives” (Silva, 2019, p. 24). The information in the Manual emphasizes the incapacity of these people, demonstrating the difficulties in their cognitive development. However, it is necessary to consider, above all, the positive aspects that influence the development of abilities aimed at the production of mathematical knowledge, understood as the transition from a lower level to a higher level of knowledge, whether developed individually or collectively.

Contrary to these deficient positions, studies such as those presented below have identified potentialities in autistic people that, contrary to what has been stated, demonstrate that they can be as talented and creative as, or even more so, than their peers with typical development (TD). These studies seek to quantitatively compare the abilities of TD people with those presented by autistic people, either through questionnaires or in verbal and figurative creativity tests.

When observing individuals with special abilities, Happé and Vital (2009) listed the aspects of ASD that predispose to talent. Thus, they sought to understand why remarkable special abilities are much more common in conditions on the autistic spectrum than in other groups. The authors found three important factors that allow ASD individuals to be talented and to present special abilities in areas such as Mathematics (rapid multiplication, identification of prime numbers), Music (absolute pitch, instant reproduction of recently heard music), and Arts (perspective drawing).

The first factor concerns the difficulty with theory of mind, that is, difficulty in understanding the mental state of others, of putting oneself in someone else's shoes. Although this is a factor that impairs social interactions and communication, this condition can contribute to originality, since, by not being able to "read other people's minds" (Happé; Vital, 2009), the ASD individual becomes skilled at thinking differently from the group's predominant ideas and popular knowledge, thus presenting original ideas.

The authors list three possibilities that justify how impairments in recognizing the mental states of others can influence the emergence of talents in ASD. In the first possibility, it is noted that ASD individuals free up mental resources and time that so-called neurotypicals would use to track and remember social content, and can use these resources to develop talents.

The second possibility is that the difficulty in tracking the mental states of others may contribute to originality, since these individuals have their own ways of thinking, regardless of what others think. Since it is common for people with ASD to have difficulty accessing stereotyped knowledge from their peers or to be guided by what they believe to be correct or not, they tend to feel less need for social acceptance. For individuals with TD, the search for approval may represent limitations on their originality, expressing a unique worldview.

The third possibility is that difficulties in recognizing the mind may result in *Mind-blindness*, that is, limitations in perceiving the mental states of others may also affect the ability to reflect on one's own internal states. This condition may generate implicit learning, recognized by the absence of explicit rules, which could lead to the rigidity of individual knowledge construction strategies, thus impairing originality and flexibility.

In this logic, under the influence of *Mind-blindness*, the subject can achieve what Csíkszentmihalyi called the Flow State — a state of reduced self-awareness and altered sense of the passage of time during periods of intense involvement with a task. The authors suggest, however, that although *Mind-blindness* can contribute to an original worldview and the development of special abilities, it is unlikely to act as the initial factor for talent. Instead, reduced social influence, lack of concern for the opinions of others, and time dedicated to talent, to the detriment of socialization, are contributors to the manifestation of talent.

The second factor refers to executive dysfunction, which includes difficulties such as loss of sense of time, lack of flexibility for change, difficulties in planning ahead and generating new responses to adapt to new demands. This impairment can, paradoxically, function as a release mechanism for the development of special abilities.

As a third factor, the authors present the detail-focused cognitive style — *weak central coherence, enhanced perceptual functioning* — which has been shown to be the most promising predisposing characteristic, or starting engine, for the development of talent. While individuals with TD tend to process information in a global manner, preserving its essence and form to the detriment of details, in ASD the opposite occurs: there is a more refined attention to specific details and individual characteristics.

The authors emphasize that this tendency toward detailed perception allows individuals with ASD to perceive and memorize aspects that go unnoticed by others. Thus, meticulous attention to detail and the tendency toward exemplar-based memory, rather than prototype extraction, are pointed out as the fundamental factors for talent. Their conclusion is that it is not autism itself that predisposes to talent, but rather the cognitive style focused on details (weak central coherence) that is characteristic, but not exclusive, to ASD. Attention to detail, exemplar-based memory encoding, and veridical representation (not distorted by context) are the elements that can be analogically considered the initial driver for talent.

Kasirer, Adi-Japha, and Mashal (2020) contribute to breaking the limiting perspective by understanding that autistic individuals are capable of presenting creative thinking. In their studies on the verbal and figurative creativity of autistic people in understanding and developing metaphors and in making semantic connections, the results indicated that these people do not present impairments in the ability to identify new semantic connections between apparently unrelated concepts, especially when dealing with non-lexicalized figurative language.

The researchers found that autistic children have more difficulty understanding conventional metaphors in which the relationship between the elements is more evident, such as anger/volcano, than their typical peers of the same age, demonstrating better performance in unusual metaphors, such as having no value/evaporated water.

The authors highlighted two cognitive characteristics that allow autistic children to construct creative responses. Firstly, they have difficulty interpreting conventional metaphors, which depend on prior knowledge encoded in the mental lexicon, but, on the other hand, they have a good ability to make new semantic connections that do not depend on this prior knowledge. Secondly, it is the presence of mind-blindness that allows them to ignore the recipient, focusing on their own thoughts. This can favor the emergence of less conventional expressions (Kasirer, Adi-Japha and Mashal, 2020), since they are not concerned with peer judgments, but are motivated to seek solutions that meet their internal thoughts, creating an internal dialogue.

Best et al. (2015) also identified peculiar cognitive processes when studying the creative aspect involved in the work of autistic people. The authors suggest that these people are capable of producing unusual responses in problem-solving because they follow a different path from that followed by people with typical development. They produce more common responses first and, over time, generate less common responses, evolving from semantic associations of what is available in their episodic memory to more elaborate strategies based, for example, on the decomposition of parts of objects and recomposition through the combination of these parts.

