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Analyzing the Thinking Trajectory of Students with Dyscalculia in Solving Spatial Mathematical Problems

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ABSTRACT

This study employs a qualitative descriptive case study design to explore the thinking trajectories of two seventh-grade junior high school students who exhibit symptoms of dyscalculia when solving mathematical spatial problems. Dyscalculia is a specific learning difficulty that affects a student's ability to understand and manipulate numerical and spatial information. The research aims to analyze how these students process mathematical problems, particularly focusing on the second phase of Simon's learning trajectory theory: the thinking trajectory. The study assessed five cognitive stages: connection, representation, communication, reasoning, and problem-solving. The research was conducted at SLB Prof. Dr. Sri Soedewi Masjchun in Jambi, Indonesia, from January to February 2025. Data collection techniques included written tests and in-depth interviews. Findings indicate that students with dyscalculia demonstrated confusion and limitations in all five cognitive processes assessed. The students often showed non-linear thinking patterns, with disruptions evident at the connection and representation stages due to limited conceptual understanding and low visual-spatial ability. For instance, one student relied heavily on external help to recall shapes and formulate strategies. At the same time, another tended to use trial-and-error approaches, struggled to provide logical explanations, and demonstrated confusion when translating verbal information into visual form. The implications suggest that additional support and inclusive instructional strategies, such as using concrete visual aids or 3D models, are essential. Teachers should adapt their methods to accommodate students with dyscalculia, helping them improve spatial reasoning and mathematical comprehension.

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1. INTRODUCTION

Mathematics significantly enhances students' cognitive capacities, notably logical, analytical, and creative thinking. These skills are vital for solving real-world problems and making rational, innovative decisions [1]. However, Indonesian students’ performance in mathematics remains below the global average. The 2022 PISA assessment reported a score of 366, placing Indonesia 73rd out of 79 countries [2]. This decline reflects persistent challenges in solving mathematical problems, especially those involving spatial understanding, such as geometry, diagrams, and the interpretation of visual information.

Spatial mathematical problems involve understanding and manipulating spatial relationships among objects, including shape, position, size, direction, and distance. Spatial skills encompass orientation (understanding the position of objects) and visualization (mentally transforming and manipulating shapes) [3]. These abilities are essential in comprehending geometry, constructing models, interpreting graphs, and reasoning spatially. Despite the importance of spatial skills, many students struggle in this domain, particularly those with learning difficulties.

Students in the seventh grade of junior high school are at a developmental stage where spatial reasoning becomes increasingly relevant, especially as they begin learning more complex geometrical concepts. However, some students may show signs of dyscalculia, a specific learning disability that affects mathematical understanding [4]. Dyscalculia does not stem from general cognitive deficits; it involves persistent difficulties in numerical processing, spatial reasoning, and problem-solving, even when the student has average or above-average intelligence [5], [6]. Students with dyscalculia often fail to grasp basic numerical concepts and struggle to visualize shapes or understand spatial relationships, which are key in solving geometry-related problems.

Learning about the cognitive strategies employed by learners with dyscalculia can help shed light on their problems [7]. A student’s thinking progresses through several steps, from understanding the subject matter to collecting relevant details and finally coming to a conclusion [8]. Analyzing these routes helps teachers choose instructional methods that improve student development. Thinking trajectories in mathematics learning are shaped not only by mental processes but also by the learning context. A structured framework of the thinking trajectory model includes five stages: connection, representation, communication, reasoning and proof, and problem-solving [9]. These stages provide a lens to observe how students comprehend and solve mathematical tasks involving spatial reasoning.

Students with lower spatial skills frequently experience difficulties translating mathematical problems into visual forms [10]. Research shows that children with dyscalculia struggle to perceive the relative positions of mathematical concepts, especially in geometry and spatial mapping tasks. Such spatial weaknesses are often intertwined with deficits in cognitive domains like working memory or visuospatial attention [11], [12]. Studying the thinking trajectories of students with dyscalculia offers insights into how targeted instructional approaches can better support their learning needs. Solving spatial problems demands orientation and visualization skills, as success depends on grasping how objects relate to each other within space [13].

