

ISSN 2518-1726 (Online),

ISSN 1991-346X (Print)

**ACADEMIC SCIENTIFIC
JOURNAL OF COMPUTER SCIENCE**

**№2
2026**

ISSN 2518-1726 (Online),
ISSN 1991-346X (Print)



ACADEMIC SCIENTIFIC JOURNAL OF COMPUTER SCIENCE

3 (359)

JULY – SEPTEMBER 2026

**PUBLISHED SINCE JANUARY 1963
PUBLISHED 4 TIMES A YEAR**

ALMATY, NAS RK

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Academic Scientific Journal of Computer Science

ISSN 2518-1726 (Online),

ISSN 1991-346X (Print)

Owner: «Central Asian Academic Research Center» LLP (Almaty).

Certificate № KZ77VPY00121154 on the re-registration of the periodical printed and online publication of the information agency, issued on 05.06.2025 by the Republican State Institution «Information Committee» of the Ministry of Culture and Information of the Republic of Kazakhstan

Subject area: *information and communication technologies*.

Currently: *included in the list of journals recommended by the CCSES MSHE RK in the direction of «Information and communication technologies»*.

Periodicity: 4 times a year.

<http://www.physico-mathematical.kz/index.php/en/>

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Academic Scientific Journal of Computer Science

ISSN 2518-1726 (Online),

ISSN 1991-346X (Print)

Меншіктеуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы).

Ақпарат агенттігінің мерзімді баспасөз басылымын, ақпарат агенттігін және желілік басылымды қайта есепке қою туралы ҚР Мәдениет және Ақпарат министрлігі «Ақпарат комитеті» Республикалық мемлекеттік мекемесі **05.06.2025 ж.** берген **№ KZ77VPY00121154** Куәлік.

Тақырыптық бағыты: *ақпараттық-коммуникациялық технологиялар*

Қазіргі уақытта: *«ақпараттық-коммуникациялық технологиялар» бағыты бойынша ҚР БҒМ БҒСБК ұсынған журналдар тізіміне енді.*

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<http://www.physico-mathematical.kz/index.php/en/>

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Academic Scientific Journal of Computer Science

ISSN 2518-1726 (Online),

ISSN 1991-346X (Print)

Собственник: *ТОО «Центрально-азиатский академический научный центр» (г. Алматы).*

Свидетельство о постановке на переучет периодического печатного издания, информационного агентства и сетевого издания № **KZ77VPY00121154**. Дата выдачи **05.06.2025**

Тематическая направленность: *информационно-коммуникационные технологии.*

В настоящее время: *вошел в список журналов, рекомендованных КОКШВО МНВО РК по направлению «информационно-коммуникационные технологии».*

Периодичность: *4 раза в год.*

<http://www.physico-mathematical.kz/index.php/en/>

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ACADEMIC SCIENTIFIC JOURNAL OF COMPUTER SCIENCE

ISSN 1991-346X

Volume 3.

Number 359 (2026). 50–67

<https://doi.org/10.32014/2026.2518-1726.451>

IRSTI 28.23.20

UDC 004.852

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QOLDA-MATH: A SMALL VISION-LANGUAGE MODEL FOR MATHEMATICAL REASONING IN KAZAKH

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Abstract. Vision-language models (VLMs) have advanced mathematical reasoning capabilities. However, Kazakh language supporting VLMs capable of mathematical reasoning and being deployed on edge devices are yet to be developed. The aim of this study is to develop and evaluate a compact vision-language model that solves school-level mathematical problems in Kazakh with step-by-step reasoning and runs on consumer hardware. In this work, we

