



Sudoku as a Bridge Between Logical Thinking and Mathematics Teaching: From Euler's Squares to Overcoming Mathematics Anxiety

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Abstract

Modern mathematics education is often reduced to mechanical calculation, which creates resistance among students and a so-called "fear of calculation errors". This paper explores the potential of Sudoku as a means to rehabilitate mathematical thinking without the pressure of arithmetic operations. In the first part, the paper illuminates the historical and philosophical genesis of the problem, linking Sudoku to Leonhard Euler's work on Latin squares as structures of order and symmetry. The second part presents a proposed didactic application for sixth-grade primary school students, examining strategies for deductive reasoning and elimination that students may employ during problem-solving. Particular emphasis is placed on the development of metacognitive skills; through awareness of their own thinking processes, students gain control over the problem, which may help reduce anxiety and shift their perception of mathematics. The paper concludes that Sudoku represents a promising model with the potential to apply ideas from the history and philosophy of mathematics to motivate students and foster a positive attitude towards mathematical science.

Keywords: Sudoku, Latin squares, mathematics anxiety, deductive reasoning, metacognition.

MSC2020: 97D40, 97C20, 97A30

1. Introduction

Logical thinking is the backbone of mathematics, and its significance must be constantly reinforced. In the 21st century, we can confidently delegate arithmetic operations to technology; however, the ability to deduce, formulate hypotheses, and recognize structures remains the sovereign domain of the human mind. For this reason, we must take a decisive stand against the emphasis on algorithmic, procedural teaching practices that are still pervasive in our educational system, as they often jeopardize the development of logical faculties and directly contribute to the development of mathematics anxiety (Ashcraft, 2002). Bertrand Russell emphasized that 'logic and mathematics are two names for the same discipline,' suggesting that the boundaries between them are merely apparent (Russell, 1919, p.194). In a modern educational context, this relationship is often distorted in favor of procedural knowledge, causing mathematics to lose its logical substance and become a set of abstract rules without clear foundations. The importance of logical thinking in the classroom is reflected not only in the correct solution of problems but also in the development of the capacity for coherent deduction and structural recognition, skills that constitute the core of mathematical literacy (Schoenfeld, 1985).

In teaching practice, a wrong step in an algorithm often leads to an incorrect result. An incorrect result leads to a bad grade, and a bad grade further increases mathematics anxiety, deepening the gap between the student and the subject. The fear of making mistakes often paralyzes students, fostering a negative attitude toward the discipline (Videnović & Radišić, 2011). Recreational mathematics (puzzles, logic games, etc.) shifts the focus from the final result to the process of thinking, exploration, and problem-solving. A mistake in a logic game is merely an additional piece of information; failure does not cause stress but rather increases curiosity. Through algorithms and strictly defined procedures, students often come to believe that there is only one fixed path to solving a problem. Recreational problems (such as those posed by Martin Gardner, 1959) often require "out of the box" thinking-recognizing patterns that are not immediately obvious. This is the moment when the student ceases to be a "performer of tasks" and becomes a constructor of solutions, developing what Boaler (2016) calls a positive mathematical mindset.

A game like Sudoku excludes arithmetic and requires constraint-based deductive reasoning: "If A is here, then B must be there, which means C is impossible..." This is an accessible practice in structural and deductive reasoning, in which structure is recognized through play rather than through dry definitions. When a student independently discovers the solution to a logical puzzle, they employ the heuristic methods described by Polya (1945) and experience intellectual satisfaction. This is the key to inner motivation-mathematics ceases to be an obligation and becomes an intellectual challenge.

The aim of this paper is to analyze the Sudoku game as a specific mathematical problem that serves as a bridge between theoretical mathematics and didactic practice. The study examines the historical development of these structures, from Euler's Latin Squares to modern puzzles, with a particular focus on the philosophical distinction between "calculation" and "thinking." Finally, the paper seeks to demonstrate, through a concrete lesson plan for sixth-grade elementary school students, how the application of Sudoku can serve as an effective didactic tool for developing metacognitive skills, alleviating anxiety, and rehabilitating the investigative spirit in mathematics education.

2. Historical Development of Sudoku and Logical Combinatorial Problems

2.1. Latin Squares and the Work of Leonhard Euler

A Latin square of order n is an $n \times n$ array filled with n distinct symbols, such that each symbol appears exactly once in each row and exactly once in each column. A standard Sudoku puzzle is a special case of a Latin square of order 9, with the additional requirement that each symbol must also appear exactly once in each of the nine 3×3 subgrids (Felgenhauer & Jarvis, 2006).