This study seeks to analyze the thinking trajectories of seventh-grade students with dyscalculia as they solve spatial mathematical problems. By identifying their cognitive pathways and the obstacles they encounter, this research aims to contribute to more effective educational approaches tailored to their needs.

2. METHOD

The study aimed to understand how two students (n = 2) with dyscalculia symptoms approach and solve mathematical spatial problems. Qualitative methodology was chosen to delve into the complex concept of how students with dyscalculia difficulties approach and solve problems in a mathematical environment. Qualitative research draws from interpretive perspectives dedicated to understanding meanings, settings, and subjective experiences [14]. The study prioritizes the exploration and analysis of unique data contributions over-generalized conclusions. The outcomes of descriptive qualitative research are meaningful analyses and interpretations of events derived from actual experiences that lay the foundation for future academic investigations [15]. A carefully planned procedure divided the research process into several phases.

Sampling Techniques

Meetings with the principal and teachers were conducted to select students who faced problems with spatial mathematical concepts. Participants were selected through purposive sampling based on criteria such as knowledge of 2D and 3D shapes, the ability to recognize and represent numbers clearly, and the capacity to explain mathematical concepts. The approach allowed the researcher to focus on subjects who met the study criteria and gained a better understanding of mathematical difficulties faced by people with dyscalculia [14].

Data Collection

The researcher relied on his expertise to ensure precise and flexible data collection methods. Both primary data obtained from tests and interviews, as well as secondary data from student records and school exams, were collected for this study.

Instruments Used

Tests were developed to assess solving mathematical spatial problems of the participants. The instruments were designed to assess students' abilities to identify relationships between objects, visualize objects in various positions, and mentally represent both 2D and 3D shapes and figures. Each test item focused on a different type of spatial reasoning challenge to capture data from different cognitive areas important to the study. The indicators were based on cognitive process dimensions from the framework of instructional objectives [16]. The type of test used is an essay test specifically designed to measure students' mathematical spatial abilities. Examining the test results allowed researchers to pinpoint precise obstacles students encountered and guided the direction of the next round of in-depth interviews.

Interview Procedure

After the test, interviews were held to understand how students approached and solved problems. These interviews aimed to explore students' mathematical connections, strategies, and reasoning. The interview structure was adaptable and responsive, permitting participants to articulate their experiences openly [14]. This interview approach is characterized by its flexibility and open-ended nature, lacking a rigid structure and formal atmosphere. Consequently, the interview process incorporates personal contexts, events, activities, emotions, motivations, responses, or perceptions, as well as the degree and form of engagement [17]. Students were posed with reflective inquiries concerning their utilization of previously acquired concepts, their approach to each problem, and the difficulties they encountered. The interview guidelines were designed to mirror indicators of connection, representation, communication, reasoning, proof, and problem-solving, consequently amplifying the qualitative data and yielding a comprehensive understanding of students' internal cognitive mechanisms.

Research Design

The research design can be delineated algorithmically through the subsequent stages: (1) conduct initial interview with teachers for participant selection (2) administer spatial mathematical assessments to selected participants (3) analyze assessment outcomes for indications of spatial reasoning patterns (4) conduct semistructured interviews based on individual student performance (5) transcribe and code the interview data thematically (6) triangulate data from assessments interviews and secondary documentation and (7) interpret and synthesize findings in relation to established theories on dyscalculia and spatial cognition. This sequence ensured consistency of data and relevance to theoretical frameworks. The integration of both assessments and interviews facilitated method triangulation, which bolstered the trustworthiness of the qualitative findings [18].