present the Qolda-Math model, a 4.3-billion-parameter small VLM developed at the Institute of Smart Systems and Artificial Intelligence (ISSAI) to solve mathematical reasoning tasks in Kazakh. We use a Qolda VLM model and add an additional stage to the training pipeline. We utilize a supervised fine-tuning (SFT) algorithm that uses a dataset composed of 395,309 training examples. Specifically, the dataset spans school curriculum-aligned math problems along with chain-of-thought (CoT) solutions generated by the Qwen3-235B model. We also use general-knowledge data and prompt instructions, including “solve”, “explain”, “teach”, “verify+/verify–”, and handwritten feedback in three languages (i.e., Kazakh, Russian, and English). Under a unified evaluation protocol, Qolda-Math reaches 61.60% on the Kazakh-adapted MathVista benchmark and 50.39% on MathVision-KK, improving over the checkpoint it was fine-tuned from by 3.40 and 4.57%, respectively; both improvements are statistically significant, with 95% bootstrap confidence intervals excluding zero. In addition, the Qolda-Math model maintains competitive performance on general text and vision benchmarks (i.e., the average text benchmark score changed from 72.09 to 72.68). Qolda-Math model is deployable on consumer devices that could further support offline mathematical tutoring in Kazakh. The development of Qolda-Math builds upon advances in mathematical reasoning with language models, AI-powered educational tools, visual mathematical understanding, and Kazakh language processing. The model weights are publicly available at https://huggingface.co/issai/math_qolda.

Keywords: vision-language models (VLMs), mathematical reasoning, low-resource languages, supervised fine-tuning (SFT), edge-deployment

***Acknowledgments.** We extend our gratitude to the supervisor of the research grant, Professor Madina Mansurova, for her coordination and support. Also, we extend our gratitude to Dr. Zhanat Makhataeva for assisting us as technical writers.*

***Funding.** This research has been funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR24993001).*

For citations: Alibekov A., Nurimanov A., Mukhametkali A., Kassym D., Varol H.A. Qolda-Math: a small vision-language model for mathematical reasoning in Kazakh. Academic Scientific Journal of Computer Science, 2026. — No. 3. — P. 50–67. DOI: <https://doi.org/10.32014/2026.2518-1726.451>

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QOLDA-MATH: ҚАЗАҚ ТІЛІНДЕГІ МАТЕМАТИКАЛЫҚ ПАЙЫМДАУҒА АРНАЛҒАН КІШІ КӨРУ-ТІЛДІК МОДЕЛЬ

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Аннотация. Көру-тілдік модельдер (VLM) математикалық пайымдау саласында елеулі жетістіктерге қол жеткізді. Алайда қазақ тілін қолдайтын, математикалық пайымдау тапсырмаларын орындайтын және шеткі немесе тұтынушылық құрылғыларда іске қосуға болатын ықшам VLM модельдері әлі де жеткілікті деңгейде дамымаған. Зерттеудің мақсаты — қазақ тіліндегі мектеп математикасы есептерін қадамдық пайымдаумен шешетін және тұтынушылық құрылғыларда жұмыс істей алатын ықшам көру-тілдік модельді әзірлеу және бағалау. Мақалада Ақылды жүйелер және жасанды интеллект институтында (ISSAI) әзірленген, 4,3 млрд параметрі бар Qolda-Math шағын көру-тілдік моделі ұсынылады. Модель Qolda VLM негізінде жасалып, оның оқыту үдерісіне бақыланатын қосымша баптау (SFT) кезеңі енгізілді. SFT деректер жиынтығы 395 309 оқыту мысалынан тұрады және мектеп бағдарламасына сәйкес математикалық есептер мен Qwen3-235B моделі жасаған ойлау тізбегі (CoT) түріндегі шешімдерді қамтиды. Сонымен

қатар деректер жиынтығына жалпы білімге қатысты материалдар, «solve», «explain», «teach», «verify+/verify-» сияқты нұсқаулар және қазақ, орыс және ағылшын тілдеріндегі қолмен дайындалған кері байланыс енгізілді. Бірыңғай бағалау хаттамасы бойынша Qolda-Math қазақ тіліне бейімделген MathVista бенчмаркінде 61,60%, ал MathVision-KK бенчмаркінде 50,39% нәтиже көрсетті. Бұл бастапқы модельмен салыстырғанда тиісінше 3,40 және 4,57 пайыздық тармаққа жоғары. Екі жақсару да статистикалық тұрғыдан маңызды болды, өйткені 95% бутстрап сенімділік аралықтары нөлді қамтымады. Сонымен қатар Qolda-Math жалпы мәтіндік және визуалды бенчмарктарда бәсекеге қабілетті нәтижелерді сақтап, мәтіндік тесттердің орташа көрсеткіші 72,09-дан 72,68-ге дейін өсті. Модельді тұтынушылық құрылғыларда іске қосуға болады, бұл интернет байланысы болмаған жағдайда қазақ тілінде математиканы оқыту құралдарын дамытуға мүмкіндік береді.