Given the impairment in broader semantic processing, predominantly associated with the right hemisphere of the brain, autistic individuals follow a different path. They have difficulty resorting to an associative or memory-based route. Instead, they start directly from more elaborate strategies, processed in the left hemisphere of the brain, which do not depend on associations of elements present in memory. Consequently, their responses, which to the audience sound more unusual, result from more elaborate processes to create their solutions (Best et al., 2015). In this sense,

> by acting in this way, the cognitive processes of autistic people compensate for what they lack (difficulties in using trivial knowledge conventionally shared in society), as they focus on creating solutions based on more elaborate associations, since they do not start from ideas that are already socially known (Carvalho and Gontijo, 2022, p. 10).

Most of these studies are based on quantitative comparisons between autistic people and people without this condition. With this in mind, Carvalho (2023) conducted qualitative research in the field of Mathematics Education, analyzing evidence of creative thinking among ASD students when solving open-ended mathematical problems with their peers with TD. The author observed that these people demonstrated a peculiar way of putting their mathematical thoughts into action, presenting creative solutions, original ways of processing information and producing ideas when working in groups. The results indicated that teachers need to transform mathematics classes into spaces for sharing ideas, creating times for analyzing/communicating solutions, exploring their possibilities for development and helping them overcome difficulties.

The content analysis identified the following characteristics present in the expression of creative thinking by an ASD student: working with non-lexical verbal knowledge, which deviated from consensus, from the association of knowledge present in their episodic memory and led to the creation of their own and more elaborate strategies; mind-blindness, in which the individual ignored others by hyperfocusing on the task at hand and not worrying about external judgments, and creating internal dialogues; rejection of trivial solutions, by seeking varied and original solutions; analogical thinking, with the realization of analogies, that is, the transfer of relational information from one source domain to another; and flexible thinking, avoiding repetitive strategies and varying solutions in search of answers different from the others.

In Carvalho and Gontijo (2022), another qualitative study was carried out in which they analyzed processes involved in the shared creativity in mathematics of an 11-year-old student with ASD, in interaction with peers of the same age. The authors aimed to understand how people with this condition are able to produce mathematical ideas when subjected to collective work, helping peers and being helped by them. Using content analysis, the authors identified personal characteristics, characteristics favorable to shared creativity in mathematics, ways of constructing ideas and ways of improving peers' ideas. In this way, they were able to identify aspects that demonstrate how an autistic person collaborates and receives collaboration in the construction of ideas. Carvalho and Gontijo (2022) concluded that the performance of the autistic student, with their unique conditions, made the process of sharing mathematical ideas a phenomenon with rich possibilities.

In order to raise considerations about creativity in ASD students, this research used content analysis to categorize studies consulted in the Capes Journal Portal that evidence what the literature points out as aspects that characterize the creative thinking of ASD subjects. Using the descriptors *creativity and autism*, *creativity and autism spectrum disorder* and *creativity and autism*, 424 publications from the last 20 years were returned, of which four were selected that specifically dealt with characterizing the creative thinking of these subjects. These studies denoted the divergent way in which ASD students carry out their mental activities, disfavoring social aspects such as interactions, communication, involvement with the task and time management, while favoring the emergence of unique thinking styles and flexible and original strategies and solutions.

The initial analysis yielded 19 aspects that, after being explored and analyzed, were grouped into five intermediate categories: a) independence of shared social content; b) disregard for social judgment; c) time management and cognition/involvement with the task; d) originality and flexibility; and e) unique cognitive style. In the final analysis phase, two final categories were identified: aspects related to interactions (categories *a* and *b*) and internal aspects (categories *c*, *d* and *e*), as shown in Table 1. The first category encompasses aspects related to the influences of the social environment on the expression of creativity and the second is related to the processing of information in the subject's mind, therefore, it concerns the individual aspects that allow or do not allow the expression of creativity.

Table 1: Aspects involved in the creative thinking of the ASD student

Aspects related to interactions	Independence from shared social content	1. It frees up mental resources and time that would be used to remember social content, using them to develop talents (Happé and Vital, 2009). 2. It makes new semantic connections that are independent of prior knowledge (Kasirer, Adi-Japha and Mashal, 2020). 3. It uses non-lexical verbal knowledge, which is the escape from consensus, from the association of knowledge present in its episodic memory to its own and more elaborate strategies (Carvalho, 2023). 4. It deviates from semantic associations of its episodic memory, starting directly from more elaborate strategies (Best et al., 2015).
Aspects related to interactions	Preterition to social judgment	1. Does not access stereotypical knowledge or knowledge that is judged as correct. Does not feel the need to be socially accepted (Happé and Vital, 2009). 2. May generate *Mind-blindness*, which gives rise to implicit learning that is not based on explicit rules (Happé and Vital, 2009). 3. Presents *mind-blindness*, ignoring the recipient, focusing on their own thoughts, favoring the emergence of less conventional expressions. Is not concerned with the judgments of their peers, but is motivated to seek solutions that meet their internal thoughts, thus engaging in an internal dialogue (Kasirer, Adi-Japha and Mashal, 2020). 4. Mind-blindness in which the hyperfocus is concentrated on the task at hand, not worrying about external judgments and creating internal dialogues (Carvalho, 2023).
Internal aspects	Time management and cognition/task engagement	1. Executive dysfunction that functions as a release mechanism for special abilities (Happé and Vital, 2009). 2. Executive dysfunction that leads to loss of sense of time (Happé and Vital, 2009). 3. *Flow state* characterized by reduced self-awareness and altered sense of the passage of time during intense engagement with a task (Happé and Vital, 2009).
Internal aspects	Originality and Flexibility	1. Lack of flexibility for change (Happé and Vital, 2009). 2. Difficulties in planning in advance and generating new responses to adapt to new demands (Happé and Vital, 2009). 3. Rejection of trivial solutions, seeking varied and original solutions (Carvalho, 2023). 4. A peculiar way of putting mathematical thoughts into action, presenting creative solutions and original ways of processing information (Carvalho, 2023). 5. Flexible thinking that allows you to avoid repetitive strategies and vary solutions in search of different answers from the others (Carvalho, 2023).
Internal aspects	Unique cognitive style	1. Enhanced perceptual functioning, in which the student perceives details that others do not, expressing a unique worldview (Happé and Vital, 2009). 2. Weak central coherence, seeking detailed information and observing features (Happé and Vital, 2009). 3. Analogical thinking, in which relational information is transferred from one source domain to another (Carvalho, 2023). 4. Presents a peculiar way of putting their mathematical thoughts into action when working in a group (Carvalho, 2023).

