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Evaluating Visual-Spatial Reasoning Among Students with Dyscalculia: An Applied Study on a Sample of Third-Grade Primary School Students

تقييم التفكير البصري الحيزي لدى التلاميذ ذوي عسر الحساب: دراسة تطبيقية على عينة من تلاميذ الصف الثالث الابتدائي

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Abstract:

The present investigation seeks to evaluate the visual-spatial reasoning capabilities among students diagnosed with dyscalculia. This research was conducted on a meticulously selected group of five students displaying signs of dyscalculia. Employing a descriptive methodology paired with a case study approach, data were collected using specialized subtests from the Zareki-R dyscalculia assessment tool and the Kohs Cubes test for visual-spatial reasoning.

The central query of this study was: Do students afflicted with dyscalculia demonstrate deficits in visual-spatial reasoning? The outcomes of this study confirm that such students indeed show significant impairments in their visual-spatial reasoning abilities.

Keywords: Visual-Spatial Reasoning ; Dyscalculia.

ملخص

هدفت الدراسة الحالية إلى تقييم التفكير البصري الحيزي لدى التلاميذ ذوي عسر الحساب، و لهذا الغرض أجريت الدراسة على عينة من التلاميذ عسيري الحساب قوامها خمسة حالات(5) تم انتقاؤهم بطريقة قصدية باعتماد المنهج الوصفي و استخدام أسوب دراسة الحالة لإجراء الدراسة، و لجمع المعطيات تم الاعتماد على بعض الاختبارات الفرعية من بطارية عسر الحساب Zareki-R-A واختبار التفكير البصري الحيزي مكعبات كوصCubs de Kohs .

وقد تم طرح التساؤل الرئيسي التالي:

- هل يعاني التلاميذ ذوي عسر الحساب من اضطراب التفكير البصري الحيزي؟

و قد أسفرت نتائج هذه الدراسة على أن التلاميذ ذوي عسر الحساب يعانون من اضطراب على مستوى التفكير البصري الحيزي.

كلمات مفتاحية: التفكير البصري الحيزي، عسر الحساب.

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1. Introduction:

It is a well-established fact that specific learning disorders, such as dyscalculia, do not invariably correlate with diminished intelligence quotients, especially when assessments are conducted using non-verbal reasoning tests. Nevertheless, it is critical to note that non-verbal reasoning is a multifaceted cognitive domain that incorporates various types of thinking; one pivotal type is visual-spatial reasoning. This form of reasoning is essential as it operates in concert with other cognitive processes to solve mathematically based problems.

Extensive scholarly work recognizes the integral role that visual-spatial reasoning plays in the mastery of mathematical concepts. Groundbreaking research in the field of neuropsychology has repeatedly demonstrated that visual-spatial reasoning forms the foundational layer upon which students scaffold their mathematical understanding.

According to the findings of the National Council for Neuropsychological Research in Canada, spatial thinking encapsulates the cognitive processes involved in positioning and maneuvering, both mentally and physically, within three-dimensional space. This cognitive style is fundamentally interactive, involving the dynamic interplay among individuals, their ideas, and objects, focusing on spatial attributes such as location, distance, direction, form, and the organization of space (Newcomb and Friche, 2010).

Henrique (1998) delineates visual-spatial reasoning into three distinct components: spatial concepts, representational tools, and cognitive processes. This tripartite framework necessitates a deep comprehension of spatial relationships and the coordination of spatial constructs, which is critical in tackling mathematically oriented challenges due to its intrinsic complexity (Henriques, 1998).

This perspective was further reinforced by Newcombe (2010), who posited spatial intelligence as a distinct intellectual category, referring to it as "spatial intelligence," a mental prowess predominantly utilized in the realms of mathematics and arithmetic (Newcombe and Friche, 2010).

Moreover, a significant inquiry by Newcombe (2013) underscored the substantial demand for visual-spatial reasoning in solving mathematical problems, showing that students with adept visual-spatial skills tend to achieve higher performance in mathematics and arithmetic tasks (Newcombe, 2013).

In a similar vein, a comprehensive longitudinal study by Wai, Lubinski, and Benbow (2009), which followed 400,000 randomly selected American school students over an 11-year period, sought to examine the correlation between visual-spatial capabilities and mathematical proficiency. This extensive study, utilizing diverse cognitive assessments, emphasized that visual-spatial abilities are pivotal for scholastic success, particularly in mathematical domains (Wai, Lubinski, Benbow, 2009).