A descriptive qualitative methodology was employed to observe and interpret the cognitive trajectories of students with dyscalculia as they engaged in resolving mathematical spatial problems. Studying in depth the way students answered and interpreted questions revealed the evolution of their thinking while completing the tasks [19].

Students' approaches to solving problems and the connections they made between the representations and the underlying ideas were comprehensively studied [20]. Researchers analyzed the qualitative data to trace the transformation of spatial reasoning in individuals with dyscalculia. The research incorporated theories on spatial cognition to analyze how students with dyscalculia think differently, improving insights into helping all students in math [21].

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Research Location/Subject Description

The investigation was carried out at the Special School (SLB) Prof. Dr. Sri Soedewi Masjchun, situated on Jalan Depati Parbo, in the Kecamatan Telanaipura, Jambi

City district. This location was chosen because it explicitly serves students with indications of dyscalculia, offering individualized learning programs for those struggling with basic math and various concepts of spatial mathematics. Key factors in selecting this site included its comfortable environment, the teachers' expertise in catering to students with special needs, and readily available access to information from students, teachers, and classroom materials. The study aimed to clarify the thought patterns underlying the mathematical challenges faced by individuals with dyscalculia.

3.1.2 Research Findings Description

Instrument Validation Data Description

Validation was conducted to ensure that the instruments accurately recorded the cognitive processes students with dyscalculia employ when working on spatial math problems. Spatial math difficulties were evaluated based on analyzing relevant criteria, the efficiency of both interviews, and the problems created. Different techniques, such as conducting interviews and observing students working on spatial math tasks, were used to cross-reference the results. The data was re-checked by conducting in-depth observations and analyzing the samples obtained during the fieldwork. This aimed to ensure that the assessment methods captured how individuals with dyscalculia process and work with spatial ideas within mathematical problems.

The test sheet featured indicators and descriptions for every question in the spatial mathematics test. The content and types of problems elucidated the obstacles students encounter when working with spatial information. The teacher interview guidelines contained four indicators, each accompanied by descriptors and interview questions. The student interview guidelines for dyscalculia students contained five indicators (connection, representation, communication, reasoning and proof, and problem-solving) with descriptors and interview questions.

Based on the validation assessment from both validators, the mathematics problem-solving test sheet for dyscalculia students and the interview guidelines were deemed valid and suitable for use in the research without revisions. The validation results for both instruments can be found in the appendices. Once the validation process was completed, all research instruments were ready to study the thinking trajectory of students with dyscalculia at SLB Prof. Dr. Sri Soedewi, Jambi City.

Subject Selection Data Description

Prof. Dr. Sri Soedewi conducted the research at SLB in Jambi City. During the subject selection process, the researcher consulted with teachers or class supervisors at the school. Two students (n = 2) were purposively selected based on specific criteria: students who exhibited dyscalculia, were willing and able to communicate, studied two-dimensional and three-dimensional shapes, could write and recognize numbers, and could comprehend instructions or verbal cues.

Discussions with the teachers and class supervisors revealed that two students at the school showed signs of dyscalculia. Both students faced difficulties in learning mathematics and had low academic performance, as explained by their class supervisors.

After assessment, both students met the established criteria for subject selection. Teacher discussions and subject selection criteria were also evaluated through data from the answer sheets and interviews conducted with the students. The summarized data for the two subjects is as follows:

Table 1. Subject Selection Criteria

No.	Subject Selection Criteria	S1	S2
1.	Dyscalculia	√	√
2.	Studied two-dimensional shape and three-dimensional shape	√	√
3.	Can write and recognize numbers	√	√
4.	Can engage in two-way communication	√	√

Explanation:
S1: Subject 1
S2: Subject 2

From the data, both subjects meet the criteria of having dyscalculia, being capable and willing to communicate, being able to write and recognize numbers, and comprehending verbal instructions and commands.