Two Latin squares of the same order n , say $A = (a_{ij})$ and $B = (b_{ij})$, are said to be orthogonal if, when superimposed, every ordered pair of symbols (a_{ij}, b_{ij}) occurs exactly once. The resulting combined structure is historically known as a Graeco-Latin square or an Euler square (Euler, 1782).

Euler studied these structures extensively and posed the famous "Problem of the 36 Officers" (1779), which asks whether it is possible to arrange 36 officers of six different ranks and from six different regiments in a 6×6 square such that each row and column contains exactly one officer of each rank and each regiment. Mathematically, this corresponds to constructing a pair of orthogonal Latin squares of order 6.

Contrary to common misconceptions, Latin squares exist for every positive integer order n , including $n = 2$ and $n = 6$. What does not exist for orders $n = 2$ and $n = 6$ is a pair of orthogonal Latin squares. Euler conjectured that no pair of orthogonal Latin squares exists for any order $n \equiv 2 \pmod{4}$ (i.e. $n = 2, 6, 10, 14 \dots$). While Euler's conjecture holds true for $n = 2$ and $n = 6$, it was disproved for all $n > 6$ by Bose, Shrikhande and Parker (1960), who proved that a pair of orthogonal Latin squares exists for all orders $n > 1$, except $n = 2$ and $n = 6$.

2.2. The Evolution of Logical Mathematical Puzzles

The term "recreational mathematics" should not be viewed merely as mathematics for leisure, but rather as mathematics in a highly accessible form. Stripped of the burden of complex formulas, it relies on logical reasoning, ingenuity and pattern recognition. Throughout history, there is evidence that great minds such as Pascal, Leibniz, and Euler used puzzles to test the boundaries of human logic (Singmaster, 1993; Gardner, 1959). This is where heuristic thinking develops the ability to find a solution even where no algorithm exists, a process that Polya (1945) defines as the essence of mathematical problem-solving.

Logical problems serve as the "entry point" into the world of mathematics for those who experience anxiety toward numbers. They demystify mathematics by demonstrating that it is not a mere collection of operations, but a way of thinking. A successfully solved puzzle provides an immediate sense of intellectual empowerment (the "Aha! moment"), which serves as the most potent remedy against mathematics anxiety (Ashcraft, 2002).

2.3. The Origin of Modern Sudoku

Although its roots trace back to Euler's Latin Squares, Sudoku as we know it today owes its existence to the American Howard Garns, who published it in 1979 under the name "Number Place." The key innovation was the introduction of 3×3 subgrids, which transformed the Latin Square of order 9 into a dynamic logical challenge requiring both local and global attention.

A Global Phenomenon: The puzzle achieved true global popularity through Japan (where it was named Sudoku, meaning "the number must be single") and later through the British newspaper The Times in 2004. Its popularity lies in its democratic nature: it requires no knowledge of any specific language or mathematical operation, but exclusively deductive and constraint-based reasoning. It serves as proof that the human mind naturally strives for order and logical coherence, even when engaged "for fun." By requiring no linguistic skills or arithmetic operations, Sudoku illustrates Russell's distinction between mathematics as a set of procedures and mathematics as a system of logical relations (Russell, 1919, pp. 194–195). The historical journey of Sudoku, from Euler's abstract combinatorial arrangements to a globally popular puzzle, illustrates the evolution of a logical problem into a powerful educational tool that redefines the boundaries between play and learning.

3. Mathematical Structure of the Sudoku Problem

3.1. Rules and the Uniqueness Condition

A standard Sudoku grid is a square matrix of order 9×9 , divided into nine 3×3 submatrices (blocks). Each cell (i, j) , where $1 \leq i, j \leq 9$, must contain an integer from the set $\{1, 2, \dots, 9\}$. The rules establish three sets of constraints:

- Row constraint: Each number $1, \dots, 9$ appears exactly once in each row.
- Column constraint: Each number $1, \dots, 9$ appears exactly once in each column.
- Block constraint: Each number $1, \dots, 9$ appears exactly once in each of the nine 3×3 blocks.

A proper Sudoku puzzle is defined as a partially completed grid that admits exactly one unique solution. If a grid allows multiple valid completions, it fails the standard formulation of a proper puzzle.

