Journal of Educational Studies in Mathematics and Computer Science

Analysis of Elementary Students' Performance in Discrete Mathematics Tasks in Competitions (2021–2024)

Bojana Borovićanin
University of Kragujevac, Faculty of Science, Kragujevac, Serbia
bojana.borovicanin@pmf.kg.ac.rs

Received: 27 November 2025; **Accepted:** 25 December 2025

Abstract

This paper presents a four-year statistical and pedagogical analysis of elementary school students' performance in discrete mathematics tasks in competitions held in the municipality of Kragujevac and the Šumadija district (Serbia) between 2021 and 2024. The analysis aims to identify patterns in achievement by grade, gender and task type, as well as the evolution of performance trends across local (municipal) and higher (district) competition levels. The findings underline the importance of discrete mathematics as a foundation for logical reasoning, combinatorial thinking, and early algorithmic literacy. Pedagogical implications suggest integrating discrete mathematics concepts more systematically into the elementary curriculum and enhancing task design in competitions to balance cognitive demands and conceptual depth.

Keywords: discrete mathematics, mathematics competitions, student achievement, educational analysis, combinatorics.

MSC2020: 97C70; 97K20

1. Introduction

Discrete mathematics, as an area of mathematics dealing with finite or countable structures, plays a key role in developing students' logical reasoning, problem-solving strategies, and algorithmic thinking (Tall, 2008). Its subfields, including combinatorics, graph theory, set theory, and number theory, form the conceptual backbone of computer science and modern data-driven disciplines (Abramovich & Connell, 2021).

Recent research highlights the importance of discrete mathematics for enhancing students' capacity to reason abstractly, recognize structural relationships, and engage in computational thinking from the early stages of learning (Sandefur et al., 2022). The psychological foundations of this development are grounded in the theory of relational understanding, emphasizing connections between conceptual structures rather than rote procedures (Skemp, 1987).

Mathematics competitions provide one of the most effective contexts for observing the emergence of such reasoning skills. They often function as informal assessments of students' ability to apply higher-order reasoning in novel contexts (Verschaffel et al., 2020). However, few systematic studies have analyzed how students perform on discrete mathematics problems over time and what pedagogical implications can be drawn from their results. In our country, recent research has examined the achievements of primary school students in mathematics competitions, with particular emphasis on the impact of grouping students into homogeneous classes attending specialized programs at grammar schools, as well as on gender differences (Milenković et al., 2025; Vulović et al., 2024). Within the findings reported by Milenković, Milikić, and Vulović, the authors showed that the largest performance gap appears in tasks from number

Original Research Article

theory, followed by geometry and combinatorics, among students enrolled in classes for gifted students at grammar schools and in regular classes (Milenković et al., 2025).

This paper focuses on competitions organized for grades 5–8 between 2021 and 2024 in the Kragujevac municipality and the Šumadija district. The aim is to identify performance trends by year, gender, and grade level, to compare results between local and regional stages, and to explore the implications for teaching discrete mathematics and problem-solving in school contexts.

2. Data and Methodology

2.1. Data Source

Data were collected from official records of elementary mathematics competitions in Kragujevac (municipal level) and the Šumadija district (district level) for the period 2021–2024. The dataset includes the average scores per grade (5–8), gender, and problem category (numbers, sets, counting, combinatorics).

2.2. Analytical Approach

A mixed quantitative – qualitative approach was applied:

- *Descriptive statistics* summarize average scores, variability, and gender differences.
- *Trend analysis* tracks performance evolution across years and identifies significant changes.
- *Comparative analysis* contrasts municipal vs. district outcomes to explore the transition between competition levels.
- *Generational analysis* follows cohorts longitudinally (e.g., students who competed as fifth graders in 2021 and as eighth graders in 2024).

3. Results and Discussion

The average scores for both boys and girls across grades 5–8 and years 2021–2024 at the municipal and district levels were summarized in Table 1.

