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WHERE DO SMALL OPEN LANGUAGE MODELS BREAK ON OLYMPIAD MATHEMATICS? DOMAIN, DIFFICULTY AND MODEL SIZE ON OMNI-MATH

Abstract. Small language models that can run on a laptop are increasingly used by students to check solutions, yet little is known about where on olympiad mathematics they fail. This study tested three open models of the same family, Qwen2.5-Instruct with 1.5, 3 and 7 billion parameters, on 287 problems from the Omni-MATH benchmark, sampled across four domains (algebra, geometry, number theory and discrete mathematics) and three difficulty bands. Before any model was run, the author predicted that a larger model would gain most in algebra, where known methods carry a solution, and least in geometry, where the right configuration or construction has to be noticed. Overall accuracy was 15.3%, 13.2% and 26.8% for the 1.5B, 3B and 7B models. The 7B model solved 50.7% of algebra problems but only 17.3% of geometry problems, 25.3% of number theory and 11.3% of discrete mathematics. From the 3B to the 7B model, algebra rose by 28 percentage points and geometry by 8. On middle-difficulty problems the 7B model solved 40% in algebra and 4% in geometry. Nine geometry problems could not be solved from the text alone because they referred to a missing figure; removing them raised 7B geometry accuracy only to 19.7%. The results support the prediction: for small models, size helps algebra much more than geometry, and the geometry gap is not explained by missing figures.

Keywords: language models, olympiad mathematics, geometry, model size, Omni-MATH

1. Introduction

Competition mathematics has long been used to measure how well computer models reason. When the MATH dataset of 12,500 competition problems was introduced, its authors found that accuracy remained low even for very large models and warned that "simply increasing budgets and model parameter counts" would be impractical for strong mathematical reasoning if scaling trends continued [1]. Since then, larger and more specialised models have improved quickly, and benchmarks such as MATH are now solved with high accuracy by the strongest systems [2]. To keep a harder test, Omni-MATH collected 4,428 olympiad-level problems, each labelled with a domain and a difficulty level, and showed that even the most advanced models of 2024 solved only about half to 60% of them [2].

Most published results describe large models. Small open models, with one to seven billion parameters, behave differently: they can run on an ordinary computer, they are free, and students increasingly use them as study tools. The Qwen2.5 family released such models in several sizes trained in the same way [3, 4], which makes it possible to change only the size and watch what happens. Work on scaling laws found that the loss of language models falls smoothly as the number of parameters grows [5], but a smooth average does not say whether every kind of problem benefits equally.

The author is an olympiad student in mathematics, and his experience suggested that domains differ in what they demand. In algebra, a problem can often be carried through by known transformations, step by step. In geometry, one missed idea, such as an auxiliary line or the right way to see the configuration, breaks the whole solution. This study asks: on olympiad problems, how does the accuracy of small open models differ by domain and difficulty, and does a larger model help some domains more than others?

2. Hypothesis

The hypothesis was written by the author on 5 October 2026, before any model was run. Model size would help differently in different domains. In algebra the gain should be larger, because known methods and transformations carry the problems. In geometry, even a model that knows many theorems has to notice the right configuration or construction, so on harder problems size may help less. Discrete mathematics was expected to be worth comparing, because a problem there often depends on a single idea, such as an invariant or an unusual way of counting.

3. Data and methods

3.1. Problems

The problems come from Omni-MATH [2], downloaded from its public Hugging Face repository (KbsdJames/Omni-MATH, test file, 4,428 problems) on 7 October 2026. Only problems labelled with exactly one of four domains were used: algebra, geometry, number theory and discrete mathematics. Within each domain, problems were divided into three difficulty bands using the benchmark's own difficulty labels: easy (1 to 3), middle (3.5 to 5) and hard (above 5). From each of the twelve cells, 25 problems were drawn at random with a fixed seed. Only 12 easy discrete mathematics problems were available, so all 12 were used, giving 287 problems in total.