Despite the apparent linkage between visual-spatial reasoning and mathematical proficiency, the research exploring the challenges associated with visual-spatial reasoning in students with dyscalculia remains notably limited. A poignant study by Rourk (1993) focusing on primary school students with dyscalculia aimed to evaluate their visual-spatial skills and identified a pronounced deficit within the cohort (Rourk, 1993).

Similarly, research by Samara and Clements (2009) highlighted that students experiencing difficulties in mathematics often struggle with the rapid estimation of small quantities, a problem closely tied to deficiencies in visual-spatial planning for target quantities (Samara, Clements, 2009).

In light of the scant research in the Algerian context, our study endeavors to probe the relationship between visual-spatial reasoning and dyscalculia among third-grade primary students, addressing the pivotal research question: Is visual-spatial reasoning compromised among third-grade students diagnosed with dyscalculia? In pursuit of answers, we hypothesize the following:

Hypotheses:

- Visual-spatial reasoning is impaired among third-grade students with dyscalculia.

1. Study Importance:

The significance of this study arises from the pertinence of its subject matter, which revolves around visual-spatial thinking and dyscalculia, a specific learning disorder that is notably prevalent within Algerian primary schools. Given the pivotal role that mathematics plays within the educational curriculum, it becomes imperative to delve into and assess this particular mode of thinking among students afflicted with dyscalculia. The objective is to facilitate these students in surmounting the obstacles presented by the disorder, thereby bolstering their mathematical capabilities and academic success.

2. Study Objectives:

The primary objective of the present study is to assess visual-spatial thinking among third-grade students diagnosed with dyscalculia, and to elucidate the significant role this cognitive process plays in the acquisition of mathematical concepts and the resolution of mathematically-based problems at the primary education level. Furthermore, this study endeavors to augment the academic library with a valuable resource that will serve educators and specialists who are engaged in the management and support of students with dyscalculia.

3. Study Concepts:

4.1 Visual-Spatial Thinking:

This refers to a cognitive process that necessitates an understanding of the interrelationships within visual-spatial configurations. This process is comprised of three fundamental components: spatial concepts, representational tools, and cognitive operations. This mode of thinking is pivotal in solving unconventional mathematical challenges. (Newcombe & Friche, 2010, p. 10)

✓ **Operational Definition of Visual-Spatial Thinking:**

The assessment of visual-spatial thinking is quantified by the scores a student achieves on the visual-spatial thinking test and the Kohs Cubes Test.

4.2 Dyscalculia:

As defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), dyscalculia represents a significant deficit in mathematical abilities, which is diagnosed through the application of standardized tests that are specific to arithmetic or logical reasoning, and administered individually. The disorder is characterized by a performance that is considerably lower than expected, taking into account the individual's age, intellectual capabilities, and the educational methods appropriate for their age. (Thomas, Caneli, 2015, p. 16)

✓ **Operational Definition of Dyscalculia:**

The diagnosis of dyscalculia is determined by the scores a student attains through the application of subtests from the Zareki-R dyscalculia assessment battery.

5. Methodological Procedures of the Study:

5.1 **Preliminary Study:**

A preliminary study represents a crucial phase in scientific research as it aims to amass a comprehensive array of data pertinent to the research question, thus enhancing the credibility of the ensuing study. This phase entailed approaching several primary schools in the Skikda province, following the acquisition of requisite permissions from the local educational authorities.

The educational teams, encompassing both teachers and principals, were thoroughly briefed on the objectives of the study and the instruments that would be utilized to gather data concerning the target student group. The Zareki-R battery subtests and the Kohs Cubes visual-spatial thinking test were administered to a select group of five third-grade students to validate the applicability and comprehensibility of these tests for the student demographic.

Throughout the preliminary study, the research subject was delineated, the data collection instruments were identified, and the methodology to be implemented for conducting the full study was firmly established.

5.2 Study Methodology:

Our investigation employs a descriptive research design, complemented by the case study method, which is deemed highly suitable for the nature of this study. This approach is designed to gather a maximal amount of data while facilitating an in-depth understanding of the unique characteristics of the case studies examined. (Robert, Yin 2009, p. 18)

5.3 **Study Sample:**

The sample for this study was meticulously chosen to reflect the specific requirements and objectives of the research. The study engaged a group of third-grade students, aged between 8 to 9 years, at Saad Guermech Ali primary school, located in the heart of Skikda province. The principal aim was to evaluate the visual-spatial thinking capabilities of students diagnosed with dyscalculia.