Table 1. Average scores by grade, year, gender, and competition level (2021 – 2024)

Grade	Year	Boys (Municipal)	Girls (Municipal)	Boys (District)	Girls (District)
5th	2021	11.50	10.14	2.65	3.75
	2022	10.12	7.93	6.19	7.29
	2023	8.14	6.54	13.63	13.91
	2024	6.29	4.82	10.58	7.64
6th	2021	14.69	13.57	5.30	4.67
	2022	4.20	5.14	6.88	7.00
	2023	6.65	6.10	11.40	9.87
	2024	6.19	3.54	7.33	6.09
7th	2021	—	—	4.17	5.87
	2022	7.04	5.38	12.78	12.15
	2023	7.29	11.00	11.33	12.33
	2024	7.91	6.84	10.63	9.83
8th	2021	12.84	12.11	5.15	8.00
	2022	7.14	5.91	6.07	5.50
	2023	4.63	3.48	8.24	7.94
	2024	8.95	8.25	7.33	6.09

Note. No data is available for the 7th grade at the municipal level in 2021, as no tasks from the considered categories were included.

Graphical visualizations (Fig. 1, Fig. 2) support the analysis of trends and patterns.

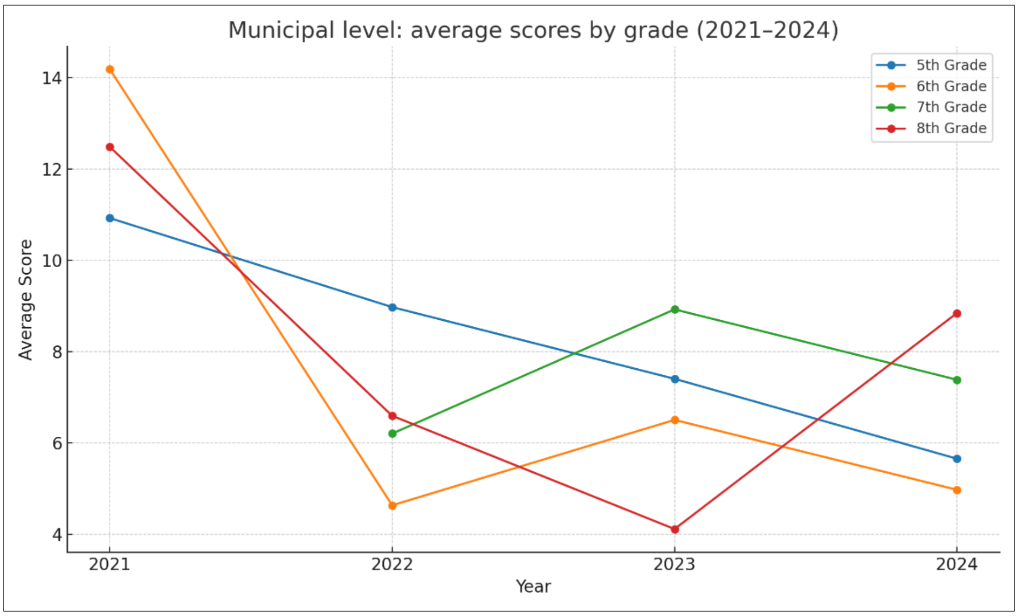

Fig. 1. Municipal level: average scores by grade (2021–2024)