The bands correspond to different competitions. Of the 87 easy problems, 84 come from the Canadian Pascal, Cayley and Fermat contests. Of the 100 middle problems, 91 come from the Harvard-MIT Mathematics Tournament (HMMT). The hard band mixes HMMT problems with problems from the International Mathematical Olympiad (IMO), the IMO Shortlist, the USA Mathematical Olympiad and national team selection tests.

3.2. Models and generation

Three instruction-tuned models were tested: Qwen2.5-1.5B-Instruct, Qwen2.5-3B-Instruct and Qwen2.5-7B-Instruct [3], in 4-bit versions run locally with the MLX library on a laptop. Each model received every problem with the system prompt used by Qwen for mathematics, "Please reason step by step, and put your final answer within `\boxed{}`", and answered with greedy decoding (no randomness), so the results can be reproduced exactly. Each answer was limited to 1,024 new tokens.

3.3. Scoring

The final answer was taken from the last `\boxed{}` expression in the model's output and compared with the reference answer. Answers that matched after simple normalisation, or that were numerically equal, were scored automatically. Answers that the automatic check could not settle, for example the same value written in a different form, were judged for equivalence one by one by the author's mentor with the help of a generative AI assistant; 240 unique pairs of answer and reference were judged in this way, and the verdicts were saved. An output without a boxed answer, including every output cut off at the 1,024-token limit, was counted as wrong.

3.4. Problems that need a figure

When the author read ten geometry problems that the 7B model had failed, several of them referred to a drawing that is not in the text. To measure this, all 75 geometry problems were read one by one, and a problem was marked as needing a figure when the text alone does not determine the answer. Nine problems were marked in this way, and two more were borderline. Before this check, the author predicted that geometry accuracy would rise noticeably after removing these problems but would still not reach algebra, because problems that need an idea or a construction would remain.

4. Results

4.1. Overall accuracy and model size

The 1.5B model solved 44 of 287 problems (15.3%), the 3B model 38 (13.2%) and the 7B model 77 (26.8%). The middle model was slightly worse than the smallest one overall, while the 7B model solved about twice as many problems as either.

Table 1. Accuracy by domain and model, correct / total (%)

Domain	1.5B	3B	7B
Algebra	23/75 (30.7)	17/75 (22.7)	38/75 (50.7)
Geometry	9/75 (12.0)	7/75 (9.3)	13/75 (17.3)
Number theory	8/75 (10.7)	9/75 (12.0)	19/75 (25.3)
Discrete mathematics	4/62 (6.5)	5/62 (8.1)	7/62 (11.3)
All	44/287 (15.3)	38/287 (13.2)	77/287 (26.8)

4.2. Domains

Algebra was the easiest domain for every model, and the gap grew with size. From the 3B to the 7B model, accuracy rose by 28.0 percentage points in algebra, 13.3 in number theory, 8.0 in geometry and 3.2 in discrete mathematics. At 7B, algebra accuracy was almost three times geometry accuracy (50.7% against 17.3%).

4.3. Difficulty

Table 2 shows that the difference between domains appears already on middle problems. The 7B model solved 22 of 25 easy algebra problems and 11 of 25 easy geometry problems. On middle problems it solved 10 of 25 in algebra but only 1 of 25 in geometry. On hard problems it solved 6 of 25 in algebra and 1 of 25 in geometry. Across the three models together, hard geometry problems were solved only twice in 75 attempts.

Table 2. 7B model, correct out of 25 by domain and difficulty (12 for easy discrete mathematics)

Domain	Easy	Middle	Hard
Algebra	22	10	6
Geometry	11	1	1
Number theory	13	3	3
Discrete mathematics	1 of 12	3	3

In number theory and discrete mathematics, the hard band was not harder than the middle band for these models (for example, 3 of 25 in both for the 7B model). With 25 problems per cell, differences of one or two problems are within chance, and some hard olympiad problems have short final answers that can be reached without a full solution.

4.4. Missing figures

Removing the nine geometry problems that need a figure changed little (Table 3). For the 7B model, geometry accuracy rose from 17.3% to 19.7%, and to 20.3% when the two borderline problems were also removed, still about 31 percentage points below algebra. On the nine figure problems themselves the models solved 1, 0 and 0. The author's prediction was correct: geometry rose, but it did not come close to algebra.