Source: Adapted from Happé and Vital (2009), Kasirer, Adi-Japha and Mashal (2020), Best et al. (2015) and Carvalho (2023)

2.2 Creativity in Mathematics and Dialogic Learning

Taking the common sense conception of creativity, one might believe that, due to their singularities, an autistic person does not possess it or has this capacity reduced. This is because, for the general public, being creative refers exclusively to creating successful works of art or creating human tools that become known worldwide. For this to happen, creativity must come from an extraordinary being, endowed with special gifts.

Pennisi et al. (2020) warn that creativity is not just originality nor is it just the result of innate and never trained talents. In this sense, two considerations can be discussed to demonstrate that creativity, in an academic context, denotes something broader than what common sense considers. One of them refers to the fact that creativity is present in all areas of knowledge (Lubart, 2007; Alencar and Fleith, 2003). The other concerns the fact that there are different levels of creativity, from the ordinary — everyday creativity — to the extraordinary, known worldwide (Glăveanu, 2014; Beghetto, 2010), from the everyday to the eminent (Lubart, 2007), from mini-C (small creativity) to big-C (creations with great social impact) (Kaufman and Beghetto, 2009). In the present study, attention is directed to creativity in the field of Mathematics and to its ordinary aspect, since creativity is considered not as a thing, but as an action in the world and with the world (Glăveanu, 2014).

Authors suggest that encouraging creativity in mathematical learning allows the development of abilities for solving fictitious and real problems (Mann, 2009). This way of conducting classes breaks with the transmission of rules disconnected from mathematical problems and the repetition of procedures, which allows for a deeper and more meaningful understanding of Mathematics. By encouraging creative thinking in the classroom, the teacher creates authentic learning situations in which students are led to use their own strategies for solving mathematical problems, without having to resort to the algorithms demonstrated by the teacher (Beghetto, 2010; Boaler, 2018).

Andreatta and Allevato (2020) show, when investigating the creativity of fifth-grade elementary school students when they develop mathematical problems, that an approach in which the development of aspects of creativity and critical thinking is prioritized contributes significantly to their learning.

Lithner (2008) characterized two types of mathematical reasoning. Imitative reasoning — dominant in schools and responsible for many of the difficulties students face — is characterized by the use of strategies based on recalling previous solutions and remembering a solution algorithm and implementing it. The second type is creative reasoning, which is generally scarce in classrooms and meets three criteria: a) novelty, the creation of new sequences of reasoning or the recreation of forgotten versions; b) plausibility, the choice or implementation of strategies that generate true or plausible conclusions; and c) mathematical foundations, which are arguments anchored in mathematical properties intrinsic to the components of reasoning.

This thought is complemented by Carvalho (2023), who argues that creative thinking can be assessed by the originality and flexibility of mathematical solutions. In the present study, a solution is considered creative when it is: a) original (unique); b) plausible, in which the strategies are appropriate to generate mathematically valid solutions; c) whose validity arguments are anchored in mathematical foundations; and d) flexible, presenting diverse ways of reaching a solution.

According to Kaufman, Beghetto and Pourjalali (2011), to encourage students' mini-creative expressions in the classroom, teachers must take the time to listen to them and try to understand how they are interpreting what they are learning; help them recognize when their contributions are not making sense; provide multiple opportunities for them to practice

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developing abilities in a domain or task; and ask them about obstacles that hinder their creative development.

For this reason, it is argued that a classroom guided by the principles of Dialogic Learning can foster the development of creative thinking in Mathematics classes. In previous research, such as that of Carvalho (2023) and Carvalho and Gontijo (2022), the first author of this article found interesting results when Dialogic Learning principles are implemented in Mathematics classes, providing egalitarian dialogues that are favorable to the exchange of ideas and the collective construction of solutions to mathematical problems and, consequently, the expression of creative thinking.

Dialogic Learning advocates the establishment of situations of egalitarian dialogue in which the strength of arguments is taken into account to the detriment of the exercise of power by those who have more power over those who have less power. In Carvalho (2019), the existence of asymmetrical power relations was identified among fifth-grade students in Elementary School, since, in Mathematics classes, not everyone had the right to speak and participate.

Thus, four distinct ways were identified in which some students dominated the discourse and others did not have the opportunity to participate: a) limited access to discourse, in which not everyone is allowed to speak; b) persuasive force, with the use of rhetorical mechanisms, such as repetition and argumentation, to convince; c) illocutionary force, in which the dominant party obtains direct control over the action through discourses that have directive pragmatic functions; and d) control of turn-taking, which determines who, when and how to speak during classes.