- ✓ The students' performance in mathematics ranged from average to weak.
- ✓ The students' performance in other subjects ranged from good to very good.

5.4 **Study Limitations:**

A. **Spatial Boundaries:** The investigation was geographically confined to the Saad Guermech Ali primary school, centrally situated in Skikda province. This location was chosen due to its accessibility and the demographic representation of the student population.

B. **Temporal Boundaries:** The research was conducted at the outset of the second semester of the 2023-2024 academic year, a time frame selected to ensure that the students were adequately acclimatized to the academic environment post their first semester experiences.

5.5 Study Tools:

The study utilized a combination of established testing tools adapted for the local educational context:

- **Zareki-R Test:**

Initially developed by German researcher Von Aster in 2001, the Zareki-R test, also known as the Neuropsychological Test Battery for Number Processing and Arithmetic in Children, underwent several adaptations. In 2006, French researcher George Dellatolas adapted it to the

French context, subsequently named Zareki-R: Battery for the Evaluation of Number Processing and Calculation in Children.

In 2011, it was standardized and adapted by Algerian researcher Lamia Hassan for the Algerian educational environment, referred to as Zareki-R-A: Battery for the Evaluation of Number Processing and Calculation in Children - Algerian Adaptation. This comprehensive battery, consisting of twelve tests, focuses on diagnosing arithmetic disorders and numerical processing issues.

For this study, five specific subtests were employed: oral reverse counting, oral mental arithmetic, visual estimation of quantities, qualitative estimation of quantities in a verbal context, and orally presented arithmetic problems.

- ✓ **Test Validity:** The battery demonstrated robust internal consistency, validated by Pearson's correlation coefficients ranging from 0.40 to 0.88, all statistically significant at the 0.01 level (Hassan, 2011).
- ✓ **Test Reliability:** The battery's reliability is well-supported by multiple indicators, including its concurrent validity, which showed significant correlations, with coefficients ranging from 0.28 to 0.84, between performances on the battery and the TAS test (Hassan, 2011).

➢ **Kohs Block Test (Cubs de Kohs Les):**

This non-verbal performance test, created by Manuel Kohs in 1920, was originally designed to measure children's intelligence levels. It has since been adapted to assess spatial structuring and symbolic abstract thinking. In this study, the test, which involves 16 colored cubes with red, white, blue, and yellow sides, and 17 cards featuring unique colored designs, was used to evaluate the visual-spatial thinking abilities of the participants.

➢ **Application Method:**

- The examiner presents a cube to the participant and describes its colors.
- Subsequently, four (04) cubes are provided, and the participant is asked to form a red square.
- The first card is then presented, detailing the colors of the drawn shape.
- The participant is required to assemble the shape using the cubes, with initial assistance provided if necessary.
- The duration for each card is ninety (90) seconds.
- From the third card onward, no assistance is given, and the colors are not mentioned.

- The test is discontinued after five consecutive incorrect attempts.
- Scoring is conducted using a scoring sheet that includes the card numbers and the specified minimum and maximum times for scoring.
- Kohs established a scoring rule where the final test score is influenced by three factors: task performance success, time taken, and precision in execution. These factors are empirically balanced as follows: one (1) point for precision, two (2) points for time, and three (3) points for successful task completion.
- There are foundational principles to consider during scoring.
- For the current study sample, aged 8 to 9 years, the procedure starts with card (03), as recommended by the test manual.
- A zero score is given if the structure is incorrect, the shape's rotation angle is 30 degrees, or the task completion time is exceeded.
- For cards 4 to 12, points range from 4 to 7, with an additional 2 to 3 points for rapid completion.
- Points assigned for spatial environmental elements equal the default point divided by the spatial environmental elements.
- The actual score is the sum of the points obtained in the spatial environmental elements.

6. **Presentation and Analysis of Results:**

6.1 Results for the Zareki-R-A Dyscalculia Test:

After applying the Zareki-R-A battery subtests to the study sample consisting of five pupils with dyscalculia, diagnoses were based on results from the oral reverse counting test, the oral mental arithmetic test, the visual quantity estimation test, the qualitative estimation in context test, and the orally presented arithmetic problems test. Below are the results from these subtests for the study sample:

Table 1: The results from the five subtests of the Zareki-R-A battery.

