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Analysis of Sudoku Compilation Algorithms: Understanding Number Concepts in Students Special Needs at Extraordinary School

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ABSTRACT

Children with autism spectrum disorder (ASD) often have difficulty understanding abstract concepts such as numbers, requiring interactive and concrete learning media. This study analyzed the systematic thinking, or algorithmic processes, of children with autism spectrum disorder as they solved complex Sudoku puzzles. Using a qualitative descriptive approach, three students with different levels of functioning at extraordinary school C TPA Jember were observed. This study used a 4x4 dot Sudoku game with pictures as a more easily understood learning medium. Data analysis was conducted by comparing data from the work results, visual documentation, and field notes. Data analysis used an interactive qualitative approach based on Miles and Huberman. The results indicated that picture Sudoku can support the algorithmic thinking of children with ASD, although the level of success varies based on individual abilities. Students with lower functional levels require full guidance, but students with higher functional levels lack sufficient independence and problem-solving skills. The conclusion of this study is that picture Sudoku has proven to be an effective tool for improving the algorithmic thinking of children with autism, highlighting the importance of concrete and adaptive learning media.

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1. INTRODUCTION

Children with special needs, including those with intellectual disabilities, often face challenges in thinking, communicating, and interacting socially (Hofmann & Müller, 2021). These difficulties are generally grouped under autism spectrum disorder (ASD), which affects the nervous system (Yenni & Anisa, 2021). Children with autism require special attention and treatment from their environment because they often struggle to establish effective communication and social relationships (Geo et al., 2022; Khatab et al., 2024; Habibi et al., 2025). In education, they also struggle to understand abstract concepts like numbers, so they need teaching materials that are engaging, easy to understand, and tailored to their learning styles (Dahlstrom-Hakki & Wallace, 2022).

One strategy that can be used is educational games like Sudoku. Sudoku is a logic-based puzzle game designed to help students improve their thinking skills quickly and also aid memory, concentration, strategy building, and mathematical problem-solving (Sembiring et al., 2024; Tansya et al., 2024). When made more visual, Sudoku can help autistic children understand number patterns in a more structured and enjoyable way. This visual adjustment is achieved by replacing the numbers on the Sudoku grid with more recognizable images, such as dots on a die, as autistic children are more responsive to visual stimuli than abstract symbols or numbers.

An algorithm is a series of logical steps used to systematically solve problems. The word "algorithm" comes from "Algoritmi," the Latin name for the Persian mathematician Abu Ja'far Muhammad Ibn Musa Al-Khawarizmi, who laid the foundation for modern algorithms (Labib, 2025). Mahrozi and Faisal (2023) define an algorithm as a set of instructions that programmers must follow to complete a specific task. This study analyzes the algorithms used by autistic children to solve Sudoku.

Angeli and Tukino (2024) explain that Sudoku is a number puzzle game originating from Japan. Sudoku is typically played on a board with nine large 3x3 squares. Research (Indriyono et al., 2023) found that this game requires players to fill in the blank spaces with the numbers 1 through 9. At the beginning of the game, several numbers are randomly placed as clues to help solve the puzzle. The player's role is to fill in the remaining empty squares until the entire board is filled with numbers. Although the rules are simple, many players struggle to complete the puzzle successfully.

Fitria et al. (2021) found that using number cards or flashcards significantly improved autistic children's understanding of numbers, with a contribution of up to 83.9%. Rohmaniyah et al. (2023) also revealed that with a multisensory approach, autistic students' ability to recognize number concepts increased dramatically, from 43.75% to 95% after intervention. Geo et al. (2022) provide evidence that autistic students possess communication skills that can develop with the right approach. Lutfi and Sari (2022) demonstrated that high-functioning autistic students were able to follow each step in problem-solving using the Polya method.

In the realm of algorithms, Yahfizham (2023) explained that algorithms are important in everyday life and computer programming, using logical and systematic steps such as pseudocode and flowcharts. Hasan & Yahfizham (2023) emphasized that learning algorithms can improve students' logical thinking skills. However, neither study focused on students with special needs using visual games like Sudoku. Building upon this research, no specific study has examined the algorithmic steps used by autistic children to solve Sudoku games featuring dice. Previous research has focused more on understanding numbers or basic arithmetic operations, without in-depth exploration of the systematic thinking processes that occur when autistic children work on logic games. The novelty of this research lies in the direct observation of the algorithm development process of autistic children through a modified 4x4 Sudoku game using dice dot images. The game serves as a concrete, engaging, and appropriate learning medium for their learning characteristics.