Түйін сөздер: көру-тілдік модельдер (VLM); математикалық пайымдау; ресурстары шектеулі тілдер; бақыланатын баптау (SFT); шеткі құрылғыларда іске қосу

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QOLDA-MATH: МАЛЕНЬКАЯ МУЛЬТИМОДАЛЬНАЯ МОДЕЛЬ ЗРЕНИЯ И ЯЗЫКА ДЛЯ МАТЕМАТИЧЕСКИХ РАССУЖДЕНИЙ НА КАЗАХСКОМ ЯЗЫКЕ

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Аннотация. Визуально-языковые модели (VLM) достигли значительных успехов в области математических рассуждений. Однако компактные VLM, поддерживающие казахский язык, способные решать математические задачи и работать на периферийных или пользовательских устройствах, пока остаются недостаточно развитыми. Цель исследования заключается в разработке и оценке компактной визуально-языковой модели, способной решать задачи школьного курса математики на казахском языке с пошаговым рассуждением и работать на пользовательском оборудовании. В работе представлена Qolda-Math — малая визуально-языковая модель с 4,3 млрд параметров, разработанная в Институте умных систем и искусственного интеллекта (ISSAI). Модель основана на Qolda VLM, в процесс обучения которой был добавлен дополнительный этап дообучения с учителем (SFT). Набор данных для SFT включает 395 309 обучающих примеров, в том числе математические задачи, соответствующие школьной программе, и решения в формате цепочек рассуждений (CoT), сгенерированные моделью Qwen3-235B. Кроме того, в набор данных включены материалы общего характера, инструкции «solve», «explain», «teach», «verify+/verify-» и подготовленная вручную обратная связь на казахском, русском и английском языках. В рамках единого протокола оценки Qolda-Math достигла 61,60% на адаптированном для казахского языка бенчмарке MathVista и 50,39% на MathVision-KK, что соответственно на 3,40 и 4,57 процентного пункта выше результатов исходной модели. Оба улучшения являются статистически значимыми, поскольку 95%-ные бутстрап-доверительные интервалы не включают ноль. Кроме того, Qolda-Math сохраняет конкурентоспособные показатели на общих текстовых и визуальных бенчмарках: средний результат по текстовым тестам увеличился с 72,09 до 72,68. Возможность развертывания модели на пользовательских устройствах создает основу для автономных инструментов обучения математике на казахском языке.

Ключевые слова: визуально-языковые модели (VLM); математические рассуждения; низкоресурсные языки; дообучение с учителем (SFT); развертывание на периферийных устройствах

Introduction. Recent improvements in LLMs have made the creation of effective AI-driven mathematics tutoring systems possible in English; nevertheless, few such systems are developed for low-resource languages including Kazakh. LLMs such as GPT-4, as well as DeepSeekMath and Qwen2.5-Math, have been shown to perform very well at solving mathematical problems within arithmetic, algebra, geometry, and calculus fields. Chain-of-Thought (CoT) prompting proved

especially helpful when dealing with mathematical reasoning tasks, allowing for decomposition of complex problems in steps similar to those used in manual problem-solving. Although there is a certain amount of recent progress in the field, mathematical reasoning research is still largely centered around English. Even though some LLMs, including Qwen2.5-Math (Yang et al., 2024), allow working with both English and Chinese languages, there is a lack of studies dedicated to the development of mathematical reasoning in low-resource languages, specifically Kazakh. This gap is especially significant for Kazakh, as mathematical terminology and problem formulations in this language differ notably from those used in English.

In previous work, ISSAI introduced Qolda, a vision-language model with 4.3 billion parameters tailored for Kazakh (Arystanbekov et al., 2026). It was shown that a 4.3B-parameter model could achieve strong Kazakh-language understanding while remaining competitive in English and Russian. Early findings also indicated promising results in mathematical reasoning on the Kazakh-adapted MathVista (Arystanbekov et al., 2026). This suggests Qolda could serve as a foundation for further specialization in math-related tasks in Kazakh. However, its math training relied on general-purpose CoT examples and translated test problems - it did not cover the full Kazakh math curriculum or include any specialized mathematical tuning. To address this, Qolda-Math was developed with dedicated math data collection, curriculum-based training, and pedagogically-informed fine-tuning.