The principles of Dialogic Learning aim to reduce the effects of these power relations, given that they promote classes in which egalitarian dialogues allow everyone to take the lead, regardless of social position, age, ethnicity, gender, among others. In this way, the aim is to establish dialogic spaces so that everyone can share their cognitions in search of knowledge production. There are seven principles that denote the methodology in which this installation becomes possible (Aubert, Garcia and Racionero, 2009).

a) Egalitarian dialogue: based on Paulo Freire's Dialogical Action and Habermas' Theory of Communicative Action, this principle states that everyone has the right to a voice, recognizing that dialogue occurs between unequals and, therefore, it is necessary to be aware of the need to be guided by the strength of arguments of validity and not by the force arising from power relations or established social hierarchies (Aubert, Garcia and Racionero, 2009). Díez-Palomar (2017) argues that people's learning results from a dialogue in which the meaning of the mathematical objects discussed is negotiated.

b) Cultural Intelligence: through this principle, it is recognized that all people have intelligence, but they put it into practice and express it in different contexts, whether in academia, in the practical world or in communicative acts. When subjects act in dialogical communicative contexts, they share knowledge formed in different cultural contexts, bringing to the group "their specific ways of thinking and expressing themselves, which enables the enrichment of learning experiences" (Marigo, 2015).

c) Transformation: Dialogic Learning is geared towards transforming the social context and learning levels, as it seeks to increase and diversify interactions with the aim of increasing the learning of all students, transforming the environment and learning (Aubert, Garcia and Racionero, 2009).

d) Instrumental Learning: this transformation aims, above all, at the instrumentalization of students. Thus, it aims to break with the logic that assigns the happiness curriculum to the excluded — which emphasizes non-academic abilities such as sociability, affection and values — minimizing the development of instrumental abilities — based on scientific knowledge necessary for the exercise of citizenship — and ends in academic failure and reduced learning (Aubert, Garcia and Racionero, 2009).

e) Creation of meaning: the school and everything that is built within it must make sense to each of its members. Egalitarian dialogue allows students to construct, through interactions, meaning in the knowledge they construct and in being part of a collective in which they are accepted (Flecha, 1997).

f) Solidarity: an environment in which solidarity is encouraged allows people to contribute to each other, benefiting everyone. Flecha (1997) believes that joint learning yields better results than imposing truths. Aubert, Garcia and Racionero (2009) emphasize that the principle of solidarity takes into account the promotion of an inclusive school that is capable of offering all students opportunities to build knowledge that is required in the information society.

g) Equality of differences: this principle demonstrates that diversity, which is summarized in the coexistence of unequals, is the strength of learning and not an obstacle to it (Aubert, Garcia and Racionero, 2009). Likewise, Marigo (2015, p. 61) understands that the fight for educational and social equality requires “transformations that expand learning and cognitive development, given the equitable consideration of differences, established within the framework of egalitarian dialogue”.

When examining the seven principles of Dialogic Learning, it is observed that they converge in the search for inclusive education, understood as one capable of offering education that allows opportunities for equitable access to knowledge for each and every one (Nogueira, 2020). The effectiveness of this model in implementing inclusive educational practices has already been confirmed by scientifically validated research (España, 2011). In this context, the principles of Dialogic Learning underpin studies carried out with ASD students, as is the case in this research.

Dialogic Learning is based on the implementation of successful educational actions, conceptualized as educational strategies evaluated by scientific research, validated by members of the international scientific community and proven to be effective in overcoming social inequalities and promoting social cohesion. An example of this approach is interactive groups, a form of classroom organization in which small groups of students are formed, grouped heterogeneously in terms of learning levels, culture, gender, race, among others. Each group performs a specific task under the mediation of a volunteer adult, whose role is to encourage interactions based on egalitarian dialogue. The dynamics occur in a rotating manner, ensuring that all students participate in all activities. This model makes it possible to meet individual needs, promoting equal opportunities and results, without having to separate or segregate students (España, 2011).

In this study, it was decided to structure the sessions by organizing the class into three dialogic groups.

3 Methodology

A qualitative methodology guided by the theory of Dialogic Learning was used. In this sense, the approach to dialogical mathematical learning (Diez-Palomar, 2017), adopting the methodology of dialogical conversation, allowed the analysis of the interactions that occurred during the implementation of mathematical problem-solving situations in interactive groups.

It is considered that the methodology of dialogical conversation allows the creation of a relational space in which one can analyze the "interactional events when two or more individuals work together to solve a mathematical task" (Diez-Palomar, 2017, p. 41), using dialogue as a means to observe cognitive learning. To this end, 11 sessions of dialogical groups were organized, in which the students solved open and closed mathematical problems in the multiplicative conceptual field.

The study included the main teacher, the volunteer social educator who accompanies the ASD student, the researcher and a student diagnosed with ASD, as well as fourteen peers with typical development, enrolled in the 5th grade of Elementary School. To preserve his identity, the TEA student was named as *Reckoner* and the participants with the letter E, followed by a number.

It is important to explain that the volunteer social educator is part of the Voluntary Social Educator Program (ESV) of the Federal District, in Brazil, whose objective is to provide assistance and improve services in units that require this support, with functions defined in an ordinance published annually by the Secretariat of State for Education of the Federal District. The social educator participating in the study has a degree in Architecture and Urban Planning and, at the time of the study, was 25 years old.

The class was divided into three interactive groups of four or five participants, with the teacher, the volunteer social educator and the researcher as mediators. In addition to mediating the dialogues, encouraging everyone to participate, the adult mediators filmed the interactions, which are the videos that made up the corpus of analysis.

