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THE COGNITIVE PARADOX: WHY MATHEMATICS MAJORS STRUGGLE WITH ELEMENTARY MATH PUZZLES

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Abstract. This paper presents the outcomes of an action research experiment examining the use of mathematical puzzles to develop problem-solving skills, critical thinking, cognitive development, microlearning, digital skills, motivation, engagement, creativity, lateral thinking, and interactivity in undergraduate students. It presents real-life applications of math puzzles and offers three case studies adapted for first-year mathematics undergraduates at the Faculty of Mathematics and Informatics of Paisii Hilendarski University of Plovdiv within the English for Specific Purposes course. The article analyzes student performance alongside the performance of popular AI models, discussing reasons for failure when mathematical subject knowledge is not the limiting factor. It also suggests how these puzzles can be adapted for primary and high school students.

Key Words: *puzzle-based learning, problem-based learning, STEM, problem-solving, critical thinking, microlearning, digital skills, motivation and engagement, lateral thinking, creativity, interactivity.*

1. Introduction

Puzzles have long been used in STEM education [1]. This paper adheres to the definition provided therein. Four criteria intrinsic to educational puzzles were formulated in [2]: generality, simplicity, a ‘eureka’ factor, and entertainment. The general methodological patterns in the literature include short repeated exposure in lectures or focused puzzle tasks in small groups; quantitative questionnaires plus qualitative interviews/observation are employed to gauge student perceptions and process evidence rather than large-scale randomized outcomes [3, 4, 5]. Mathematical puzzles are designed to develop and promote problem-solving, critical thinking, cognitive development, microlearning, digital skills, motivation, engagement, creativity, lateral thinking, and interactivity in undergraduate students.

This paper addresses why mathematics majors, who presumably have strong mathematical backgrounds, struggle with puzzles requiring only basic mathematics – a cognitive paradox that remains underexplored. Math majors excel at formal, algorithmic mathematics but struggle with the creative, exploratory thinking required for puzzle-solving. This action research experiment faced sample size limitations because mathematics majors constitute a small population. Ethical use was made of SciSpace for literature review and Claude Sonnet 4.0 for literature review and research gap analysis.

2. Sample cases of adapted math puzzles

Due to space constraints, this paper presents 3 math puzzles from a pool of 30. These puzzles were adapted by the first author from various sources and used for many years as warm-up activities with first-year FMI students of Mathematics and other programs. Students were encouraged to be creative by not only justifying but also illustrating their answers using Excalidraw and Gamma.

Student performance and the mathematical knowledge required for solving these problems, expressed in terms of the grade level at which Bulgarian students typically learn the relevant material, are shown in Table 1.

Table 1. Math undergraduates' performance on three math puzzles and minimum mathematical prerequisites (Bulgarian school grades)

Puzzle		**Correct solutions (% of subjects)**	**Grade (minimum)**	**Grade (conservative)**
Full text	**Reference**			
	Bikes	0%	2	3
	Picnic	12.5%	3	5
	Badminton	14%	4	8

- Due to the limited population of mathematics majors, this was not a representative sample, but the observation outcomes have been consistent.

For the bikes puzzle, even first-grade pupils can add, subtract, and compare integers up to 30 as required here. This mathematical problem demands imagination, resourcefulness, and creative thinking.

Regarding the picnic puzzle, if a third-grade pupil realizes that since each friend consumed the same amount of food and the third friend left €50 as his share, this was also each friend's share, making the total €150. Therefore, each sandwich cost €30 (€150/5). The fair compensation would be €10 for the first friend (€60 spent – €50 consumed) and €40 for the second friend (€90 spent – €50 consumed). However, solving the puzzle using a single-variable equation requires fifth-grade knowledge.

For the badminton puzzle, while an eighth-grader will have some combinatorics background, it can be adapted for primary school by asking pupils to draft a tournament schedule with two representatives (a boy and girl) from each of the first four classes: A, B, C, and D. Primary school pupils can solve this puzzle either as a class or in small groups through hands-on thinking, involving Creative Mathematics in addition to Procedural Mathematics. However, teachers need to provide scaffolding, e.g. four color-coded letter sets, a schedule template, etc. Pupils can move letters from the initial tray to the schedule while following constraints and making two verifications: (1) no player plays more than once *with* the same player; (2) no player plays more than once *against* the same player.