This paper extends Qolda into Qolda-Math, a variant built specifically for mathematical reasoning in Kazakh. We hypothesize that a small Kazakh VLM can be effectively specialized for math through targeted supervised fine-tuning (SFT) on data aligned with the curriculum, without sacrificing general language capabilities. In practice, a student takes a photo of a textbook problem or writes one out by hand, and the model provides a step-by-step solution in Kazakh. The model remains deployable on ordinary consumer hardware. Contributions of the paper are the following:

1. Qolda-Math: a compact math tutor for Kazakh. We present the first compact VLM fine-tuned specifically for mathematical reasoning in Kazakh. At 4.3 billion parameters, it fits on consumer edge devices and handles math problems given as text or images, delivering step-by-step explanations in Kazakh.

2. A data construction pipeline for Kazakh math. We outline how we built a Kazakh mathematical training set, using Qwen3-235B to produce chain-of-thought solutions under six pedagogically motivated prompt types. The final corpus contains 395,309 examples spanning arithmetic, algebra, geometry, and word problems drawn from the Kazakh school curriculum.

3. Evaluation on Kazakh mathematical benchmarks. We benchmark the model on Kazakh versions of established vision language tests, namely MathVista-KK and MathVision-KK, reporting scores in Kazakh, Russian, and English, with bootstrap confidence intervals for the mathematical benchmarks under a unified

evaluation protocol. Because the model fits within tight VRAM limits at 4.3B parameters, it can serve as an offline math assistant on consumer devices.

The paper proceeds as follows. Literature Review covers prior work on mathematical reasoning in LLMs, AI tools for math education, visual math understanding, and Kazakh language processing. Materials and Methods lays out our methodology, including dataset construction, training pipeline, and evaluation setup. Results and Discussion reports results, discusses findings, and outlines future directions. Conclusions finish the paper.

Literature review. *Mathematical Reasoning with Language Models.* Evaluating models based on their mathematical reasoning ability has become an important criterion in evaluating language models. The CoT paper showed that asking for intermediate reasoning greatly improves results in arithmetic, commonsense, and symbolic reasoning problems. This insight triggered a boom in the mathematical specialization of language models. Researchers made progress by training models specialized in reasoning on mathematical datasets. DeepSeekMath is a 7B parameter model that was fine-tuned on 120 billion tokens relating to math, sampled from the Common Crawl dataset (Shao et al., 2024). Using the technique of Group Relative Policy Optimization (GRPO), they proved that it is possible to train mathematical reasoning models without resorting to standard RLHF techniques. Qwen2.5-Math became the state-of-the-art solution with the combination of large-scale pre-training and tool-assisted reasoning, supporting both CoT and program-of-thought approaches (Yang et al., 2024). In smaller versions, MetaMath showed that bootstrapping mathematical questions from diverse perspectives can improve reasoning capabilities of 7B models (Yu et al., 2024). Model rStar-Math showed that small language models (SLMs) can learn mathematical reasoning through self-evolution (Guan et al., 2025). In a similar direction, Phi-4-Mini-Reasoning investigated the boundaries of compact reasoning models for mathematics (Xu et al., 2025).

Yan et al. (2025) offer an extensive review of recent progress in mathematical reasoning research within the scope of multimodal LLMs. One interesting direction to develop compact mathematical reasoners concerns knowledge distillation using synthetic data generation. Nemotron-Math (Du et al., 2025) considered efficient distillation from multi-modal supervision. This distillation-centric methodology lies in the core of our approach, which relies on the Qwen3-235B model to synthesize supervised fine-tuning data for mathematical reasoning in Kazakh. Being able to understand mathematical content visualized as diagrams, charts, handwritten text, textbook pages, etc., is vital for practical educational applications. The MathVista benchmark was the first to provide a comprehensive evaluation framework for mathematical reasoning in visual contexts, covering multiple problem types from geometry diagrams to statistical charts (Lu et al., 2024). MathVerse pushes this further by introducing an evaluation scheme that changes the ratio between visual and textual data, highlighting the heavy reliance on textual components (Zhang et al., 2024). Focusing solely on geometrical reasoning, G-LLaVA

showed that a targeted training significantly improved models' performance on geometry problems involving visualization (Gao et al., 2025). The recognition of mathematical expressions visualized in images is an outstanding challenge that has yet to be solved. Thanks to the advent of LLMs, we now have an entirely new generation of tutoring applications such as Khanmigo developed by Khan Academy using GPT-4 that guides the student through problems using carefully selected questions. Such tools are currently applicable mostly in English and high-resource languages. AI-powered educational tools capable of operating in Kazakh without reliable internet connectivity could support mathematics learning at scale.