3.1.3 Research Data Presentation

The study was conducted on Monday, February 24, 2025, at 09:30 in classroom 7C at SLB. The researcher prepared the test sheets and interview guidelines, as well as the necessary equipment to record audio during the research. Below is the presentation of the data obtained from subjects S1 and S2:

a. Data Presentation for Subject S1
Problem Understanding Stage

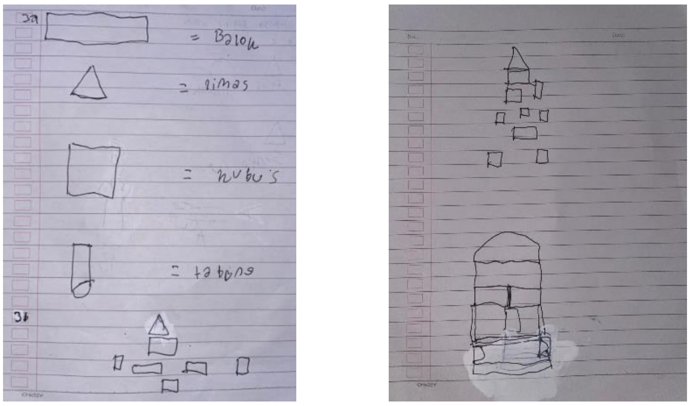

Figure 1. S1's answer.

At this stage, S1 understood the question with the assistance of the researcher. The researcher and S1 read the instructions together. The following is the interview result.
P: "What were you asked to do in that question?"

S1: “I was asked to determine and draw the 3D shapes needed to build a toy castle. Then, if the cylinder shape is removed, what would the final shape of the toy castle be.” [S1 Interview, Line 2-3]
P: “Okay. So, based on that question, what were you asked to do? First, you were asked to...”
S1: “Umm...”
P: “Try to look again. What were you asked to do?”
S1: “Draw.” [S1 Interview, Line 6]
P: “Draw, good. Then, what else?”
S1: “If the cylinder shape is removed.” [S1 Interview, Line 8]
P: “If the cylinder is removed, what were you asked to do?”
S1: “Determine the final shape of the toy castle.” [S1 Interview, Line 10]
P: “Okay. So, you already understand the intention of this question, right?”
S1: “Yes.” [S1 Interview, Line 12]

With prompting, S1 successfully identified core instructions (draw, determine the final shape, remove cylinder). This suggests an initial grasp of explicit commands.

Planning Stage

At this stage, S1 required assistance in formulating a plan, particularly concerning the visualization of shapes. The interview highlights the following:
P: “Have you ever encountered a question like this before?”
S1: “Yes, I have. I have toys, and I like to arrange them.” [S1 Interview, Line 14]
P: “So, you can differentiate between rectangular prisms and cubes, right?”
S1: “Yes, and there are cylinders too.” [S1 Interview, Line 16]
P: “You have encountered cylinders, too, right? So you are quite familiar with them.”
S1: “Yes.” [S1 Interview, Line 18]
P: “When recalling these 3D shapes, did you find it easier to work on this problem?”
S1: “It was easier, but for this one, I somewhat forgot the shape of the cylinder.” [S1 Interview, Line 20]
P: “You forgot the cylinder part, right? What were the steps when you recalled the shapes and solved the problem?”
S1: “I could do it with help from you too.” [S1 Interview, Line 22]
P: “You were helped in recalling by me, then.”

S1 drew on prior experience with physical toys to conceptualize shapes but explicitly stated forgetting the cylinder's form and relied on the researcher's help to develop a solution plan. This indicates a dependency on external prompts for spatial recall and planning.

Execution Stage

Based on S1's answer in the image and the interview results, it can be concluded that S1 understood the intent of the question and the commands in the problem. This is evident from their ability to identify the requested instructions, such as drawing the 3D shapes and determining the final shape of the castle if the cylinder shape was removed.

However, according to the command, S1 appeared to have difficulty representing the 3D shapes. This difficulty indicates an obstacle in understanding spatial concepts and visualizing 3D shapes, which can be one indicator of dyscalculia symptoms.