The instrument developed by Silva (2021) was used in this study. It is a set of 22 mathematical problems from the multiplicative conceptual field, divided into four blocks. Block 1 covers 10 mathematical problems that prioritize the basic idea of *correspondence* function[2], being of the combination type with the whole or with an unknown part (questions 1 to 7) and involving area — rectangular configuration (questions 8 to 10). Block 2 emphasizes the basic idea of *dependence* function, covering three mathematical problems of simple proportion — one to many or quota (questions 1 and 2) or mixed (question 3). Block 3 addresses four mathematical problems with the basic idea of *regularity* function, classified as simple proportion — one to many and quota (questions 1 and 2) and mixed[3] (questions 3 and 4). In the last block, five mathematical problems are presented with the basic ideas of *variable* function and *generalization*, being classified in simple proportion (one to many, quota, partition, fourth proportional and fourth proportional with measures that are multiples).

In an attempt to encourage the emergence of creative thinking through varied and original solutions, and critical thinking through mathematical problems that enable interpretation, analysis, evaluation, inference, explanation and self-regulation (Facione, 2011), 12 more open mathematical problems were developed, six to stimulate creative thinking (PCRIA) and six to stimulate critical thinking (PCRI).

Although it is almost impossible to analyze creative thinking and critical thinking separately, this text seeks to understand the aspects that led children with ASD to develop, in collaboration with their peers, creative strategies and produce unusual solutions and the possible factors that negatively interfered with creative thinking. Thus, the instrument consisted of 34 items that were proposed to the students during the 11 sessions, and in each of them, two or three items were given to be solved collectively, depending on the complexity of what was

[2] At the time of Silva's research (2021), carried out within the scope of the Study and Research Group on Mathematics Didactics (GEPeDIMA), whose main scope is to map the Conceptual Field of the Affine function, *correspondence* was considered a basic idea (it was also written without a hyphen, in Silva's thesis (2021)). Based on Merli's research (2023), GEPeDIMA researchers began to consider only variable, dependence, regularity and generalization as basic ideas of function.

[3] Mixed problems, according to Vergnaud (2009), are those that involve at least one addition (or subtraction) and one multiplication (or division) operation.

required of the respondents.

Through content analysis (Bardin, 2011), the interactions that occurred in the collective semi-structured interviews, in the transcripts of the videos and in the solutions recorded in the tasks were analyzed. To this end, three phases needed to be carried out: 1) pre-analysis; 2) exploration of the material, categorization or coding; 3) processing of the results, inferences and interpretation.

4 Results and Discussion

The strategies and solutions produced by the ASD student when solving mathematical problems in the multiplicative conceptual field in interactive groups are presented below, demonstrating creative thinking. Together with the information gathered in the dialogues, the aspects present in his way of thinking were highlighted, categorizing them according to the literature researched. The mediators were instructed to minimize the guidance that could lead to solutions, so that the children could lead the search for strategies and solutions.

The first episode of creative thinking occurred in the first session and illustrates some aspects of the ASD student's creative thinking that allowed, throughout the study, his original, plausible and flexible ideas to be identified when solving mathematical problems. In this session, all the questions were closed. When starting the interactive groups, the child needed a long time to sit down and concentrate on the activity, demonstrating resistance to getting involved in the task. It is noteworthy that this fact was repeated during all the sessions. However, when he concentrated, he became completely involved in carrying out the tasks, demonstrating pleasure in finding solutions, entering a state of involvement that, at times, made him ignore the opinions and suggestions of his peers, something very close to the state of flow, as can be seen in the following dialogues.

To help them, the researcher provided some resources, such as plastic fruits, pictures of dresses, and colored rings, for them to use freely in developing solution strategies. Then, the child became agitated and rejected the resources, as in the following dialogue:

> Reckoner: *He's going to use the kid's toy.*
> Researcher: *Wow, I already told you that this isn't a kid's toy* [laughs].
> Reckoner: *Will I have to come here later? Do I have to use these toys?*
> Researcher: *Only if you want to.*
> Teacher: *You're going to use it to count. It's not for playing. It's for using in other ways.*
> Reckoner: [shouting] *I don't want it! Oh, no! Not even if I don't need it?*
> Researcher: *Don't use it. It's just to help, if it's going to get in the way, you don't need to use it.*

This episode demonstrates that, when the environment changed, the child showed agitation and difficulty concentrating on carrying out the activities, which Happé and Vital (2009) call a lack of flexibility for change. In this study, this cognitive rigidity constituted a barrier to creativity, since time and cognition were directed towards questioning the changes, instead of engaging in the proposed task. Thus, the adults needed to provide time and act sensitively so that, in each session, the child would be involved in the activities.

A clear aspect was the pattern of concentration observed: when engaging in the tasks, the child, at many times, ignored the presence of others, immersing himself in an internal dialogue in which he was dedicated to finding solutions. In this sense, attempts to help him became barriers, since they interrupted his line of reasoning. This process is illustrated in the following excerpt, in which, in addition to disregarding the researcher's support, the child demonstrates that external intervention was harming his concentration:

> Reckoner: *One, two... three..., four, five, six, seven, eight..., nine, ten, eleven, twelve, thirteen, fourteen, fifteen.*
>
> Researcher: *Reckoner, but you're not doing...* [interrupting his reasoning]. *Look, I think you're counting the same combination several times. Do you remember how E8 explained it to you?*
>
> Reckoner: *17, 18, 19* [continues counting] *30, 31.*
>
> Researcher: *Hey, pay attention. It goes like this, look. Oh, today I'm going to wear yellow with green. It was a combination. Then I'm going to wear yellow with purple. Another combination. There you go, with yellow it's all combined. Now I'm going to combine it with green.*
>
> Reckoner: [screaming and crying] *Oh, you made me forget!*
>
> Researcher: *Do you have to scream like that?*
>
> Reckoner: [calmer] *You made me forget!*

Although these aspects present in the thinking of children with ASD demand a reorganization of the spaces for solving mathematical problems — requiring more time, listening and careful observation of their speech and actions — the internal dialogue allowed the child to create or recreate original solution strategies at various times.