Sample	Oral Reverse Counting	Oral Mental Arithmetic	Visual Quantity Estimation	Qualitative Estimation in Context	Orally Presented Arithmetic Problems	Total
1	4/4	44/44	5/5	10/10	12/12	75/75
	0	14	2	1	2	19

2	0	21	2	2	3	28
3	0	12	1	2	2	17
4	0	30	1	3	3	37
5	0	15	1	1	2	19

The Kohs Cubes Visual-Spatial Thinking Test revealed a range of abilities among the participants. Although all individuals in the study faced challenges with the task, their scores exhibited some variability. Specifically, the scores spanned from a low of 5 to a high of 15 out of a possible 20 points. This distribution of scores indicates a varying degree of visual-spatial reasoning ability among the students, with none achieving full marks but some showing moderate levels of competence.

A. Qualitative Analysis of the Results from the Five Subtests of the Zareki-R-A Battery:

Following the administration of the tests, it became clear that every participant in the study experienced considerable difficulty with reverse counting, as underscored by their uniformly low scores of zero in this segment. Additionally, the time taken to complete tasks was markedly prolonged, particularly with tasks involving larger numbers in subtraction exercises. This suggests a prevalent inadequacy among the majority of participants in devising effective strategies for computing differences. Moreover, significant challenges were encountered in the task of visually estimating quantities, which was manifested in their consistently low scores that did not surpass two points. There was also a pronounced difficulty observed among the students in qualitatively estimating quantities in verbal scenarios, with one participant explicitly expressing their incapacity to accomplish the task. This difficulty was mirrored in their exceedingly low scores, which ranged merely from 1 to 3 points. When considering the standardized scores from the table pertinent to the orally presented arithmetic problems test, it was discernible that all participants grappled with disorders in mathematical processing and the resolution of arithmetic problems.

6.2 Results from the Kohs Cubes Visual-Spatial Thinking Test:

After administering the Kohs Cubes test to the study sample, the following results were obtained (Table 02):

Table 02: Results from the Kohs Cubes Test

Case	Depth	Color & Size	Shapes	Directions	Parts	Whole	Total
1	5.28	3.74	4.59	2.34	2.34	0.51	18.80
2	1.32	1.38	3.06	2.34	1.43	0.51	10.04
3	1.98	2.59	3.06	2.34	1.30	0.17	11.44
4	2.64	0.84	3.06	1.30	1.30	0.85	9.99
5	0.66	0.77	2.38	0.91	0.32	0.34	5.38

A. Qualitative Analysis of the Kohs Cubes Visual-Spatial Thinking Test Results:

As delineated in Table 2, which presents the outcomes of the Kohs Cubes test, it was observed that participants exhibited subdued performance in depth perception, with scores varying from 0.66 to 5.28. They also faced hurdles in accurately perceiving colors and sizes, with scores confined between 0.77 and 3.74.

Similarly, in terms of shape recognition, the participants struggled considerably, as evidenced by consistently low scores throughout the sample; Case (1) registered a score of 4.59, while Cases (2), (3), and (4) each recorded a score of 3.06, and Case (5) noted a score of 2.38.

In the task concerning the application of directions, the scores fluctuated from 2.34 in Cases (1), (2), and (3), to 1.30 in Case (4), and 0.91 in Case (5). Additionally, in the assembly of parts task, the scores were as follows: Case (1) scored 2.34, Case (2) 1.43, and Cases (3) and (4) each scored 1.30, while Case (5) managed only a score of 0.32. Regarding the task of distinguishing the whole from the part, the results were exceedingly low, peaking at just 0.85, with Case (3) achieving the lowest score at 0.17, Cases (1) and (2) each at 0.51, Case (4) at 0.85, and Case (5) at 0.34.

B. Qualitative Analysis of the Kohs Cubes Visual-Spatial Thinking Test Results:

Upon conducting the Kohs Cubes test with the study cohort, comprising typical students diagnosed solely with dyscalculia, it was unveiled that they face significant obstacles in grasping and perceiving spatial concepts. The Kohs Cubes test outcomes indicated pronounced difficulties in depth perception, as reflected in the notably low scores on the initial task associated with this ability.