Regarding the minimal number of clues required for uniqueness, McGuire et al. (2012) proved through exhaustive computation that no standard Sudoku puzzle with 16 or fewer clues can have a unique solution. Since valid Sudoku puzzles with 17 clues and a unique solution are known to exist, 17 is established as the absolute minimum number of clues necessary for a unique solution in a standard 9×9 Sudoku.

3.2. Constraint Satisfaction and Graph-Coloring Formulations

Sudoku can be formally modelled as a Constraint Satisfaction Problem (CSP):

- **Variables:** A set of 81 variables X_{ij} , where $i, j \in \{1, \dots, 9\}$, representing the cells.
- **Domains:** For each unassigned variable, the domain is $D_{ij} = \{1, 2, \dots, 9\}$. For given initial clues, the domain is restricted to the single assigned value.
- **Constraints:** A set of all-different constraints applied to each row, column, and 3×3 block.
 - There are no equal numbers in $\{X_{i1}, X_{i2}, \dots, X_{i9}\}$ for each $i \in \{1, 2, \dots, 9\}$.
 - There are no equal numbers in $\{X_{1j}, X_{2j}, \dots, X_{9j}\}$ for each $j \in \{1, 2, \dots, 9\}$.
 - There are no equal numbers X_{ij} in nine cells (i, j) that belong to block k for each $k \in \{1, 2, \dots, 9\}$.

Alternatively, Sudoku can be expressed as a vertex coloring problem in graph theory. Let $G = (V, E)$ be a graph with $|V| = 81$ vertices corresponding to the 81 cells. Two distinct vertices $u, v \in V$ are connected by an edge $(u, v) \in E$ if and only if their corresponding cells share the same row, column, or 3×3 block. The degree of every vertex in this graph is 20 (8 peers in the row, 8 peers in the column, and 4 additional peers in the block).

Solving a given Sudoku puzzle corresponds to extending a partial 9-coloring of G (determined by the initial clues) to a valid proper 9-coloring of the entire graph, such that no two adjacent vertices share the same color (number).

When a player makes an incorrect placement (a wrong assignment), it does not necessarily cause an immediate global contradiction; rather, the invalid entry may remain locally consistent for several steps before propagating constraints that eventually lead to an empty candidate set or prevent the completion of a valid grid.

Furthermore, human logical deduction and algorithmic approaches should not be viewed as opposing concepts. Modern computational solvers do not merely rely on brute-force search; they also utilize sophisticated constraint propagation, backtracking algorithms, heuristics, and exact-cover algorithms (such as Knuth's Algorithm X). In human problem-solving, structural pattern recognition and strategic elimination mirror the principles of algorithmic constraint propagation.

3.3. Sudoku Solving Strategies as Applied Logic

Sudoku solving strategies illustrate elementary principles of deductive logic, such as negation, conjunction, and candidate elimination.

3.3.1. Direct Elimination (Naked Single)

The simplest deductive move occurs when 8 distinct numbers are already present in the combined set of peers (row, column, and block) for a specific cell. Since all other values have been eliminated from the domain of that cell, the remaining value must be assigned to it.

3.3.2. Naked Pairs vs. Hidden Pairs

Naked Pair: Occurs when two cells within a single unit (row, column, or block) contain *only* the same two candidate numbers $\{a, b\}$ and no other candidates. Since these two numbers must occupy these two cells, a and b can be eliminated as candidates from all other cells in that unit.

Hidden Pair: Occurs when two numbers $\{a, b\}$ appear as candidates *only* in two specific cells within a unit, even though those two cells contain additional candidate numbers. Because numbers a and b are constrained to these two cells, all other candidate numbers can be eliminated from these two cells.