In the following excerpt, we can see how the *Reckoner* adapted a strategy suggested by a classmate. After hearing the suggestion of writing the names of four girls and three boys to find the number of combinations to be made, he began to completely ignore the suggestions of names that his friend provided, opting to invent funny names, as he verbalized. These names, which seemed unusual to the other classmates, were created based on dialogues that he overheard in the environment. A notable example is the name Piora, given to one of the girls in the mathematical problem, inspired by hearing a classmate mention this word.

> E1: *Reckoner, let's pay attention.*
>
> Researcher: *Go on, put this here so you can pay attention to what she's explaining there.*
>
> E1: *Reckoner, I started by writing the girls' names... Four girls and three boys...*
>
> Reckoner: *It's hard to write four girls' names.*
>
> Researcher: *Because there are four girls. Think of four girls' names.*
>
> Reckoner: *I don't want to! I don't like writing four, it'll take too long!*
>
> E1: *Calm down! Calm down, Reckoner!*
>
> Reckoner: *Just a name today. Geometry. Geometry.*
>
> E1: *Oh, Geometry. Yeah.*
>
> Researcher: *Why are you writing the word geometry? He's writing the name of the game, geometriyc or something.*
>
> Reckoner: *No, the girl's name will be Geometriya Dasha.*
>
> Researcher: *Oh, the girl's name* [Laughter]. *Another girl's name.*
>
> E1: *Oh, you can write Lais.*
>
> Reckoner: Whoa... Whoa... Whoa, her name will be Whoa.

By ignoring peers and adults and focusing on his own thoughts, the child ended up generating two consequences that influenced his creative thinking: the presentation of incorrect solutions because he was not paying attention to the commands and the emergence of less conventional expressions, since he was not supported by shared social knowledge.

It is observed that, even if the names were original, the solution cannot be considered creative, since the child was not able to efficiently solve the proposed mathematical problem, as his classmate did. However, this attitude of the ASD student was important to announce another aspect of his creative thinking that differentiated him from the others and allowed him to present creative solutions (original, flexible, plausible and based on mathematical arguments) in the other sessions. In other words, avoiding common, trivial suggestions provided by his classmate, he was able to create original names.

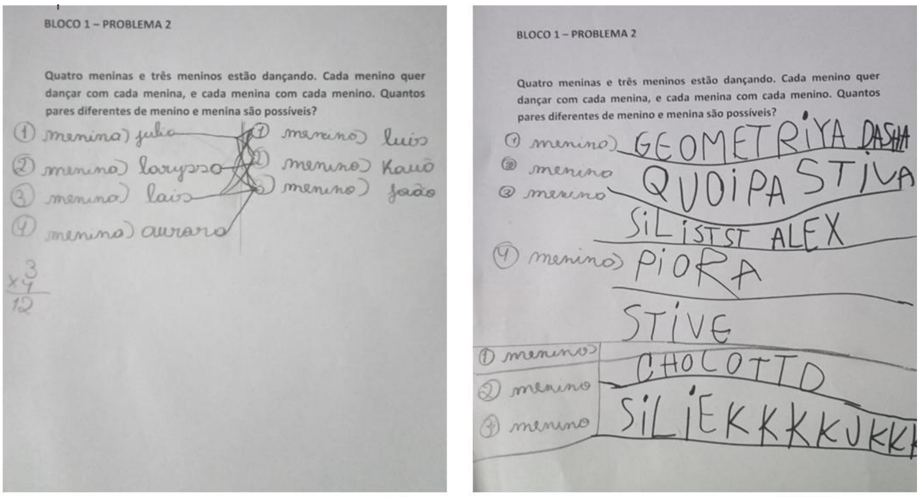

Figure 2: E1 Suggestions and Reckoner Solution (Study data)

The second example of creative thinking emerged in the fourth session, in which all the mathematical problems were closed, that is, they required a single answer. When creating a strategy to discover how many times larger the new project was than the initial project (Figure 3), the child with ASD divided the larger rectangle, counting and numbering the number of squares in the smaller rectangle.

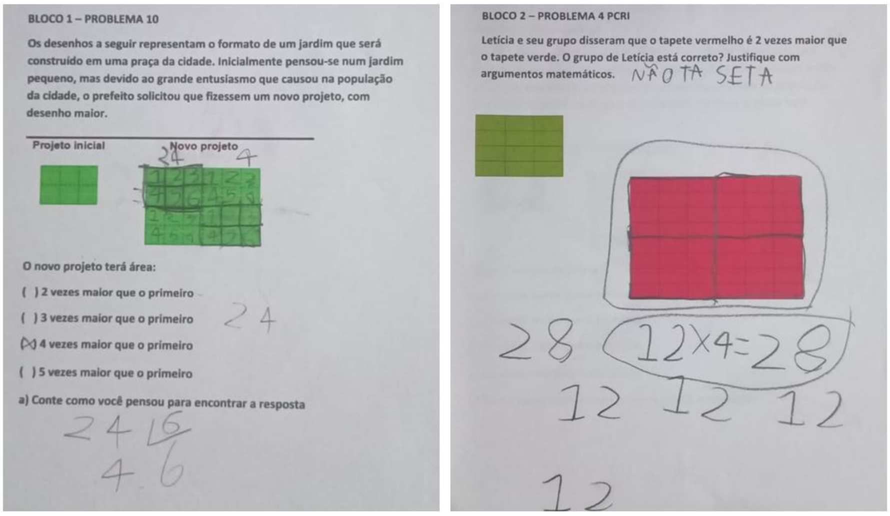

Figure 3: Unusual strategies of the Reckoner (Study data)

When he realizes that he has found the correct solution, he starts to speak out loud, sharing the solution strategy with the whole class. His classmates initially tended to say that the difference was twice as big. However, upon hearing the announcement from their ASD classmate, everyone started to use the same strategy, arriving at the correct solution. To confirm, the ASD child performed the division 24÷6, attesting to the correct solution.