Table 3. Geometry accuracy with and without problems that need a figure

Model	Algebra	Geometry, all 75	Without 9 figure problems	Without 11
1.5B	30.7%	12.0%	12.1% (8/66)	10.9% (7/64)
3B	22.7%	9.3%	10.6% (7/66)	9.4% (6/64)
7B	50.7%	17.3%	19.7% (13/66)	20.3% (13/64)

Without the figure problems, the 7B model solved 55% of easy geometry problems against 88% of easy algebra, 4% of middle geometry against 40% of middle algebra, and 5% of hard geometry against 24% of hard algebra.

4.5. Answers cut off

About one in five outputs reached the 1,024-token limit before giving a final answer: 71 for the 1.5B model (24.7%) and 59 for both the 3B and 7B models (20.6%). None of these was counted as correct. Number theory was affected most for the 1.5B model (29 of 75 outputs).

5. Discussion

The results agree with the hypothesis written before the experiment. A larger model helped algebra far more than geometry: between the 3B and 7B models, algebra gained 28 percentage points and geometry 8. The author's own explanation is that in geometry one missed idea breaks the whole solution, while in algebra a solver can go step by step. The pattern in Table 2 fits this reading. On easy problems, which are mostly direct calculations from the Canadian contests, geometry is behind algebra but still within reach. On middle HMMT problems, where a construction or a non-obvious view of the figure is usually needed, the 7B model solved 10 algebra problems and only one geometry problem.

The missing-figure check was important because it could have explained the gap in a simpler way. Olympiad geometry problems often come with a drawing, and a text-only model cannot see it. The check showed that this explains the failures on the nine problems that need a figure, but not the size of the gap: with those problems removed, geometry remained about 31 points behind algebra for the 7B model. The remaining failures are on problems that are fully stated in words.

Discrete mathematics was the weakest domain for all three models and grew least with size. This also fits the author's expectation that such problems often depend on one idea, such as an invariant or an unusual way of counting, which is hard to reach by routine steps.

The smallest model was slightly better than the 3B model overall, mostly because of algebra (23 against 17 correct). A larger model does not always do better on a small sample, and the 1.5B model was not uniformly stronger: it was weaker than the 3B model in number theory and discrete mathematics. The clear jump appears only at 7B.

For students, the practical point is that a small model running on a laptop can be a reasonable helper on routine algebra but is unreliable on olympiad geometry and combinatorics, even at the easy level, and its confident answer should not be trusted without checking.

5.1. Limitations

Each cell contains only 25 problems (12 for easy discrete mathematics), so differences of a few problems are not meaningful. Only one model family and three sizes were tested, all in 4-bit form, which may lower accuracy slightly compared with the full models. The 1,024-token limit cut off about a fifth of the answers; with a longer limit, some of them might have reached a correct answer, especially in number theory. Answers that the automatic check could not settle were judged by the mentor with an AI assistant, which may contain errors. Difficulty bands mix different competitions, so band and source cannot be fully separated. Finally, only final answers were checked, not the reasoning, so a correct answer reached by a wrong argument counts as correct.

6. Conclusion

On 287 olympiad problems from Omni-MATH, small open Qwen2.5 models were much stronger in algebra than in geometry and discrete mathematics, and increasing the size from 3 to 7 billion parameters helped algebra about three and a half times as much as geometry. The geometry gap opens already on middle-difficulty problems and is not explained by problems that need a missing figure. As the author predicted before the experiment, model size helps most where known methods carry a solution and least where a solver has to find the right idea.

Author's contribution

The author chose the research direction from three options, wrote the hypothesis before any model was run, classified ten failed geometry problems by the reason for failure, predicted the result of the missing-figure check before it was made, and contributed the interpretation of the differences between domains used in the discussion. The data were downloaded, the models were run and scored, the remaining answers were judged, and the text was drafted by his mentor with the help of a generative AI assistant (Claude, Anthropic). Every number in the paper comes from the saved model outputs and scoring files.

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