School teachers interested in using mathematical puzzles with their students (e.g., for warm-up or revision/reinforcement activities) should adapt not only the settings but also the language and instruction length and the illustrations.

3. AI as a math puzzles assistant

It was surprising how few students used AI tools with the puzzles. Some avoided AI due to previous negative experiences with AI puzzle-solving, while others responded with "TL;DR." The latter group wanted straightforward answers as if from a cheat sheet and found several pages of AI solutions with reasoning and verifications too overwhelming. Another reason for avoiding AI assistance could be that AI models sometimes chose more complicated solution methods. Some students also underestimated the school-level of the math problems.

AI models used during the experiment occasionally struggled to grasp meaning, such as "with or against" in the badminton puzzle. Sometimes technical issues prevented AI chat completion, and students were reluctant to try multiple AI models rather than one all-purpose model despite teacher encouragement.

Several months after the semester ended, the free plans of popular AI models were tested at the end of August 2025 (Table 2).

Table 2. AI models and performance on the three math puzzles as of 29.08.2025

Puzzle	GPT-5 Thinking mini	Claude Sonnet 4.0	Deepseek v 3.1	Gemini 2.5 Pro	Grok Auto (3 or 4)	MS Copilot
Bikes	C	N	N	N	N	N

Picnic	C	C	C	C	W/C	C
Badminton	N	N	W	C	C	C

Legend: **C** = correct answer; **W** = wrong answer; **N** = no answer; **W/C** – wrong answer on 28.08.2025 followed by a correct answer on 29.08.2025.

This is not a valid comparison but rather observational notes. The data reflects the most recent responses by AI models, so since Nov. 2022 when our undergraduates started using AI assistance, the models may have been trained on correct answers revealed in class. Respondents used these assistants in January 2025 for the picnic puzzle and then received some wrong answers form some of the AI models, which have undergone significant development since then. An error such as an incorrect table illustrating a correct solution is likely to discourage students from reading further to arrive at the correct solution.

4. Reasons for poor performance at solving math puzzles

Year after year, reflecting on this experiment, the same question emerged: why do undergraduates fail (cf. Table 1) at math puzzles that can generally be solved with basic mathematical knowledge? Students had ample time – 20 minutes overall with no practical restrictions. They had computer access with internet connectivity and could consult any AI model, conduct desktop research, etc. They had long mastered the required mathematical knowledge and skills.

Based on long-term observations, some shared by students themselves in interviews, several reasons explain unsatisfactory performance:

- **Underestimating puzzles** as requiring Elementary rather than Higher Mathematics, and not working at full capacity;
- **Failing to see relevance** to current or future jobs/interests;
- **Limited or no previous experience** with such puzzles;
- **Negative previous experience** with such puzzles;
- **Cognitive overload** may impede creativity. The curriculum is demanding, and some students must work part-time;
- **Linguistic competency deficits** in some students;
- **Performance anxiety** caused by potential embarrassment before peers, regardless of teacher encouragement that mistakes and failures are part of learning and the path to success;
- **Creativity anxiety** can make students "freeze" when facing open-ended problems with multiple possible approaches;
- **Fear of failure**: "Students do not like to fail. They do not like to grapple with difficult problems or tasks that they have the potential to fail" [6];

- **Difficulty switching from algorithmic thinking** (required by most textbook problems) **to creative, exploratory problem-solving** (required by puzzles). Some differences between learning mathematics in school versus university regarding cognitive approaches, computational skills, and algorithmic facility are provided in [7];
- **Getting stuck in familiar patterns** and struggling to think flexibly;
- **Inability to break down complex problems** into manageable sub-problems, which even affects their prompting skills;
- **Inability for sustained mental effort**. Paradoxically, there is "a significant negative correlation between frequent use of AI tools and critical thinking abilities, mediated by cognitive offloading" [8];
- **Feeling pressured by time constraints** for puzzle-solving – some tend toward quick guesses rather than systematic approaches;
- **Avoidance behaviors** by some students. "Teachers might create contexts that encouraged or discouraged adoption of avoidance strategies" [9]. For example, Ivan Shotlekov's "cake in the fridge" approach [10]. Students were encouraged to address math puzzles not as math problems but as job interview questions. The metaphor refers to scenarios where you know there is some cake left in the fridge and you want it now, but you cannot see it at first glance. In such circumstances, most people would persevere! Students were coached not to give up before they had started.