This study aims to analyze the algorithms used by autistic children in completing Sudoku-based mathematical literacy tasks. The urgency of this research lies in its potential to contribute significantly to the development of inclusive and adaptive mathematics learning media for autistic students. In fact, many autistic students do not fully understand number concepts and struggle to organize systematic steps (Rohmaniyah et al., 2023). By understanding their algorithmic thinking patterns, the results of this study are expected to provide a foundation for teachers and education practitioners in designing effective, enjoyable, and autism-friendly learning strategies, thereby supporting the achievement of inclusive education goals.

2. METHOD

This study used a descriptive qualitative approach to describe and analyze how autistic children solve a modified Sudoku game. This method was chosen because it allows for a profound understanding of the participants' natural behavior and thought processes. The researcher was the primary data collection tool, as explained by Sugiyono, cited in Damayanti et al. (2023). This method aligns with Rani and Reni's explanation (2021), which states that a descriptive approach aims to present a detailed picture of the actual state of the research object through direct and regular observation.

This research design was designed to directly observe the subjects' activities while solving a modified version of a 4x4 image-based Sudoku game. This game was modified to suit the learning characteristics of autistic children, using concrete visual symbols instead of abstract numbers. The algorithms observed in solving Sudoku were adapted from research by Indriyono et al. (2023). (1) The first step involves identifying the dot symbols on the dice image. (2) Cutting the image from the provided sheet. (3) Place the images in the appropriate empty squares on the Sudoku board. (4) Observe the patterns in the rows, columns, and blocks, and compare the placement of the symbols. (5) Recheck all image placements to ensure there are no repetitions, and the entire board is filled correctly. The following is a 4x4 Sudoku worksheet presented in Figure 1.

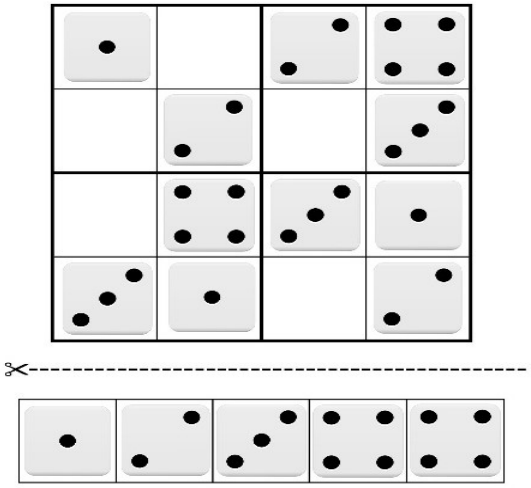

Figure 1. 4x4 Sudoku Worksheet

Figure 1. This is a modified Sudoku, starting with numbers taken from research (Rahayu et al., 2017), which were transformed into a dotted image. Throughout the process, the researcher recorded strategy patterns, nonverbal expressions, and emerging difficulties, supported by photo and video documentation. This research was conducted at Extraordinary School C TPA Jember, East Java. This school serves children with special needs, including autism, with a curriculum and learning services tailored to their needs.

The subjects were selected directly based on their availability at the research site: autistic children who were able to recognize numbers or basic symbols and were willing to participate in visual-based learning. This study involved three boys with moderate and severe autism spectrum disorders studying at the research site. Subjects were selected because the school only had three children with this condition: Subject N, who is 9 years old and in the third grade, has been diagnosed with moderate autism and ADHD. He can communicate verbally fluently, has outstanding motor coordination, and is independent in various activities. However, subject N often walks around and cannot sit still. Subject H, 16 years old, is in the 10th grade of high school and is also in the moderate autism category. He can communicate but often makes mumbling sounds to himself, has strong motor coordination, and is relatively independent in following instructions. Subject K, 15 years old, is in the 9th grade of junior high school and is suspected of having severe autism or even severe intellectual disability. He never speaks during activities, has poor motor coordination, and requires direct direction at every stage of the activity. All three subjects have poor concentration and therefore require assistance to accompany them. This study follows the steps of descriptive qualitative research according to Santoso et al. (2022). The researcher carried out the following steps:

1. Data collection: The researcher prepared and refined the observation instrument, documentation guidelines, and field note format. Next, the researcher created a modified 4x4 Sudoku puzzle using visual symbols in the form of dice dots. Observations were conducted directly in the classroom while the subjects completed Sudoku, and the entire process was documented using mobile phones (photos and videos). The researcher also recorded the children's spontaneous reactions, facial expressions, and nonverbal communication patterns in field notes.
2. Data analysis was conducted by comparing data from the work results, visual documentation, and field notes. Data analysis used an interactive qualitative approach based on Miles and Huberman, as described in Sofwatillah et al. (2024), consisting of three stages: Data reduction by filtering information from observations, visual documents, and field notes to focus on the algorithms used by autistic children. Data presentation by organizing the data into a descriptive narrative that explains the subjects' thought processes. Conclusions were drawn by interpreting the thought patterns formed while the subjects were completing the Sudoku game.

3. RESULTS AND DISCUSSION

Results

The results of this study were obtained from direct observations during the process of solving a 4x4 Sudoku puzzle using dice dots by three participants. The data presented was processed from field notes and visual documentation. At each stage of completing the 4x4 Sudoku puzzle using dice dots, observations were conducted to determine each subject's ability to recognize symbols, cut and paste images, and understand the rules of the game to avoid repeating the same number. The following are the results of observations of the subjects who were the initial focus of this study.

Results from Subject K

Subject K initially could not recognize the dot symbol in the image, but he was able to recognize it after receiving direct instruction from the researcher. He needed sample images and clear verbal explanations to distinguish the number of dots in each image. This finding finding indicates that Subject K requires clear visual and verbal explanations to understand the task. Without instructions, he tends to remain silent and is unwilling to begin the task independently.

When cutting the image, Subject K had difficulty holding scissors properly. When holding the scissors, Subject K often bit them. This behavior indicates difficulties with fine motor skills. Furthermore, his movements were poorly controlled; the researcher often had to restrain him and help him position the scissors to prevent him from biting them and ensure the pieces could be used. When pasting the pictures, Subject K also bit the glue provided. Therefore, he needed considerable assistance to place the symbols in the correct boxes. He often pasted symbols haphazardly, even outside the game box. Such behavior indicates that he was not yet able to connect the images to the rules of Sudoku.

In the pattern-notice stage, he did not yet understand that symbols cannot appear repeatedly in rows, columns, or blocks. Even with direct guidance from the researcher, Subject K still did not understand and required further assistance. Understanding this concept was a major challenge for Subject K in completing the game correctly. In the rechecking stage, Subject K was unable to complete the task on his own. After pasting all the symbols, he assumed the task was complete and did not attempt to double-check. During the activity, Subject K rarely spoke, focusing more on the objects he was holding. He often bit glue, pencils, or other tools around him. This behavior indicates that his focus often shifted to objects with physical sensations rather than the task at hand.

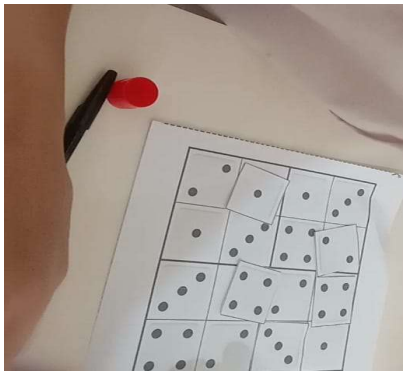

Figure 2. 4x4 Sudoku Work by Subject K

Figure 2. Shows the results of a Sudoku task performed by subject K, who initially had difficulty recognizing the dot symbols on the dice. It appears that the subject required extensive guidance in cutting, pasting, and placing the symbols in the correct squares, and did not yet understand the rules for symbol repetition.

Research Results From Subject H

Subject H differed from subject K in that he was able to quickly recognize the dot symbols on the dice. He was able to correctly distinguish the number of dots without direct instruction, demonstrating an initial understanding of how the image represents these symbols. This ability demonstrates a better understanding of visual concepts.