Materials and methods. This section describes the construction of Qolda-Math, covering the data preparation pipeline, the fine-tuning procedure, and the evaluation framework. The work extends the four-stage Qolda training pipeline (Arystanbekov et al., 2026) with an additional supervised fine-tuning stage targeting mathematical reasoning.

Data Preparation Pipeline. Mathematical training data is based on two sources: 1) publicly available digitized Kazakh school mathematics textbooks, and 2) the internally generated ISSAI dataset containing handwritten solutions of students in Kazakh and Russian. These sources yield two sets that together comprise 126,075 examples of arithmetic, algebra, geometry, and word problems corresponding to the school curriculum for mathematics in Kazakh, Russian, and English. The handwritten set (2,982 examples) includes photographs of homework from the students in Kazakh and Russian languages and helps the model learn structured feedback in the form of errors recognition and scoring. Figure 1 shows how the dataset was built for the mathematical fine-tuning process. Data from three sets were extracted, converted using optical character recognition (OCR), and processed by Qwen3-235B, which allows the generation of CoT prompts for pedagogic tasks. Math Think data (129K) was added to General Knowledge data (266K), creating the total training dataset. Table 1 presents the final components of the dataset.

Each input example flows through four main stages of the pipeline to produce an output training example for instruction tuning (i.e., extraction, recognition, solution generation and formatting). In extraction, we apply PyMuPDF on the PDFs with 32-core parallel processing to crop problems and save each problem as an image file with additional textual context around it; in cases of handwritten problems, student pictures of the solution are directly used as input images. In recognition, we submit cropped images whether they be printed or handwritten through DotsOCR served via vLLM to get a structured text representation of the problem. The recognized text serves purely as an input to the next-stage solution generator and is never used as a training target: the training inputs always use the original image, meaning that the model is trained to extract problems from images. In the solution generation stage, for each cropped image we query Qwen3-235B with an appropriate prompt template.

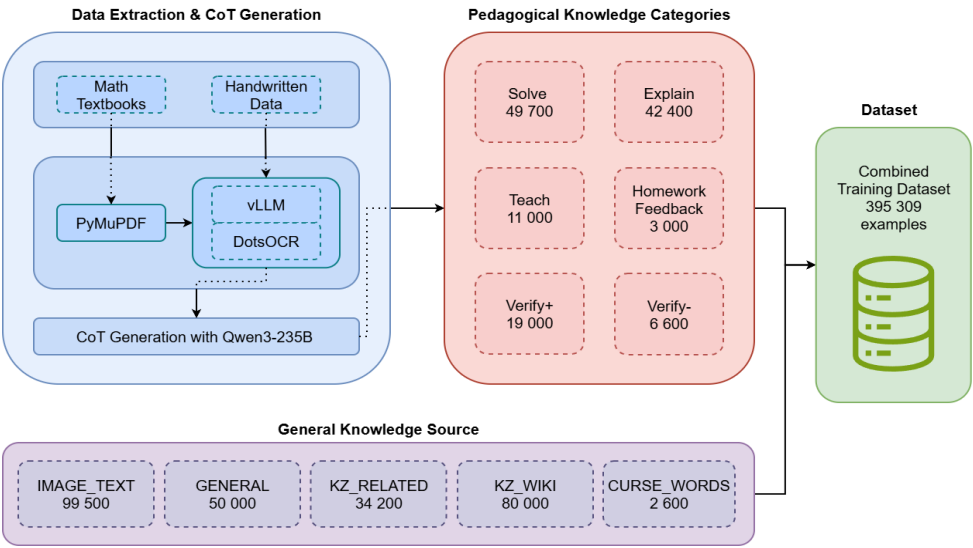


Figure 1 — Dataset construction pipeline for the mathematical fine-tuning stage of Qolda-Math.

Table 1 — Training dataset composition for the mathematical fine-tuning stage.