Some of these factors seem to create compound barriers to successful puzzle-solving performance in some learners.

5. Conclusion

Why math undergraduates with strong mathematical backgrounds fail at solving puzzles requiring only basic mathematics is a straightforward question, but the answer is complex, and this cognitive paradox needs further exploration. Teaching professionals need to reflect more on procedural versus creative mathematics in teaching and learning experiences when solving real-life problems.

This paper serves as a foundation for additional research on using mathematical puzzles to develop and stimulate problem-solving, critical thinking, cognitive development, microlearning, digital skills, motivation, engagement, lateral thinking, and creativity in undergraduates, assessing practical implications, benefits, and limitations.

Future research will examine how sustained exposure to structured mathematical puzzle interventions over a full academic semester affects undergraduate students’ creative problem-solving approaches in their major-specific coursework, and what factors predict long-term skill retention.

References

[1] Thomas, C., M. Badger, E. Ventura-Medina, C. Sangwin, Puzzle-based Learning of Mathematics in Engineering, *Engineering Education*, 2013, 8 (1), pp. 122–134, DOI: https://doi.org/10.11120/ened.2013.00005

[2] Michalewicz, Z., M. Michalewicz, *Puzzle-Based Learning: An introduction to critical thinking, mathematics, and problem solving*, Melbourne: Hybrid Publishers, 2008

[3] Klymchuk, S., Puzzle-based learning in engineering mathematics: students' attitudes, *International Journal of Mathematical Education in Science and Technology*, 2017, 48 (7), pp. 1106–1119, DOI: https://doi.org/10.1080/0020739X.2017.1327088

[4] Evans, T., S. Klymchuk, M. Thomas, *Puzzle-based Learning in University Mathematics: Students' Perspectives*, AUT Open Repository, 2018, Available: https://openrepository.aut.ac.nz/handle/10292/11896, accessed: Aug. 27, 2025

[5] Rezvanifard, F., F. Radmehr, Y. Rogovchenko, Advancing engineering students’ conceptual understanding through puzzle-based learning: a case study with exact differential equations, *Teaching Mathematics and its Applications: An International Journal of the IMA*, June 2023, vol. 42, Issue 2, pp. 126–149, DOI: https://doi.org/10.1093/teamat/hrac005

[6] Doyle, J., *A coach's favorite strategies for math retention*, 2022, Available: https://betterlesson.com/blog/strategies-math-retention, accessed: Aug. 27, 2025

[7] Newton, D., Y. Wang, L. Newton, ‘Allowing them to dream’: fostering creativity in mathematics undergraduates, *Journal of Further and Higher Education*, 2022, vol. 46, no. 10, pp. 1334-1346, DOI: https://doi.org/10.1080/0309877X.2022.2075719

[8] Gerlich, M., AI Tools in Society: Impacts on Cognitive Offloading and the Future of Critical Thinking, *Societies*, 2025, vol. 15, no. 6, DOI: https://doi.org/10.3390/soc15010006

[9] Turner, J., C. Midgley, D. Meyer, M. Gheen, E. Anderman, Y. Kang, H. Patrick, The Classroom Environment and Students’ Reports of Avoidance Strategies in Mathematics: A Multimethod Study, *Journal of Educational Psychology*, 2002, vol. 94, no. 1, pp. 88-106, DOI: https://doi.org/10.1037//0022-0663.94.1.88

[10] Шотлеков, И., *Уеб-базирано интердисциплинарно проектно-ориентирано обучение по информационни технологии на студенти по информатика*, Пловдив, 2012, дисертационен труд