It is also observed that the child has a cognitive style focused on details. He numbers the squares, realizing that it is necessary to form sets of six of them. This numbering is essential for him to realize that the larger rectangle contains four sets of six squares, a detail that was not noticed by most of the students and that led them to tend to choose the first alternative, motivated by the comparison of the height and width measurements of the rectangles — in which the larger one is twice the size of the smaller one.

It is interesting to note that this idea ended up being used again by the child in the following session (see Figure 3), at which point the strategy was transferred to a question designed to assess critical thinking. Once again, he measures the small rectangle using his hands and realizes that he could divide the larger rectangle into four parts, noting that it was not twice as big, but four times as big. Once again, he hurries to announce the solution to the others, who immediately use the same strategy as his classmate. It is observed that in both activities, the child used a practical strategy, dividing the rectangle into equal parts, and others validated through mathematical operations.

These solutions are considered creative, because they were original (they were not thought of by another child in the class and inaugurated a new way of thinking about the problem), plausible (they resulted in a valid solution), supported by mathematical arguments, and flexible. Unlike his peers, he used a strategy that did not depend on a previously taught mathematical operation and did not require the search for an operation that would satisfy the question raised. In other words, while the others asked each other what the calculation was, he sought a solution that anticipated the mathematical operations and allowed the others to use them.

The last example of creativity was responsible for giving the child the title of *reckoner*, a term he used during the dialogues of the sixth session. A few days before the session, he went to the school principal's office and became interested in a Reckoner that was on the principal's desk. He asked to play with the reckoner and, from then on, he went to the principal's office every day to get the object and take it to the classroom. He then started using the reckoner in Math classes, and there were times when he would check his classmates' solutions using the instrument.

Thus, after finishing answering problem 3 of Block 2 with his group, the child said: *"I'm going to check if they got it right. I'm the reckoner"*. For this reason, the term reckoner was used in the title of the text and in the identification of the child. A divergent reckoner who appropriated the functions of the reckoner to find solutions to mathematical problems.

After completing the activities, the children did a kind of modeling, assembling hot dogs and calculating the amount they should pay, according to the problem's criteria. The ASD student was tasked with checking the answers on the reckoner and giving the change with educational money.

When solving items *d* and *e* of problem 2 of Block 2, the child used the reckoner and surprised the adults by explaining the strategy used to arrive at the solutions. The problem, which contained two sheets, contextualized a situation in which a child was playing in a park where the entrance fee was R$ 3.00 each. While the solutions of the other members of the class included addition operations (3 + 3 + 3 + 3 + 3 + 3 + 3 + 3 + 3), multiplication (9×3 = 27) and division (27÷3), only the Reckoner used subtraction to find the solution for item *d*. The strategy consisted of subtracting the unit value of the ticket (three Reais) from some value on the reckoner so that the negative three would remain in the reckoner's memory. Then, to form the value that the child in the problem had (27 Reais), he performed the subtraction 30 – 3, finding the total value that the character had, at the same time recording the value –3 in the reckoner's memory. Then, he pressed the equal sign and counted how many times he pressed it, finding the result nine.

This episode, and others presented during the study, illustrate that it was common, as an aspect of his creative thinking, to direct time and mental resources that he would use to, as

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others did, find a socially shared mathematical operation, to find a plausible solution, but that followed different paths from the ways of thinking of his peers.

Initially, the child followed the instructions of his peers and the researcher, performing an addition (3 + 3 + 3 + 3 + 3 + 3 + 3 + 3 + 3) and, then, a multiplication (9 × 3). However, when asked by the researcher about the answer to the problem — *How many toys can he use?* — he showed difficulty in recognizing, in the operations he performed, which data would be used to answer the question. Faced with this difficulty and with the intervention of the researcher, the child changed tactics, picked up the reckoner and demonstrated an unusual strategy to solve the problem.

Researcher: *How many toys can he use, Reckoner? He has 27 Reais.*

[Reckoner seems confused, changes the subject and the researcher encourages him to answer].

Researcher: *No, pay attention, look. He has 27 Reais, how many toys can he use?*

Reckoner: [Remains silent for 9 seconds] *What?*

Researcher: *How many toys can he use?*

Reckoner: *Two.*

Researcher: *Only two? He has 27 Reais. Each toy is 3 Reais.*

Reckoner: *So, he can use more than two...*

He stopped for a moment, realized he was making mistakes, and started to create an unusual strategy that no other child in the class had thought of, by observing the details of the problem and realizing that he could subtract the ticket price from the available amount, observing how many times he could subtract *3* from *27*. So he took the Reckoner, typed in the number *30* and subtracted *3*, leaving the value -*3* in the Reckoner's memory.

Then he pressed the equal sign and counted how many times he needed to press it to zero out the 27 Reais, as illustrated in Figure 4.

Figure 4: Subtraction strategy, using Reckoner (Study collection)

Reckoner: *One, two, three, four, five, six, seven, eight, nine.*

Researcher: *Nine. That's why it's three times nine. Write it down here.*

In this way, the researcher calls the group's attention so that he can explain this strategy, emphasizing that he used a different operation from those used by the group and the class.