Verification Stage

At this stage, S1 confirmed that all questions were answered. The following interview excerpt demonstrates this:

P: "When you were working on the problem earlier, I saw a part you covered with correction tape."

S1: "Yes." [S1 Interview, Line 25]

P: "So, you had written another answer before writing your final, correct answer?"

S1: "Yes, I did." [S1 Interview, Line 27]

P: "When you realized your previous answer was not quite right, how did you make sure? How did you know that the last answer was correct?"

S1: "So, at first, I was still confused looking at the castle picture because I had just started learning. Then I asked, and you explained it. From there, I understood." [S1 Interview, Line 29]

P: "So, after asking and listening to the explanation, you could understand that the last answer was correct and the previous one was not quite right?"

S1: "Yes." [S1 Interview, Line 31]

During the verification stage, S1 noted prior incorrect answers and sought external help (asking the researcher) to verify the final answer. This indicates a reliance on direct instruction and external confirmation rather than independent self-assessment of spatial accuracy.

b. Data Presentation for Subject S2

Problem Understanding Stage

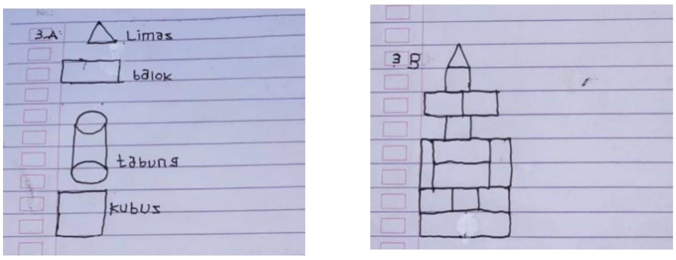

Figure 2. S2's answer.

At this stage, S2 understood the question with the researcher's help. The following interview excerpt shows the understanding:

P: "What were you asked to do in that question?"

S2: "I was asked to draw, then the cylinder shape was to be removed." [S2 Interview, Line 2-3]

P: “Oh, I see. After removing the cylinder, could you successfully redraw the castle shape?”

S2: “Yes, I was.” [S2 Interview, Line 5]

S2 could articulate the main tasks (drawing, removing cylinder, redrawing) without extensive rephrasing, suggesting a foundational understanding of the instructions.

Planning Stage

At this stage, S2 required substantial support and the use of physical objects to develop a problem-solving plan, particularly due to challenges with visual information. The following interview shows:

P: “When you tried to understand the problem and looked at the pictures I provided, did you find it difficult?”

S2: “Yes.” [S2 Interview, Line 7]

P: “May I know what made you feel difficult?”

S2: “Because there were many pictures, and they were stacked.” [S2 Interview, Line 9]

P: “Then, how did you imagine it when you worked on the problem earlier?”

S2: “I imagined I was building a house from the toys I have.” [S2 Interview, Line 11]

S2 explicitly stated difficulty with "stacked" (overlapping) images, highlighting visual processing challenges. The use of personal experience with physical toys indicates a need for concrete references to aid spatial visualization and plan formulation.

Execution Stage

Based on S2's answer in the image and the interview results, it can be concluded that S2 understood the intent of the question and the commands in the problem. This is evident from her ability to explain that she was asked to draw and remove the cylinder shape and claimed to have completed the request. However, while working on the problem, S2 expressed difficulty due to the many overlapping images, which complicated the visualization process. To help imagine the shapes, S2 used her experience playing with building toys as a reference. This difficulty in processing visual and spatial information may indicate an obstacle to understanding geometric concepts, one characteristic of learning disabilities such as dyscalculia.

Verification Stage

At this stage, S2's verification focused on confirmation rather than an independent re-assessment of spatial accuracy, relying on external input.

P: “Earlier, when you were working on the problem, I saw a part you erased using correction tape. Is that right?”