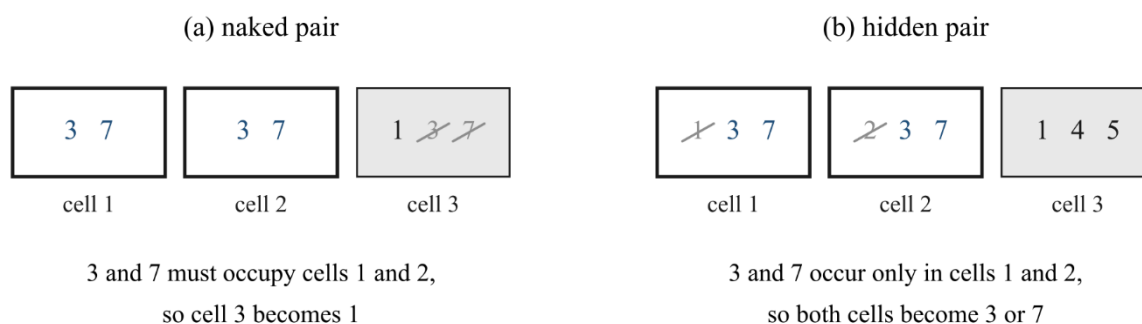


Fig. 1. Naked pair and hidden pair within a single unit. (a) Cells 1 and 2 contain only the candidates 3 and 7, so these two numbers are eliminated from the remaining cells of the unit. (b) The candidates 3 and 7 occur only in cells 1 and 2, so all other candidates are eliminated from those two cells.

3.3.3. X-Wing Pattern

An X-Wing pattern for a candidate number x occurs when:

- Number x appears as a candidate in exactly two cells in each of two different rows (say r_1 and r_2).
- These candidate cells lie in the same two columns (say c_1 and c_2).

Since x must be placed in (r_1, c_1) and (r_2, c_2) , or alternatively in (r_1, c_2) and (r_2, c_1) , number x is guaranteed to occupy columns c_1 and c_2 in rows r_1 and r_2 . Consequently, number x can be eliminated as a candidate from all other cells in columns c_1 and c_2 outside of rows r_1 and r_2 . The configuration is illustrated in Fig. 2.

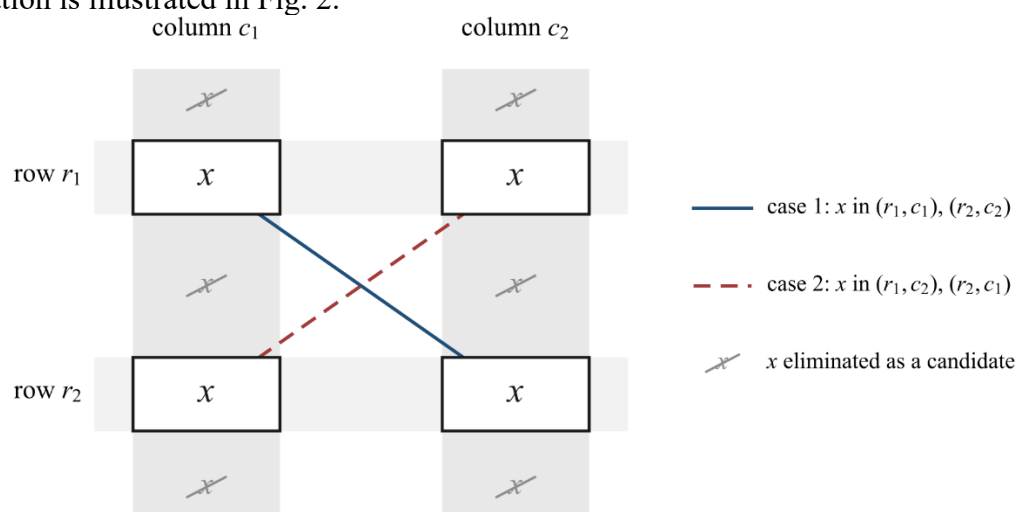


Fig. 2. Illustration of the X-Wing pattern for candidate number x in rows r_1 and r_2 and columns c_1 and c_2 .

3.4. Combinatorial Aspects

While standard Sudoku puzzles are designed to have a unique solution, a grid with multiple valid completions remains a well-defined logical structure. The presence of multiple solutions does not introduce randomness or transform the puzzle into a game of chance; rather, logical deductions remain valid along each solution branch, though uniqueness can no longer be used as a constraint to eliminate candidates. The number of possible 9×9 Sudoku grids is immense, totaling 6,670,903,752,021,072,936,960 (Felgenhauer & Jarvis, 2006).

4. Philosophical Aspects of Mathematical Thinking in Sudoku Problems

Sudoku serves as an accessible model for examining core philosophical themes in mathematics education, particularly the relationship between formal rule-governed systems, deduction, and mathematical reasoning.

Sudoku can be understood as a miniature formal system operating under strict syntactic constraints. The rules dictate allowable placements and ensure internal consistency. When a student encounters a contradiction during problem-solving, it illustrates the concept of logical consistency: a single false premise or invalid deduction disrupts the structural coherence of the system.