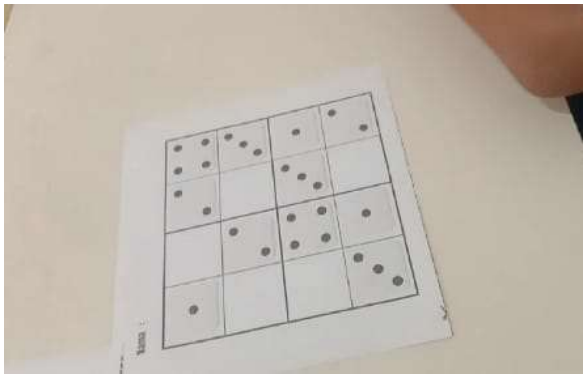

Figure 3. 4x4 Sudoku Work by Subject H

Figure 3. Depicts the initial stages of Sudoku work by Subject H, who was able to recognize dot symbols independently. During the cutting activity, Subject H's motor coordination was quite good. His cut pictures neatly, and he even wanted to cut the worksheet assigned to his friend. While doing the activity, he often made incoherent sounds or mumbled. However, these sounds did not interfere with his work and appeared to be a way to maintain his focus.

During the pasting stage, Subject H was able to place the pictures in the empty squares without assistance. However, he sometimes placed the same symbols in the same row or column, violating the rules of the game. This error occurred because he

was unable to consistently observe the pattern before pasting the symbols. When the researcher pointed out the error, Subject H was able to understand the explanation and correct the symbol positions himself.

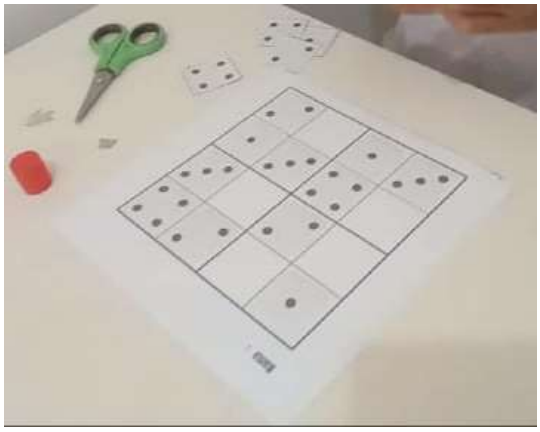

Figure 4. 4x4 Sudoku Work by Subject H

Figure 4 shows Subject H as he began to try to adjust the symbol placement and then paste the answer according to the Sudoku rules. During the pattern observation stage, Subject H demonstrated an effort to adjust the position according to the rules, but had not yet implemented a systematic strategy. He tended to randomly select boxes to fill, so the risk of symbol repetition remained high. Nevertheless, this effort indicated that Subject H was beginning to understand the importance of observing patterns in the game. With proper guidance, he was able to complete the task correctly.

Rechecking was only performed after receiving direction from the researcher. During this stage, Subject K discovered and successfully corrected several errors, such as data discrepancies and pasting errors that had previously gone unnoticed. The students' active involvement through hands-on practice and collaboration supported their understanding of abstract kinematic concepts. This approach was relevant to their work, although the habit of independently rechecking had not yet fully developed.

After completing the Sudoku, Subject H jogged from his desk to the front of the desk, clapping his hands, and then returned to his seat. This indicated that Subject H was pleased to have successfully completed the dot-image Sudoku. His joyful expression conveyed a high sense of satisfaction, which significantly contributed to his enthusiasm for learning. This action also indicates that subject H was interested and enjoyed the learning process.

Research Results from Subject N

Subject N demonstrated superior performance compared to the other three subjects. He demonstrated an exceptional ability to recognize dot symbols in Sudoku puzzles, performing this task very quickly and accurately without requiring any assistance from the researcher. This approach was relevant and he was able to connect the numbers to

their correct positions, demonstrating highly developed visual and cognitive mapping skills. This ability demonstrates a rapid motor response rate.