The participants also exhibited challenges in spatial orientation, specifically in discerning directions such as right, left, front, back, above, and below. These challenges were mirrored in the scores, which did not exceed 2.43 for Cases (1), (2), and (3), and were even lower for Case (4) at 1.30 and Case (5) at 0.91.

Furthermore, difficulties were observed in the participants' ability to perceive colors and sizes, as well as in recognizing and distinguishing shapes. In tasks involving the assembly of shape components, the participants struggled to differentiate the components and discern the interrelationships among them.

Additionally, they found it challenging to perceive parts within a whole and to identify the relationships among these parts, with a marked disorder in finding mechanisms to assemble the parts into a cohesive whole. The scores -0.51 for Cases (1) and (2), 0.17 for Case (3), 0.85 for Case (4), and 0.34 for Case (5)- were considerably low, illustrating the challenges faced by the students in executing these tasks.

The data gleaned from the study highlight that disorders in visual-spatial thinking among students markedly impair their mathematical achievements, specifically in identifying and resolving arithmetic problems that have a geometric nature.

This includes difficulties in distinguishing between similar mathematical symbols and numerals, along with challenges encountered in solving geometric arithmetic issues that entail understanding shapes, areas, and dimensions.

Furthermore, these students displayed pronounced difficulties in addressing problems related to volumes, which is especially pertinent within the curriculum for third graders, due to their impaired perception of these concepts.

Jean Piaget extensively discussed the concept of visual-spatial thinking and the development of spatial awareness, as well as the progressive stages through which a child acquires these critical cognitive abilities. It was noted that from the initial testing, the participants in the study exhibited difficulties, prompting specific interventions particularly for Cases (4) and (5), to provide them with a secondary opportunity to grasp the concepts being tested.

Given the age range of the study sample, which was between 8 and 9 years, the tests commenced directly with the third figure. The participants exhibited difficulties in applying the concepts, necessitating multiple explanations. Despite these extensive efforts, the participants were unable to complete the subsequent, more complex models after five unsuccessful attempts.

Moreover, there was a substantial deviation from the time allocated for the tests. The time required to complete these tasks serves as an indicator of the integrity of visual-spatial thinking, which appeared to be lacking among the cases studied.

Scores were meticulously collected for elements related to spatial structure, calculated as the default point divided by the number of elements, which totaled six elements. The actual score was then determined by summing the elements achieved in the units.

According to the theories of Jean Piaget, it is postulated that a child's perception of colors remains constant and does not alter with variations in type, location, or addition. Contrary to Piaget's assertions, the participants in this study displayed significant difficulties in perceiving colors and sizes consistently.

For instance, Cases (2) and (3) failed to recognize the colors yellow and white in one scenario, and red and blue in another. Similarly, Cases (1), (4), and (5) were distinctly unable to discern sizes, both large and small, which can be attributed to a disorder in segmenting the visual field and a deficiency in recognizing and differentiating shapes and their respective sizes.

Visual-spatial thinking encompasses the capacity to receive and process images, contemplate their components such as lines and figures, formulate spatial visual concepts, retain these images in memory, and utilize them as necessary. This entire cognitive process, throughout its various phases, is characterized by significant disorders in students diagnosed with dyscalculia, as evidenced by the five cases examined in this study.

Additionally, spatial orientation exhibited inconsistent discernment of directional concepts such as right and left; at times, the individuals could distinguish these directions, while at other times, they failed to comprehend these basic spatial concepts.

This inconsistency corroborates the findings from the Rourk (1993) study, which identified spatial orientation disorders in primary school students with dyscalculia and emphasized the necessity for proper acquisition of lateral skills in children. The study participants also displayed difficulties in distinguishing specific shapes, such as diamonds and triangles, with Case (5) showing only partial recognition of the shapes.

Furthermore, the cases exhibited a deficiency in depth perception, struggling to perceive the spatial relationships either within solids or between their bodies and objects in their visual field, a difficulty attributable to their visual-spatial thinking disorder as discussed in the study conducted by Wai et al. (2009).

7. Results Discussion:

Upon evaluating the outcomes derived from the application of the five subtests of the Zareki-R-A battery and the Kohs Cubes visual-spatial thinking test on the study sample, and considering the insights from previously reviewed literature, it can be affirmed that the study's hypothesis has been substantiated. This hypothesis asserted that third-grade primary students diagnosed with dyscalculia manifest disorders in visual-spatial thinking.