Furthermore, Sudoku provides a clear pedagogical distinction between mechanical calculation and structural mathematical thinking. Because the symbols 1, 2, 3, 4, 5, 6, 7, 8, 9 in Sudoku can be replaced by letters, colors, or abstract geometric shapes without altering the underlying logic, the activity demonstrates that mathematics is not inherently bound to arithmetic computation. Instead, mathematical reasoning involves recognizing structural patterns, analyzing constraints, and constructing valid deductive chains.

Algorithmic reasoning and intuitive problem-solving are complementary facets of mathematical capability. Rather than opposing algorithms, Sudoku helps students understand algorithmic constraint propagation in a visual, interactive format, encouraging systematic thinking alongside heuristic discovery.

5. Sudoku as a Didactic Tool in Mathematics Education

5.1. The Role of Recreational Mathematics in Teaching

Recent studies in mathematics education emphasize that recreational mathematics and logic-based games can significantly enhance student engagement and reduce mathematics anxiety. [Alanazi \(2020\)](#) demonstrated that participation in recreational mathematical activities leads to measurably lower anxiety scores compared to traditional instruction, while [Balt et al. \(2022\)](#) confirmed that game-based interventions provide students with opportunities to re-evaluate their relationship with mathematics.

Unlike standard tasks that are often perceived as a mandated "chore," recreational mathematics activates intrinsic motivation through play (gamification). The student does not solve Sudoku for a grade, but for a personal triumph over the puzzle. This approach fosters a "growth mindset," where challenges are viewed as opportunities for brain development ([Boaler, 2016](#)). In Sudoku and similar problems, the student maintains full control. There are no hidden formulas; all rules are visible. This has the potential to reduce the feeling of helplessness. The logical puzzle encourages the student to view a mistake as a "logical contradiction" from which to learn, rather than a personal failure. It is anticipated that such resilience may subsequently transfer to classical mathematical tasks.

Solving problems that require "if-then" chains directly strengthens cognitive capacities. The student must hold several hypotheses in their mind simultaneously. This has the potential to strengthen working memory, which is crucial for solving complex equations and geometric proofs. By understanding that numbers in Sudoku are merely symbols (as discussed in the section on Latin Squares), the student becomes accustomed to abstract thinking, which is the core of algebra. Metacognition, defined by Flavell as the ability to monitor and regulate one's own thought processes ([Flavell, 1979, p. 906](#)), is activated precisely at the moments when the student consciously selects a strategy or identifies an error in their chain of reasoning.

The implementation of Sudoku in primary schools has the potential to enable active learning and differentiated instruction. It serves as a tool that may help reduce mathematics anxiety by eliminating the fear of "computational error" and focusing instead on logical and constraint-based structure ([Videnović & Radišić, 2011](#)). By developing mathematical intuition through play, students build a solid foundation for the later understanding of abstract algebra and geometry.

6. Lesson Plan: Sudoku in Mathematics Education

6.1. Lesson plan

Table 1. Outline of the lesson plan.

Subject	Mathematics
Grade	6th Grade (Primary Education)
Lesson Type	Problem-solving / Practice lesson
Duration	45 minutes
Instructional Theme	Development of logical and deductive thinking through constraint-based problem solving.
Lesson Objectives	By the end of this lesson, students will be able to apply deductive reasoning and elimination strategies to solve Sudoku puzzles, while developing concentration, systematic thinking, and a collaborative approach to mathematical problem-solving.
Learning Outcomes	By the end of the lesson, the student will be able to: • identify which numbers are possible in a given cell using the elimination strategy; • verbally justify each step in their reasoning process; • demonstrate persistence when faced with logical obstacles; • engage in mathematical discussion, explaining their strategies to peers.
Methods	Problem-solving method, Socratic dialogue, demonstration, and independent student work
Tools	Whiteboard, Sudoku worksheets, pencils

Table 2. Structure of the lesson procedure.

Phase	Time	Activities
Introduction	5–7 minutes	The teacher initiates a discussion with the following questions: • "Have you ever solved logical puzzles?" • "Do you know what Sudoku is?" The teacher briefly explains the rules: the use of numbers 1, 2, 3, 4, 5, 6, 7, 8, 9 and the requirement that every row, column, and block must contain all numbers without repetition. A simple Sudoku grid is displayed on the board for visual reference.
Main Body of the Lesson	30 minutes	• Collaborative Analysis (10 minutes): The class fills in a few cells together. The teacher guides the discussion: "<i>Which number can go here? Why? Which numbers are already present in this row or column?</i>" The focus is on the <i>elimination strategy</i>. • Independent Work (15 minutes): Students receive worksheets with simplified Sudoku puzzles (4×4 or easy 9×9). Their task is to complete the grid and be ready to explain their reasoning. The teacher circulates, providing scaffolding and support.