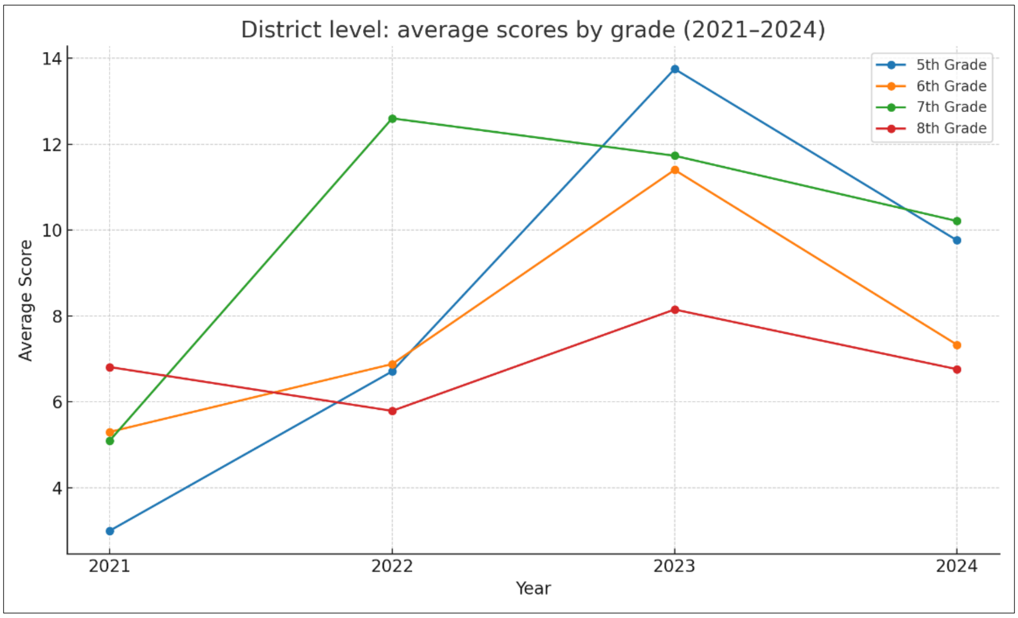

Fig. 2. District level: average scores by grade (2021–2024)

3.1. Municipal Level Results – Grade 5

At the municipal level, results for fifth-grade students show a consistent decline in average scores from 2021 to 2024 (from 10.93 to 5.66 points). As shown in Table 1, boys outperformed girls each year, with the largest difference observed in 2024 (6.29 vs. 4.82). The results by task type indicate that number-based tasks were the most successfully solved across all years, while counting and set theory tasks showed moderate scores.

A year-by-year breakdown shows that in 2021, the highest scores were achieved in the *numbers* category (≈14 points on average), while *sets* and *counting* tasks remained around 9.5 points each. In 2022, results varied substantially: *Sets* and *Numbers (Task 1)* were high (≈12 points), but *Numbers (Task 2)* dropped drastically (≈2.6 points), suggesting a sharp increase in task difficulty. The 2023 average stabilized, but the decline in 2024 indicates that the level of complexity may have surpassed students' preparation.

3.2. District Level Results – Grade 5

At the district level, average scores displayed a clear improvement throughout the observed period. Results increased steadily from ≈3.0 points in 2021 to a peak of ≈13.8 points in 2023, then declined moderately to ≈9.8 points in 2024. Despite this decline, the 2024 results remain considerably higher than those recorded in the initial competition years (2021–2022), indicating overall progress in student achievement. This trend suggests that students gradually adapted to the competition structure and developed greater familiarity with discrete mathematical problem-solving.

3.2.1 Gender Analysis

Gender differences were inconsistent over the four-year period. While boys generally achieved higher averages, girls outperformed them slightly in 2022, scoring 7.29 points compared to 6.19 points among boys. From 2023 onward, boys again showed marginally better results, but the gap remained relatively small, suggesting a balanced level of competence across genders.

3.2.2 Task-Type Analysis

The 2022 competition was particularly notable for strong results in set theory problems, with boys averaging 9.37 points and girls 11.83 points. However, number-related tasks demonstrated greater variability, ranging from 1.8 to 9.7 points, indicating differences in students' ability to generalize numerical reasoning. In 2023, the best results were achieved in both sets and numbers, with averages exceeding 12 points for both genders. The combination of improved averages and reduced variability suggests that students were not only better prepared but also more accustomed to recognizing structural similarities across task types.

Overall, the rise in district-level averages between 2021 and 2023 reflects both increased student experience and the likely impact of task calibration.

3.3. Comparative Analysis – Municipal vs. District (Grade 5)

Comparing municipal and district levels (Fig. 1 and Fig. 2) reveals that during 2021–2022, municipal results were notably higher, while in 2023–2024, the district averages surpassed them. This inversion may indicate an improvement in higher-level preparation and alignment of competition formats. Moreover, task calibration appears inconsistent: earlier years featured disproportionately more demanding district tasks, while later years saw adjusted difficulty, facilitating better performance.

3.4. Municipal and District Results – Grade 6

For sixth graders, a significant downward trend is observed across the years. Municipal results fell from 14.19 points in 2021 to 4.98 in 2024. The sharp decline in 2022 (4.64 points) and the modest rebound in 2023 (6.51 points) suggest changing task difficulty and student motivation. Boys consistently scored higher than girls, except in 2022. The largest gender gap was in 2024 (6.19 vs. 3.54 points).