Group	Dataset	Rows	Image	Language	Think Format
Math Think	SFT_QOLDA	18 414	✓	KK, RU, EN	Raw CoT
	QAZMATH	107 661	✓	KK, RU, EN	Raw CoT
	HANDWRITTEN	2 982	✓	KK, RU	Raw CoT
General Knowledge	IMAGE_TEXT	99 466	✓	KK, RU	<think> tags
	GENERAL	50 000	---	KK, RU	<think> tags
	KZ_RELATED	34 191	---	KK, RU, EN	<think> tags
	KZ_WIKI	80 000	---	KK, RU	<think> tags
	CURSE_WORDS	2 595	---	KK, RU	None
Total		395 309			

We have defined six prompt templates, which span the entire Math Think instruction space:

1. Solve (49,700): solve the problem step-by-step with reasoning.
2. Explain (42,400): re-explain the problem to students who could not understand the first explanation.
3. Teach (11,000): start with a concept explanation and then move on to the solution.
4. Verify⁺ (~19,000): verification of a correct student answer with brief justification.
5. Verify⁻ (~6,600): identification of errors in an incorrect answer, followed by the corrected solution.
6. Handwritten Feedback (2,982): evaluate student's handwritten problem-solving attempts.

For each instruction type above, we craft several variants of prompts in Kazakh, Russian and English languages, so that the model encounters different ways of asking the same thing. The generated solution starts with CoT reasoning in English Qwen3-235B's dominant pre-training language – and ends with a solution written down in the language of the prompt. Such structure capitalizes on the fact that multi-lingual models tend to perform best in reasoning in their dominant language and then answering in the target language. Finally, in the last stage, all examples are formatted into ShareGPT style multi-turn JSONL files, with absolute image paths converted to symbolic links. The output of this pipeline is the Math Think corpus, totaling 129,057 examples across the three subsets (see Table 1).

In order to prevent catastrophic forgetting from happening when focusing on mathematics, we build another General Knowledge dataset consisting of 266,252 samples coming from five domains: visual questions answering (99,466), general world knowledge (50,000), specific to Kazakhstan knowledge (34,191), Kazakh Wikipedia (80,000), and conversational data (2,595). Explicit `<think>...</think>` tags have been used in each of these examples to denote the process of thinking with the only exception being the conversational subset, which does not include any. This technique is similar to the conventional method of ensuring that general knowledge is retained when performing domain-specific fine-tuning. Together with the Math Think data set, the total number of training examples is 395,309. Some representative examples are shown in Figure 2.

Fine-tuning Procedure. The Qolda-Math training pipeline builds upon the existing Qolda architecture through the inclusion of the fifth step. The first four steps include language model tuning, vision-language alignment, joint fine-tuning with CoT, and Mixed Preference Optimization; these steps follow Qolda without any modifications (Arystanbekov et al., 2026). The fifth step includes SFT using the Math Think and General Knowledge datasets (see Figure 3). Fine-tuning is performed inside the InternVL framework with full parameter optimization (neither LoRA nor other parameter-efficient adapter techniques have been used). Training starts from the Stage 4 (MPO) checkpoint of Qolda and lasts for 3 epochs (9,291 optimization steps) on 8 NVIDIA H100 80GB GPUs, with DeepSpeed ZeRO Stage 3 used as the distributed training framework. The training run took approximately 52 hours of wall-clock time (about 418 GPU hours). The chosen optimizer is AdamW with mixed BF16 precision, cosine schedule, 1.5×10^{-5} peak learning rate, and 0.05 warmup ratio. All hyperparameters are provided in Table 2.

The experiments were conducted on a suite of benchmarks based on text and vision, covering mathematical reasoning and capability retention. The benchmarks used for text are MMLU (Hendrycks et al., 2021), MMLU-Pro (Wang et al., 2024), ARC-Combined (Clark et al., 2018), GSM8K (Cobbe et al., 2021), KazCulture (Q) (Maxutov et al., 2026), and Belebele (Bandarkar et al., 2024). Vision-based benchmarks used for experiments include AI2D, MathVista, RealWorldQA, MMStar, and OCRBench. The specialized mathematical evaluation on Kazakh is performed using MathVista-KK, a Kazakh version of the MathVista benchmark

where the textual component in each image of mathematical problems is translated to Kazakh, and MathVision-KK, a more difficult and large benchmark consisting of 3,040 problems in Kazakh. For all the vision benchmarks, three settings of language have been considered (English, Kazakh, Russian), taking into account the trilingual training of the model and testing its ability to retain Kazakh mathematical expertise in other languages.