Phase	Time	Activities
		• Discussion (5 minutes): Students share the strategies they employed and identify where they encountered difficulties, emphasizing the importance of logical consistency.
Conclusion	5–8 minutes	Reflective questions for the class: • <i>"Is Sudoku a mathematical problem?"</i> • <i>"Did you need to perform calculations to solve it?"</i> • <i>"What type of thinking did we use today?"</i> Final takeaway: Sudoku demonstrates that mathematics is not just calculation, but a system of logical thinking and problem-solving.

6.2. Methodological Note on Classroom Implementation and Anticipated Outcomes

Sudoku tasks are highly effective in mathematics education because they foster deductive reasoning, encourage active participation, and serve as an excellent example of recreational mathematics in a formal setting.

The lesson plan presented in this paper was implemented in a sixth-grade classroom as part of regular mathematics instruction. While this single implementation does not constitute a formal empirical study, the observed classroom dynamics offer preliminary illustrations of the theoretical assumptions outlined in previous sections.

It is anticipated that the removal of arithmetic pressure may contribute to a reduction of defensive behaviors among students who typically exhibit mathematics anxiety. The logical structure of Sudoku, where every step must be verbally justified, has the potential to spontaneously activate deductive vocabulary: "If 5 is here, then 3 must be there..."

Furthermore, the collaborative nature of the task may foster peer explanation and discussion, transforming the classroom from a space of passive reception into a community of active problem-solvers. Individual differences in cognitive approach visual intuition versus step-by-step logical sequencing may become observable, suggesting the value of differentiated instruction.

These preliminary observations point to the potential of Sudoku as a didactic tool and serve as the basis for future empirical investigation, as outlined in the conclusion of this paper.

7. Discussion

The findings of this paper suggest that Sudoku holds considerable potential as a didactic tool in primary mathematics education. The theoretical analysis presented in the preceding sections, combined with the preliminary classroom observations, points to several educationally relevant dimensions that merit critical reflection.

First, Sudoku's capacity to foster critical thinking operates at multiple levels. As noted in the educational literature, successful mathematical reasoning requires not only procedural knowledge but also the ability to evaluate the validity of an argument and detect logical inconsistencies (Schoenfeld, 1985). The structure of Sudoku naturally demands precisely these skills: students must question assumptions, identify contradictions, and revise their reasoning accordingly. This process of self-correction represents one of the highest forms of critical thinking in a mathematical context.

Second, the differentiated nature of Sudoku tasks, ranging from 4×4 grids for younger or lower-achieving students to complex 9×9 puzzles requiring advanced techniques aligns with contemporary principles of inclusive education. The absence of arithmetic computation as a prerequisite removes a significant barrier for students who experience mathematics anxiety, allowing them to engage with logical and constraint-based structure regardless of their computational proficiency (Alanazi, 2020).

Third, the collaborative dimension of Sudoku implementation deserves particular attention. When students are required to verbally justify each step in their reasoning, the classroom transforms from a space of passive reception into a community of active problem-solvers. This shift reflects the broader pedagogical principle that mathematical understanding is deepened through articulation and peer discussion (Boaler, 2016).

Finally, it is important to acknowledge the limitations of the present study. The observations reported here derive from a single classroom implementation and do not constitute formal empirical evidence. The educational benefits described above remain theoretical propositions supported by existing literature, rather than established findings. A systematic empirical investigation, as proposed in the concluding section, would be necessary to substantiate these claims.

8. Conclusion

In conclusion, Sudoku serves as a prime example of how ideas from the history and philosophy of mathematics can be successfully applied within modern classroom settings. By bridging the gap between combinatorial structures, logical reasoning, and didactic practice, it opens up a different approach to learning—one that prioritizes understanding over mechanical calculation. Such a paradigm shift has the potential to alleviate mathematics anxiety and rehabilitate the primordial joy of discovery. Based on these encouraging preliminary observations, future work will focus on expanding this pedagogical proposal into a formal qualitative case study. Such a study would incorporate systematic classroom observation, analysis of students' completed Sudoku tasks, and short self-reflection questionnaires, with the aim of providing robust empirical evidence on student engagement, logical reasoning, metacognitive processes, and attitudes towards mathematics.

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