Researcher: *The Reckoner did a calculation that was not times, not more and not division. The Reckoner did less. Explain to them how you did the calculation for less.*

E1: *Less? And it came to nine?*

Researcher: *It came to nine, the same as yours. Everyone gets up and comes over here so he can explain.*

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Reckoner: *See this 27 here, look.* [Types 30 on the Reckoner and subtracts 3, resulting in 27]. *Look, I did it like this, look. See the 3 here? Right above the zero?*

E2, E3, E4: *Yes, yes, yes.*

Researcher: *How did you put this 3 up there that I don't even know how to put it?*

Reckoner: [Types 30] *Minus 3.*

Researcher: *Why did you put 30?*

Reckoner: *To make 27.*

Researcher: *To make 27, how much do you have to take away from 30?*

Reckoner: *3 from 30.*

Researcher*: So look what he's going to do now to get the answer. Go, Reckoner. He'll press the equal sign and take away the 3.*

Reckoner: *One, two, three, four, five, six, seven, eight, nine.*

Researcher: *He'll take away 3 and buy the tickets.*

Reckoner: *That makes nine.*

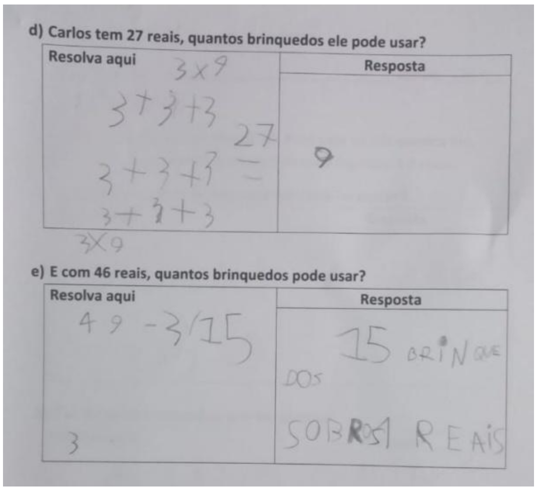

Figure 5: Subtraction strategy using Reckoner (Study data)

Despite using a good tone of voice to explain the solution, the others had difficulty understanding his explanation. With the intervention of the researcher so that the explanations of his colleague were understood by everyone, the peers in the group used the same strategy, discovering how many tickets could be purchased with 46 Reais, a situation requested in item *e*.

Initially, the child with ASD had difficulty transferring the strategy to the similar problem contained in this question, as he could not identify which number should be used to subtract three from it, forming 46. However, he had the help of his peers, especially E3, who told him that he should use the number 49, subtracting 3 to form 46. Then, he pressed the equal sign 15 times and realized that there was 1 left over. The researcher asked how many times it was possible to use the toy with that amount and he answered 16 times. Then, he looked at the Reckoner and corrected it to 15 times. When asked about the number 1 registered on the Reckoner, he answered that there was one Reais left over.

It was observed that, while the others were trying to find an operation that would be effective in finding a solution to the question, he was focused on the Reckoner, little concerned with what the others were discussing. This allowed the child to present this original solution, as he was not thinking like his peers. However, his peers benefited from the unusual strategy shared by his colleague, when they realized that subtraction could also lead them to find the answer.

Table 2: Aspects involved in the creative thinking in mathematics of the ASD student

Aspects related to interactions	Independence from shared social content	1. Ignored the recipient (peers and adults), focusing on his own thoughts. This had two consequences: incorrect solutions because he was not paying attention to commands and the emergence of less conventional strategies, as he did not rely on shared social knowledge. 2. Difficulty communicating his strategies, since peers did not understand his reasoning, requiring intervention from adults. 3. Sharing unusual strategies for the whole class.
	Preterition to social judgment	1. Ignoring the recipient (peers and adults), focusing on their own thoughts. This had two consequences: incorrect solutions because they were not paying attention to commands and the emergence of less conventional strategies, since they did not rely on shared social knowledge. 2. Engaging in internal dialogue in which they created their own strategies or recreated strategies when accepting the opinions or ideas of their peers.
Internal aspects	Time management and cognition/task engagement	1. Need for additional time to concentrate on carrying out activities. 2. When concentrating, he became involved in carrying out tasks, demonstrating pleasure in finding solutions, something similar to the *Flow* state.
	Originality and Flexibility	1. Lack of flexibility for change: changes in the environment served as a barrier to creativity, as time and cognition were diverted from tasks and directed towards questioning these changes. 2. Avoidance of common, trivial suggestions 3. Flexible thinking, creating more than one solution strategy.
	Unique cognitive style	1. Notices details that others don't notice, finding solutions quickly, creatively and efficiently.

Source: Own elaboration

These aspects allowed the emergence of the child's creative thinking, which demonstrated innovative strategies for the proposed problems. However, they also represented barriers, such as the need for more time and more focused attention to the ASD student, to encourage him to concentrate and get involved in the tasks.

5 Conclusion

The data set analyzed allowed us to conclude that the ASD child presented unusual, plausible strategies, based on mathematical and flexible arguments, guided by aspects categorized as shown in Table 2. It is noted that both the ASD student and his peers demonstrated poor performance in open-ended questions, with no multiple solutions or varied and original solutions being observed, which allows us to conclude that these children had, during their schooling, little experience with this type of task.

However, the ASD child demonstrated creativity in solving closed problems, which, even though they had a single answer, were solved through creative strategies. Thus, creativity was manifested in the presentation of unusual strategies and not in the quantity and variation of solutions. The way he behaved in interactions, the mediation of adults and the differentiated cognitive style were drivers of creativity in solving problems in the multiplicative field.

Finally, it is important to note that the divergent way of acting when faced with mathematical problems indicated the need for the teacher to pay close attention, observing weaknesses and strengths that can be redirected to allow the ASD student access to mathematical knowledge.

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