At the district level, the results for the 6th-grade students in the 2024 competition show a moderate performance overall, with an average score of 6.7 points. When analyzed by gender, boys achieved an average of 7.33 points, while girls scored 6.09 points, indicating a slight yet consistent advantage in favor of boys. Compared with previous years, the district trend demonstrates a gradual improvement from 2021 to 2023, followed by a slight decline in 2024. The 2023 peak (average score of 10.74) corresponds to a generation that maintained stable performance throughout multiple competition cycles.

Regarding task type, performance varied by topic: *combinatorics* tasks were stronger in 2021–2022, while *number theory* tasks peaked in 2023, then declined in 2024. This pattern indicates that the students' reasoning skills improved temporarily with exposure to structured tasks but weakened when task types shifted.

A comparative overview between the municipal and district levels reveals that district participants generally achieved higher averages after the qualification stage. This difference is particularly evident in 2023, when the district average of 10.74 points considerably exceeded the municipal mean of 6.51 points. Such improvement implies that the most successful students at the municipal level were effectively filtered through to the district stage, showing higher mastery of combinatorial and logical reasoning tasks. However, this improvement may also reflect variations in task difficulty between competition levels. In cases where the overall municipal results are weaker, the district competition committee tends to design slightly easier problems to ensure fairer evaluation and maintain student motivation. This adaptive adjustment process likely contributed to the improved averages in certain years and highlights the importance of maintaining consistency in task calibration across competition levels.

3.5. Results – Grade 7

3.5.1 Municipal level

At the municipal level, the results for seventh-grade students show a positive progression from 2022 to 2023, followed by a slight decline in 2024. The average score increased from 6.21 points in 2022 to a peak of 8.93 points in 2023, before dropping moderately to 7.39 points in 2024. This pattern indicates overall improvement in performance, with minor year-to-year variations likely influenced by changes in problem structure and difficulty.

Gender-based differences show an alternating trend. In 2022, boys achieved higher scores (7.04 points) than girls (5.38 points), while in 2023 the pattern reversed, with girls averaging 11.00 points compared to 7.29 among boys. In 2024, the results were again in favor of boys (7.91 points) compared to 6.84 for girls. These fluctuations suggest that non-cognitive factors such as motivation, persistence, and test anxiety may have had a significant impact on individual performance.

3.5.1.1 Task-Type Analysis – Municipal Level (2024)

In the 2024 competition, performance was analyzed across two major task categories: *numbers* and *combinatorics*. For boys, combinatorial tasks were slightly more successful (8.48 points) than number-related tasks (7.33 points). A similar pattern appeared among girls, who scored 8.08 points in combinatorics and 5.60 points in number problems. This suggests that, by this stage, students were generally more adept at recognizing logical patterns and solving combinatorial problems than performing routine numerical calculations.

3.5.2 District level

At the district level, the seventh-grade results demonstrate a more pronounced upward trend, particularly between 2021 and 2022. The average score increased sharply from 5.1 points in 2021 to 12.6 points in 2022, more than doubling in a single year. This improvement may be attributed to better preparation or the inclusion of more accessible problems in that year's competition. A gradual decline followed, with averages of 11.73 points in 2023 and 10.21 points in 2024, although these results remain significantly higher than those from the initial period.

3.5.2.1 Gender Analysis – District Level

Gender differences again vary over time. In 2021, girls slightly outperformed boys (5.87 vs. 4.17 points). In 2022, boys recorded a marginal advantage (12.78 vs. 12.15 points), while in 2023, girls again achieved higher averages (12.33 vs. 11.33 points). The 2024 results show a slight reversal, with boys averaging 10.63 points compared to 9.83 points among girls. These alternating results indicate that both genders maintained a comparable level of competence, with minor fluctuations likely reflecting the variability in task complexity and focus areas each year.

3.5.2.2 Task-Type Analysis – District Level (2022)

The 2022 results further emphasize this balance. Boys scored 16.0 points on combinatorics tasks, outperforming their results on number-based tasks (9.56 points), while girls achieved 16.7 points in combinatorics and 7.6 points in numbers. This alignment with municipal-level trends reinforces the observation that, despite its abstract nature, combinatorial reasoning has become one of the strongest areas of performance for both genders.