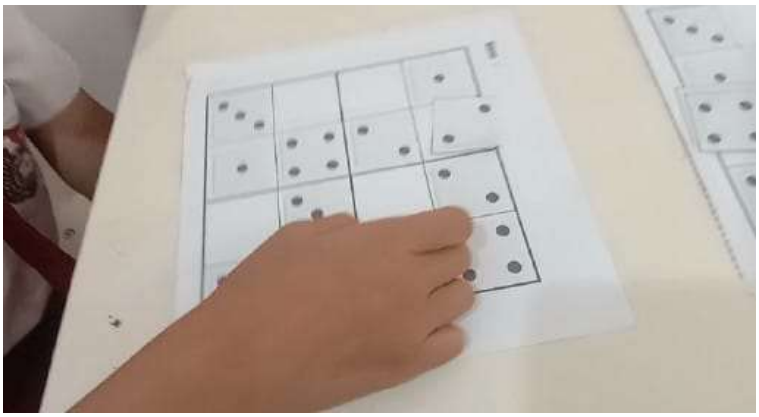

Figure 5. 4x4 sudoku work by subject N

Figure 5 shows Subject N, who was able to quickly recognize the dot symbols on the dice without assistance and began trying to guess the correct answer. During the cutting stage, he demonstrated good hand-eye coordination, resulting in neat and accurate cuts. This process occurred quickly, as if he had become accustomed to holding the scissors correctly. With this skill, he could more easily complete tasks requiring precision and accuracy. This ability also demonstrated a high level of confidence in using the tool.

During the symbol-pasting stage, Subject N employed a structured strategy. He tended to fill the game board sequentially, starting with a specific row or block and completing it before moving on to the next section. This strategy helped reduce the possibility of errors in symbol repetition. This indicates that Subject N understood the importance of planning in completing tasks. Thus, he not only improved his accuracy but also his efficiency in completing the game.

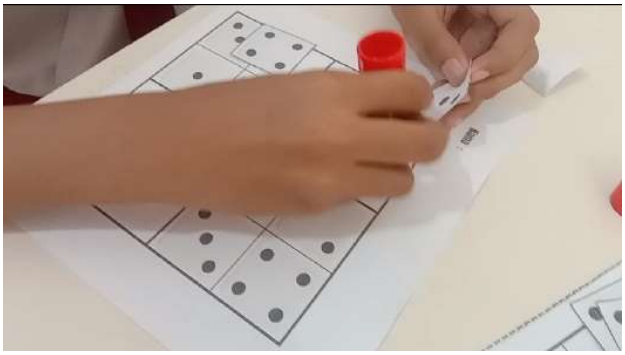

Figure 6. 4x4 Sudoku Work by Subject N

Figure 6 shows Subject N strategically placing symbols, filling the board sequentially and checking the pattern before placing the next symbol. While checking the pattern, he actively checked each row, column, and block before placing the next symbol. He occasionally encountered difficulties, and the researcher had to re-explain the rules to

remind him. However, he confidently stated, "I can do it," demonstrating a good understanding of the Sudoku rules. His confidence in completing this task reflects clear progress in the learning process. Although some challenges remain, his positive attitude indicates a readiness to continue learning and developing.

Subject N performed the re-checking stage himself without being asked, demonstrating a strong sense of responsibility in completing the task. He checked all sections neatly, scrutinizing every detail with meticulous attention to detail to ensure no errors were missed. Subject N also compared the position of each symbol and double-checked the instructions given with his work. When he discovered a minor error, he immediately corrected it without waiting for a supervisor's reminder. Once confident that the task had been completed successfully, he confidently declared it complete. Without wasting time, Subject N immediately saved his work as a form of accountability for the task. This behavior reflects a strong sense of discipline and self-awareness in the learning process.

Throughout the activity, Subject N demonstrated high levels of participation by actively speaking and engaging in each step. He frequently commented on each stage, both regarding challenges encountered and solutions found, reflecting the integration of art and collaboration in hands-on practice. This approach was clearly evident in his enthusiastic facial expressions and tone of voice. Although he remained focused throughout the work process, Subject N occasionally became distracted while completing the task, particularly when drawn to other activities, such as examining the contents of a picture book on the teacher's desk. This behavior demonstrated his strong curiosity and ability to explore various sources of information around him. Engaging in other activities can also be a way for Subject N to relax after completing tasks that require concentration.