S2: “Yes, that is right.” [S2 Interview, Line 13]

P: “So, you had previously written another answer before writing your final answer, which you thought was the most correct?”

S2: “Yes, that is right.” [S2 Interview, Line 15]

P: “When you realized your previous answer was not quite right, how did you confirm it? How did you know that the last answer was correct?”

S2: “I asked you and then remembered the lesson.” [S2 Interview, Line 17]

P: “So, after being reminded a little by me, you immediately remembered the lesson and could solve the problem, right?”
S2: “Yes.” [S2 Interview, Line 19]

Similar to S1, S2 acknowledged initial incorrect answers and sought external clarification ("I asked you") to confirm the final correct answer, implying a dependence on external guidance for verification of accuracy rather than an independent spatial re-assessment.

This detailed examination of the stages and responses of both subjects, S1 and S2, offers significant insights into how students with dyscalculia approach spatial math problems and highlights the need for personalized support in overcoming these challenges.

3.2. Discussion

This section discusses the findings from the research on two subjects (S1 and S2), focusing on how their cognitive processes align with or diverge from the five stages of mathematical thinking: connection, representation, communication, reasoning and proof, and problem-solving skills. By analyzing their responses and interview data, we aim to shed light on the difficulties students with dyscalculia face at each stage.

Thinking Path Indicator: Connection Process

S1 and S2 demonstrated an ability to connect new tasks with prior knowledge, but this process relied heavily on external assistance and mediation. They struggled to spontaneously establish these links without explicit help from the researcher/interviewer.

Part of mathematical learning involves making and using connections between different concepts, relating new issues to what we already know, merging different mathematical concepts, and showing connections between abstract theories and the real world. This helps in understanding and remembering new information [22]

However, students with dyscalculia often find it hard to initiate this process independently. As observed, both S1 and S2 managed to apply previously learned concepts to the new tasks but consistently required prompting or guidance to do so. For instance, S1 recalled prior experience with toys for spatial understanding but needed the interviewer's direct help to proceed [S1 Interview, Line 22]. Similarly, S2 explicitly relied on imagining building a house from toys when facing complex visual information [S2 Interview, Line 11]. This dependency highlights the specific difficulties that children with dyscalculia have while learning about numbers and spatial relations; their connections appear to depend mainly on mediation and support rather than on independent self-initiation. This aligns with the findings that students with dyscalculia face difficulties in the initial step of problem-solving, which requires matching the problem with known mathematical ideas [23]. Young learners and those with learning difficulties often need a structured organization to build necessary links between learning experiences and problem-solving techniques [24].

Actionable strategies for teachers and educators are to provide ample structured and meaningful tasks that explicitly guide students in making connections. This includes articulating how new concepts relate to existing knowledge and real-life applications.

Instead of expecting spontaneous connections, teachers should offer explicit cues, guided questions, and visual aids to help students link spatial aspects of a problem to geometric shapes and orientation changes. Overloading students with challenging material too early can induce stress and hinder the application of learned concepts, slowing their development.

Thinking Path Indicator: Representation Process

S1 and S2 could interpret and make sense of visual materials presented to them but faced significant challenges when required to self-generate or independently manipulate mathematical representations (symbols, diagrams, drawings).

Mathematics utilizes various forms—words, symbols, diagrams, or concrete objects—to help grasp and address problems. Representing solutions enhances understanding. However, students with dyscalculia, as evidenced by S1 and S2, often struggle with independent development, reading, and handling mathematical symbols. While S1 successfully identified the need to "draw" the shapes [S1 Interview, Line 6], the actual execution and accuracy of the drawn spatial figures (as noted in the Execution Stage in Findings) indicated difficulty in accurate self-representation. S2 explicitly articulated difficulty due to "many pictures and they were stacked," indicating a struggle with processing complex visual information, which further complicated self-representation [S2 Interview, Line 9]. This aligns with observations that students needing extra help, especially in visualizing things or rearranging symbols in tasks like linear equations, often require additional support [25]. This suggests that while forms of representation aid understanding, their inherent restrictions can make independent problem-solving more challenging for these learners.