Overall, the results for seventh-grade students reflect both growth and variability. The general trend shows improvement in reasoning and abstraction, accompanied by fluctuations that stem from alternating task focus, variations in difficulty calibration, and differences in the motivational structure between cohorts. Both municipal and district averages demonstrate that seventh-grade competitors have reached a balanced level of mathematical maturity, capable of handling complex combinatorial challenges while maintaining solid results across fundamental topics.

3.6. Results – Grade 8

At the municipal level, the results for eighth-grade students reveal a moderate decline in overall performance compared to the preceding grades. The average score in 2024 was 8.85 points, indicating partial recovery from the lower results observed in 2023 (4.12 points). This oscillation corresponds to the changing composition of the participants and the variation in task structure across years. In earlier years, such as 2021 (12.5 points), students achieved notably higher results, suggesting a stronger generation or a set of problems better aligned with their prior knowledge. The municipal results, therefore, reflect the fluctuating nature of task difficulty and student preparedness.

At the district level, average results show greater stability and higher achievement than in the municipal phase. The mean score for 2024 was 6.76 points, close to the long-term average for this grade, while the 2023 results (8.15 points) represent the performance peak. A comparison between genders reveals no significant difference, although boys slightly outperformed girls, except in 2021 (5.15 vs. 8.00). The gender differences appear to diminish over time, suggesting a gradual balancing in problem-solving approaches and confidence across genders.

When task types were examined, the highest performance was observed in number-based problems at both levels, while set theory and counting tasks were moderately successful. The combinatorial tasks remained the most challenging, with scores ranging from 5 to 9 points, depending on the year and gender. This pattern of results confirms that, while students are developing solid arithmetic and algebraic reasoning, higher-level combinatorial abstraction remains an area requiring more targeted classroom practice.

A comparative analysis between the two levels highlights that the district average significantly exceeded the municipal average in 2023, when district participants achieved 8.15 points versus 4.12 points at the municipal stage. This gap indicates that district-level competitors demonstrate higher conceptual understanding and accuracy in multi-step reasoning tasks. Nevertheless, differences in task calibration again play a role – in years when municipal results were weaker, district-level tasks tended to be simplified to ensure fairness and maintain competition balance. Overall, the eighth-grade analysis shows that while discrete mathematical reasoning is progressively improving, stability in achievement is still influenced by variations in task design and by the differing levels of conceptual maturity among participants.