Discussion

This study in-depth analyzes the use of dot-picture Sudoku-solving algorithms in children with autism spectrum disorder (ASD). Through this approach, we seek to understand how algorithms can help improve cognitive skills and problem-solving abilities in children with ASD. Active student engagement through hands-on practice, collaboration, and art integration supports the understanding of abstract kinematic concepts. This approach is relevant to children's cognitive developmental levels.

Subject N's Algorithm Pattern

Subject N successfully mastered all algorithms for solving Sudoku. He successfully completed the five stages: recognizing symbols, cutting, pasting images in a structured manner, observing patterns, and conducting self-checks. Although he occasionally needed to be reminded of the game rules, his ability to proactively verify each row, column, and box before pasting a new symbol demonstrates that he not only followed instructions but also understood the basic logic of the game.

This aligns with research Lutfi and Sari (2022), Adako et al. (2024), which states that autistic children with moderate abilities have outstanding potential to implement

complex algorithms if given the right tools. The study emphasized the importance of using appropriate tools to help children with autism spectrum disorders learn. In Subject N's case, Sudoku with dots proved to be an effective way to improve their thinking and problem-solving skills. This Sudoku also helped improve Subject N's focus and patience.

Subject H's Algorithmic Pattern

Subject H was able to understand two algorithms for solving Sudoku. Early in the game, he successfully recognized symbols and cut out images. This ability indicates that Sudoku with dots significantly helped Subject H grasp basic concepts. However, Subject H still struggled with the next three algorithms, such as observing patterns to prevent symbol repetition. This result suggests he did not yet fully understand the game's algorithm. However, Subject H's potential to develop algorithmic skills with continued guidance is evident in his ability to correct errors after receiving hints.

This aligns with research Fitria et al. (2021), which emphasizes that visual media can be an important bridge, provided it is accompanied by structured and repeated feedback to reinforce logical understanding. Visual media not only engages children but also helps them understand complex concepts in a simpler and more memorable way (Arsyad et al., 2024). Therefore, the combination of visual media and consistent feedback may be key to helping Subject H achieve more significant progress in his algorithmic skills.

Subject K's Algorithmic Pattern

Unlike the other two subjects, Subject K could only understand one basic algorithm, namely recognizing symbols, and even then, he required extensive assistance. He consistently required intensive guidance at every stage, from holding scissors to pasting pictures. His ability to observe patterns or double-check was still lacking, indicating that he did not yet understand more complex algorithmic processes. This highlights the crucial role of a caregiver in providing appropriate support and intervention for children with low functioning.

This finding aligns with findings Zhang et al. (2022), Dewi and Morawati (2024), which state that children with low-functioning autism require one-on-one intervention. In this case, the dotted Sudoku served more as a tool to stimulate feelings and fine motor skills, rather than to train algorithmic thinking. This approach emphasizes the importance of tailoring teaching methods to suit each child's individual needs. This way, children with low functioning can benefit optimally from the activities. Therefore, the role of a person who accompanies with an active and responsive attitude is very important to help Subject K in forming the basic skills needed before learning more complex concepts.

4. CONCLUSION

This study shows that children with autism differ in their abilities when solving Sudoku with dots. The differences in algorithm mastery between the three subjects were clear. All

three subjects—N, H, and K—could perform the first algorithm, which involves recognizing symbols on dice. However, only N and H could progress to the second algorithm, which involves cutting the image, while K struggled at this stage. The most significant differences in the algorithms were the ability to observe patterns and double-check. Only N could perform these two tasks, while H and K could not yet perform them independently. This suggests that their algorithmic understanding develops slowly, progressing from simple to more complex tasks.

As a recommendation, teachers can apply the Sudoku algorithm as a learning method to improve number concept understanding in students with special needs. This research can serve as a reference for developing innovative and effective learning media to improve number concept understanding in students with special needs. Teachers can participate in training to learn how to apply the Sudoku algorithm in mathematics teaching for students with special needs. Suggestions for further research include developing a more effective algorithm-based learning model to improve the understanding of number concepts in students with special needs. Furthermore, further research can be conducted to develop interactive learning media that utilizes Sudoku algorithms to improve the understanding of number concepts in students with special needs.

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