Actionable strategies for teachers are instructional strategies that emphasize multiple modes of representation, moving from concrete manipulatives to pictorial representations and gradually toward abstract symbols. Dynamic geometry software, models, and diagrams can be highly beneficial. Teachers should actively scaffold the transition between forms, guiding learners from physical manipulation of numbers and shapes to more abstract mental models, which is particularly crucial for individuals with dyscalculia.

Thinking Path Indicator: Communication Process

S1 and S2 benefited significantly from interactive discussions and direct communication with the researcher, facilitating clarification, sharing difficulties, and memory recall. They relied on verbal interaction to articulate their thinking and resolve confusion.

Communication in mathematical thinking involves explaining ideas, justifying reasoning, asking questions, and collaborating. This is especially vital for students with dyscalculia, who often benefit from external dialogue to enhance their mathematical understanding. In this study, interactive discussions and asking questions proved crucial. For instance, S1 explicitly stated, "Then I asked, and you explained it. From there, I understood," indicating that direct communication was the key to resolving confusion and understanding the correct solution [S1 Interview, Line 29]. Similarly, S2 stated, "I asked

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you and then remembered the lesson," highlighting the role of communication in recalling knowledge [S2 Interview, Line 17]. This shows how conversations helped both students articulate their struggles, solidify learning, and clarify misunderstandings. This aligns with findings that supportive environments benefit students with dyscalculia to overcome reasoning hindrances [23]. Furthermore, developing phonological and language abilities supports mathematical communication for those with learning difficulties [10].

Actionable strategies for teachers are to create safe and supportive classroom environments that encourage students to express their ideas and ask questions without fear of judgment. Teachers should actively facilitate discussions, use questioning techniques, and model problem-solving processes aloud. Collaborative learning activities can also promote peer-to-peer communication and understanding. These interactions can build students' confidence and improve their ability to articulate mathematical ideas independently over time.

Thinking Path Indicator: Reasoning and Proof Process

S1 and S2 exhibited difficulties in independent reasoning and justification of their responses, often relying on intuition or external validation rather than systematic logical steps.

Mathematical thinking heavily relies on reasoning and proof, encompassing deductive/inductive logic, pattern recognition, conjecture formulation, testing, and verification. These processes are crucial for ensuring answer correctness and building a more profound understanding. However, learners with dyscalculia, as observed in S1 and S2, showed a tendency not to justify or confirm their responses spontaneously. S1, for example, admitted to an initial incorrect answer and only understood the correct one after the interviewer's explanation rather than through independent reasoning [S1 Interview, Line 29]. S2 similarly relied on the interviewer's reminder to recall the lesson and confirm the answer [S2 Interview, Line 17]. This suggests that their analysis often relied on intuition rather than thorough, thoughtful reasoning. Reasoning, which involves carefully checking ideas and gathering proof, is often tough for students with brain-based learning disabilities [9]. Difficulties understanding spoken language, idea-sharing, or visual representations can further hinder the construction of strong arguments [25]. This implies that challenges in reasoning are not solely mental process deficiencies but can also stem from difficulties in visualizing and sharing ideas.

Actionable strategies for teachers are to guide students through reasoning paths using step-by-step instructions, guiding questions, and diagrams; explicitly teach strategies for formulating conjectures, testing them, and providing justifications. Motivate students to explain their thought processes and double-check their methods and answers for consistency. This activity trains students’ thinking skills and forms a base for future learning in mathematics, gradually shifting them from intuitive responses to structured reasoning.

Thinking Path Indicator: Problem-Solving Process

S1 and S2 found the problem-solving process challenging, demonstrating difficulties in sequential planning, conceptual integration, and persistent effort without strong external support.