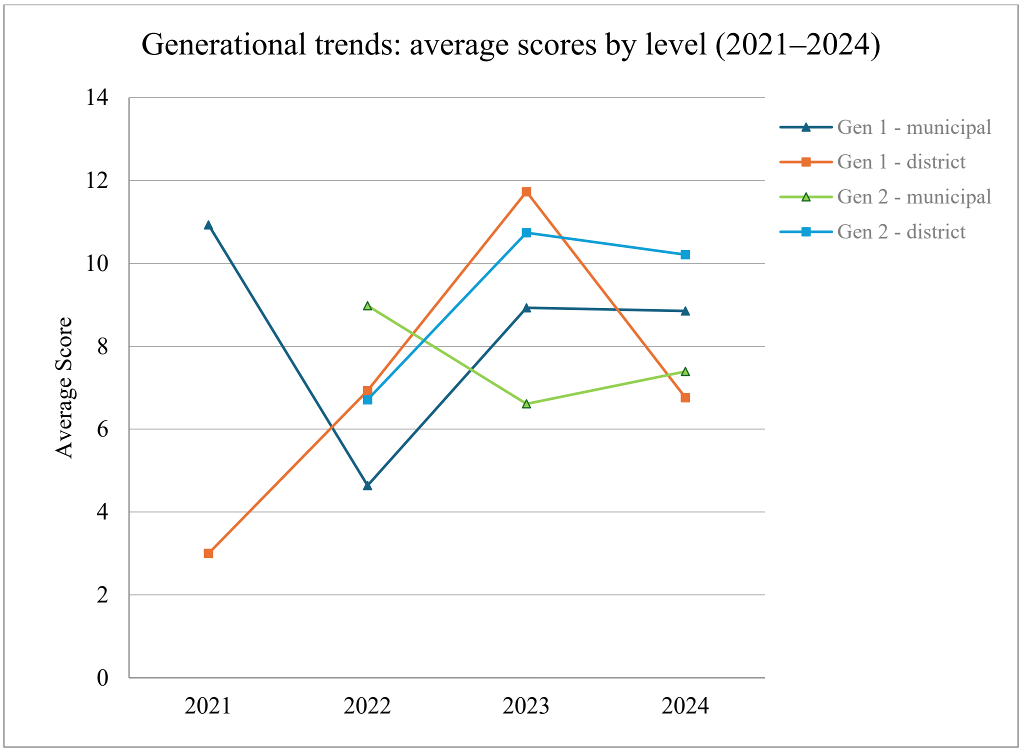

Fig. 3. Generational trends - average scores for Generations 1 and 2 at the municipal and district competition levels (2021–2024).

3.7. Generational Analysis

Two longitudinal cohorts were analyzed to observe performance over time.

- Generation 1 (2021–2024): Progressed from grade 5 to 8 with relatively stable district-level averages (around 10 points), while municipal results decreased gradually (from 10.9 to ≈7 points).
- Generation 2 (2022–2024): Started stronger but displayed a similar decline by the final year.

The findings (see Fig. 3) emphasize that long-term participation improves performance consistency rather than absolute results. Generational analysis supports the idea that continuous engagement in discrete mathematics tasks fosters persistence and analytical stability.

3.8. Interpretation of Performance Oscillations and Low-Performance Tasks

It should be emphasized that the observed year-to-year oscillations in average scores are not solely a reflection of students' knowledge or preparedness. An important contributing factor lies in the structure of the competition itself, particularly in the selection of the most demanding task. In certain years, the competition committee deliberately designed tasks from number theory or combinatorics as the most challenging, whereas in other years, this role was assigned to problems from different domains, such as geometry. Such variations in task emphasis inevitably influence overall performance trends and partially explain the fluctuations observed across years.

It is also important to note that although discrete mathematics topics are formally included in the national curriculum, they are typically taught at a basic operational level during regular classes. More advanced applications, such as modular arithmetic, Diophantine equations, parity arguments, or combinatorics with structural constraints, are most often introduced only in competition preparation classes, which not all students attend. Limited systematic exposure to higher-order discrete reasoning may therefore partially explain lower success rates on the most demanding competition problems.

Several concrete examples illustrate the structure of tasks that produced the weakest performance.

An example of a discrete mathematics task that many fifth-grade students found challenging involved determining the greatest common divisor of the numbers consisting of six and nine consecutive 1-digits. The solution required factorizing: $111111 = 111 \cdot 1001$ and $111111111 = 111 \cdot 1001001$. From this, it follows that the number 111 is a common divisor, and since the remaining factors share no additional common prime divisors, the greatest common divisor is 111. A large proportion of students did not approach the problem through factorization and thus failed to solve it. This suggests that structured approaches to greatest-common-divisor reasoning are still fragile at this stage of learning.

One of the lowest-performing problems in Grade 6 at the municipal level required students to determine whether there exist prime numbers p and q such that $13p + 3q = 2022$. The solution requires the use of divisibility arguments: since $3 \mid (13p + 3q)$, it follows that $3 \mid p$, and therefore the only possible value is $p = 3$. Substituting into the equation gives $q = 661$, after which one must verify that 661 is a prime number. Many students failed to recognize the need to apply divisibility reasoning and the properties of prime numbers, instead attempting to guess pairs of values or to solve the equation without considering the primality condition. This indicates that modular reasoning and structured work with prime factors are not yet fully consolidated at this age level.

A representative example of a low-performing task among seventh-grade students involved arranging nine distinct books on a shelf under adjacency constraints. In part (a), students were required to count the number of permutations in which books 1 and 2 are placed next to each other, which is solved by treating the two books as a single block and then accounting for the two possible internal orders. Part (b) required the complementary principle: subtracting the number of "adjacent" arrangements from the total number of permutations. Many students had trouble structuring the solution process, either by failing to apply the block method consistently or by double-counting configurations. These errors indicate that systematic case analysis and the use of combinatorial counting principles are still being developed at this stage.