Throughout the study, all participants displayed significant challenges in executing tasks related to visual-spatial thinking and consistently demonstrated an inability to accurately perceive visual-spatial concepts, such as depth, colors, and sizes. Additionally, deficiencies were noted in their capability to recognize the relationships between various parts of shapes, alongside evident disorders in spatial orientation and lateralization.

This observation aligns with the findings of J.F Shumway (2013), who confirmed the disruption of cognitive processes associated with visual-spatial concepts in students with dyscalculia. Furthermore, the study by L.Y Cheng and S.K MIX (2012) elucidated the correlation between impairments in visual-spatial thinking abilities and dyscalculia among primary school students.

Similarly, the research conducted by Samara and Cléments (2009) highlighted that students with mathematical learning difficulties struggle with the rapid perception of quantities and dimensions due to disruptions in the mental representation of these elements.

This difficulty is also connected with challenges in understanding visual-spatial language and perceiving space, corroborating Mannoni's (1979) research, which verified the disturbances in mental imaging processes and visual-spatial thinking in students with dyscalculia and associated mathematical-logical nature disorders.

8. Conclusion:

The findings presented in the current study, titled "Evaluating Visual-Spatial Thinking Among Students with Dyscalculia: An Applied Study on a Sample of Third-Grade Primary School Students," aimed to explore the assessment of one mode of abstract thinking -visual-spatial thinking- in students afflicted with dyscalculia.

The intent of this investigation was to elucidate the role of this mode of thinking in mathematical achievement, to assist students with dyscalculia in navigating the challenges they encounter throughout their educational journey. As mathematical prowess significantly influences a student's academic progress, it becomes imperative to understand these correlations.

The results of this study clearly indicate a pervasive disorder in visual-spatial thinking among students with dyscalculia, further emphasizing that visual-spatial abilities significantly impact all facets of mathematical skills, including geometry, arithmetic, and algebra. Consequently, visual-spatial thinking emerges as a crucial diagnostic and therapeutic indicator in the management of dyscalculia.

9. Recommendations:

In light of the insights gained from this applied study and the consequent results, the following recommendations can be advanced:

- ✓ Implement early detection and diagnostic programs tailored for students exhibiting learning difficulties to ensure the effectiveness of early intervention strategies spearheaded by educational specialists.
- ✓ Develop comprehensive treatment programs and protocols specifically aimed at addressing the needs of students with learning difficulties, with a particular focus on dyscalculia.
- ✓ Design and introduce innovative software tools that are crafted to aid students with dyscalculia in ameliorating their challenges associated with visual-spatial abilities.
- ✓ Organize awareness days for parents and educational professionals to disseminate knowledge about specific learning disorders such as dyscalculia, highlighting the cognitive challenges involved and emphasizing the critical importance of early intervention to prevent the exacerbation of these difficulties.

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References:

1. Butterworth, B. (2006). *Developmental dyscalculia*. Macmillan.
2. Hassan, L. (2011). *Battery for the evaluation of number processing and calculation in children: Algerian adaptation*. University of Algiers.
3. Henriques, A. (1998). *Play and understand*. Sentiers Editions.
4. Mannoni, F. (1979). *The reeducation of mathematical reasoning in primary and secondary classes* (5th ed.). ESF.
5. Maxwell, K. (1972). *Kohs cubes test manual* (2nd ed.). Centre for Applied Psychology.
6. Mix, K. S., & Cheng, Y. L. (2012). *The relation between space and math: Developmental and educational implications*. Academic Press.
7. Newcombe, N. S., & Friche, A. (2010). *Early education for spatial intelligence: Why? What? And how?* Main Brain Edition.
8. Piaget, J., Montenegro, J., & Bilter, J. (1977). *The correlates: Reflective abstraction*. Editions J. Piaget.
9. Rourke, B. P. (1993). Arithmetic disabilities, specific and otherwise: A neuropsychological perspective. *Journal of Learning Disabilities*.
10. Samara, J., & Clements, D. (2009). *Early childhood mathematics education research: Learning trajectories for young children*. Taylor & Francis.
11. Shumway, J. F. (2013). Building bridges to spatial reasoning. *Teaching Children Mathematics*, National Council of Teachers of Mathematics.
12. Thomas, A., & Cannoli, L. (2015). *Difficulties in mathematics: Dyscalculia or math anxiety?* Pleura Dys.
13. Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*.
14. Yin, R. K. (2006). *Case study research design and methods* (4th ed.). SAGE Publications.