Problem-solving integrates all prior skills (connection, representation, communication, reasoning) to plan, execute, review, and analyze solutions, particularly in spatial challenges. For students with dyscalculia, like S1 and S2, problem-solving proved difficult. S1 needed explicit "help from you too" to solve the problem [S1 Interview, Line 22], indicating a reliance on external support for execution. S2, despite claiming success, expressed initial difficulty with "many pictures, and they were stacked" [S2 Interview, Line 9], suggesting a struggle in the initial planning and conceptual integration needed for problem-solving. This aligns with the notion that students with dyscalculia struggle with breaking down problems into manageable steps and often benefit from concrete illustrations [26]. Polya's approach is suggested to aid dyscalculia students in problem articulation [23].

Actionable strategies for teachers include guiding students in breaking down problems into multiple steps, providing clear tactics (for example, making drawings, explaining each stage verbally), and encouraging using physical items for better understanding. Instructional programs should be inclusive, providing support that improves spatial reasoning through specific activities and frequent practice. Emphasize the process and the final solution and encourage analyzing outcomes to foster better learning.

Implications for Dyscalculia Intervention Models

The findings from this study critically reflect on current dyscalculia intervention models. The consistent reliance of both S1 and S2 on external mediation for connection, independent representation, communication, and reasoning suggests that many existing interventions may not adequately address the foundational need for structured scaffolding across all cognitive stages. Interventions should move beyond merely teaching mathematical concepts to explicitly fostering meta-cognitive skills, such as self-monitoring and independent verification. Current models might benefit from a stronger emphasis on:

1. Explicit Scaffolding: Building structured support into every learning activity, gradually withdrawing it as students develop independence.
2. Multimodal Representation: Systematically integrating concrete, pictorial, and abstract representations.
3. Verbalization and Collaborative Learning: Actively incorporating dialogue and peer interaction as core learning tools.
4. Process-Oriented Reasoning: Shifting focus from just "getting the right answer" to understanding and articulating the "why" and "how" of problem-solving.
5. Targeted Spatial Training: Developing specific interventions that directly address spatial visualization and manipulation difficulties, which are central to the challenges faced by these students.

This suggests a need for holistic intervention strategies that teach mathematical content and actively develop the underlying cognitive processes and self-regulation skills crucial for independent mathematical competence in students with dyscalculia.

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4. CONCLUSION

This study investigated the thinking patterns of two students with dyscalculia (S1 and S2) across five cognitive stages in the context of mathematical spatial problem-solving. Both subjects exhibited a non-linear thinking trajectory and encountered significant difficulties, particularly in the connection and representation stages, primarily due to challenges with fundamental mathematical concepts and limited visual-spatial abilities. S1 demonstrated a high dependency on external assistance throughout the problem-solving process, especially in planning and execution. In contrast, S2 leaned more towards a trial-and-error approach, struggling to integrate verbal information with visual representations. Across all stages, a consistent challenge was observed in independently devising problem-solving strategies and logically articulating their thought processes. Specifically, students struggled to connect prior spatial concepts to new problems, visualize multi-dimensional objects from varying perspectives, effectively communicate their strategies, logically justify their answers (often resorting to guessing), and outline sequential approaches to problem-solving.

These findings underscore the critical need for tailored educational interventions for students with dyscalculia. To foster a more inclusive learning environment and enhance mathematical comprehension, it is recommended that teachers and policymakers implement strategies focusing on explicit scaffolding across all cognitive stages. This includes providing concrete, multimodal representations for spatial concepts, fostering collaborative learning environments that encourage verbalizing thought processes, and actively teaching logical reasoning and justification skills. Future research should explore the effectiveness of specific intervention programs designed to address these identified difficulties, particularly focusing on developing independent spatial reasoning and self-regulation skills in students with dyscalculia through larger-scale, longitudinal studies.

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