One of the lowest-performing problems in Grade 8, at the municipal level, required students to determine all natural number pairs (x, y) satisfying the linear Diophantine equation $8x + 3y = 2022$, and then compute the sum of all corresponding x-values. Although the algebraic structure of the equation is simple, solving it efficiently requires several coordinated reasoning steps: recognising that $3 \mid x$, introducing the parameterisation $x = 3k$, ensuring that both variables remain in the set of natural numbers, and determining the admissible range of the parameter. The need to integrate divisibility arguments, parametric representation, and inequality constraints proved demanding for many students, who often resorted to guess-and-check strategies or produced only a single solution instead of the complete solution set.

Taken together, these findings suggest that students generally handle routine number and set-theoretical tasks with ease, but encounter obstacles when discrete concepts must be integrated, generalized, or applied under multiple simultaneous constraints. Such insights are pedagogically valuable because they indicate the specific dimensions of discrete reasoning, including modular thinking, case structuring, and abstraction; that require more explicit instructional attention, both in regular classrooms and in competition preparation.

4. Pedagogical and Educational Implications

The observed trends reinforce the crucial role of discrete mathematics in nurturing algorithmic and combinatorial thinking. Students who regularly encounter tasks on sets, counting, and numbers develop not only accuracy but also abstraction and generalization skills. However, fluctuating yearly averages signal that conceptual understanding remains uneven.

To enhance stability in results, the following steps are recommended:

- Curricular integration: introduce discrete topics progressively in elementary curricula.
- Task design improvements: balance tasks between procedural computation and conceptual modeling, ensuring progressive complexity.
- Teacher training: strengthen teachers' methodological preparation for discrete mathematics teaching.

- Gender-responsive pedagogy: address motivational differences through collaborative, context-based learning environments.
- Long-term monitoring: continue data collection to track cohorts and inform curriculum reforms.

5. Conclusion

This four-year analysis provides a data-driven perspective on how elementary students perform discrete mathematics tasks in competitions and reveals that results vary notably across years, grades, and genders. Nonetheless, the 2021–2023 upward trend, followed by a mild 2024 decline, reveals the potential and challenges of integrating discrete reasoning into early education. The findings advocate for sustained curricular inclusion and methodological refinement in teaching discrete structures, ensuring that competitions act not merely as tests of knowledge but as laboratories for developing logical and creative thinking.

Acknowledgment

This work was supported by the Serbian Ministry of Science, Technological Development and Innovation (Agreement No. 451-03-137/2025-03/ 200122). The author gratefully acknowledges the mathematics teachers and the organizers of mathematics competitions in Kragujevac and the Šumadija district for granting access to the competition data.

References

ABRAMOVICH, S., & CONNELL, M. L. (2021). *Developing deep knowledge in middle school mathematics: A textbook for teaching in the age of technology.* Springer International Publishing.

MILENKOVIĆ, A., MILIKIĆ, M., & VULOVIĆ, N. (2025). Analysis of Seventh-Grade Students' Performance in National Mathematics Competitions by Topic and Task Type: A Comparison of Specialized and Regular Classes, *Studies in Teaching and Education, 2025, 74*(3), 469-483, https://doi.org/10.5937/niv74-60067

SANDEFUR, J., LOCKWOOD, E., HART, E., & GREEFRATH, G. (2022). Teaching and learning discrete mathematics. *ZDM – Mathematics Education*, 54, 753–775. https://doi.org/10.1007/s11858-022-01399-7

TALL, D. (2008). The transition to formal thinking in mathematics. *Mathematics Education Research Journal*, 20, 5–24. https://doi.org/10.1007/BF03217474

SKEMP, R. R. (1987). *The psychology of learning mathematics.* Hillsdale, NJ: Lawrence Erlbaum Associates.

VERSCHAFFEL, L., SCHUKAJLOW, S., STAR, J., & VAN DOOREN, W. (2020). Word problems in mathematics education: A survey. *ZDM – Mathematics Education*, 54(3), 1–16. https://doi.org/10.1007/s11858-020-01130-4

VULOVIĆ, N., MILENKOVIĆ, A., & MILIKIĆ, M. (2024). Uticaj grupisanja učenika 7. i 8. razreda u homogena odeljenja na zastupljenosti uspeh na državnim takmičenjima iz matematike. *Zbornik radova Pedagoškog fakulteta, Užice*, *27*(26), 221-244.