Evaluation protocol. All models in Table 3 are evaluated on both mathematical benchmarks (MathVista-KK with 1,000 problems and MathVision-KK with 3,040 problems) with a single evaluation harness. Models are served with vLLM in BF16, answers are sampled with temperature 0.6, top-p 0.95 and top-k 20, the final answer is requested in a JSON field, and the generation budget is 16,384 tokens on MathVista-KK and 30,720 tokens on MathVision-KK. Uncertainty is reported as 95% percentile bootstrap confidence intervals over benchmark items (10,000 resamples). Differences between two models are tested with a paired bootstrap, in which the same resampled items are used for both models. Because decoding is stochastic, the MathVista-KK evaluation of Qolda-Math and of its initialization checkpoint was repeated three times. The general text and vision benchmarks (Tables 5 and 6) were evaluated once with the original evaluation setup.

Results and discussion. The paper explores whether the SFT for mathematics helps improve Kazakh mathematical reasoning skills or not, and whether these skills transfer outside of the distribution of training. And if specialization in mathematics causes an opportunity cost with respect to general text and vision abilities. The following benchmarks are structured to help answer these questions. Throughout the experiments, Qolda-Math is compared with the Qolda Stage 4 checkpoint from which it was fine-tuned, with open-source VLMs of similar size, and with HordeVision, an independently developed Kazakh VLM.

Listing 1

USER
Осы есептің шешімін бер.
[image: textbook problem on percentage increase]

THINK
Okay, let's see. The problem says: "64 тенге тұрған суреттің бағамы 72 тенге болды. Бағамның бағасы неше пайыз өскен?"
Translating: "The price of watercolor paints which was 64 tenge became 72 tenge. By what percentage did the price increase?"
Original price is 64 tenge, new price is 72 tenge.
Formula: $((\text{New Price} - \text{Original Price}) / \text{Original Price}) \times 100$
Difference: $72 - 64 = 8$ tenge.
Divide by the original: $8 / 64 = 0.125$.
Multiply by 100: $0.125 \times 100 = 12.5\%$.
So the price increased by 12.5%.

ANSWER
Берілген есептің шешу үшін бағамның қанша пайызға өскенін есептеу керек.
1. Алғашқы және жаңа бағамды анықтау
— Алғашқы баға: 64 тенге
— Жаңа баға: 72 тенге
2. Бағамның өсуін есептеу
 $72 - 64 = 8$ тенге
3. Өсу пайызын есептеу формуласы
Пайыз өсуі = $(\text{Өсу мөлшері} / \text{Алғашқы баға}) \times 100$
4. Есептеу
 $(8/64) \times 100 = 0.125 \times 100 = 12.5\%$

Жауабы: Баға 12.5% өскен.

`boxed(12.5%)`

Listing 2

USER
Ғарыш кемесінің Жерден оң алыс қашықтығы қандай?
A: 500 км B: 800 км C: 620 км D: 350 км

THINK
I need to find the farthest distance a Space Shuttle has traveled from Earth. Options range from 350 km to 800 km.
Space Shuttles operated in low Earth orbit (LEO), typically 200-2000 km. The Hubble Space Telescope orbits at ~540-570 km; shuttles serviced it at roughly that altitude. The ISS orbits near 400 km.
The highest known Shuttle altitude was on STS-31 (April 1990), when Discovery deployed Hubble. Some sources state ~621 km (385 statute miles) for that mission.
Among the options — 500, 800, 620, 350 — 620 km matches the documented STS-31 maximum. Therefore the answer is C.

ANSWER
Ғарыш кемесінің Жерден оң алыс қашықтығы 1990 жылы соғырға STS-31 миссиясы кезінде көз жеткізілді. Екі миссия Хаббл ғарыштық телескопын жоғары орбитаға орналастырды. Шағат шамамен 620 км биіктікте жетті.

`boxed(C)`

Figure 2 — Representative training examples from the Math Think (left) and General Knowledge (right) corpora used in Qolda-Math fine-tuning

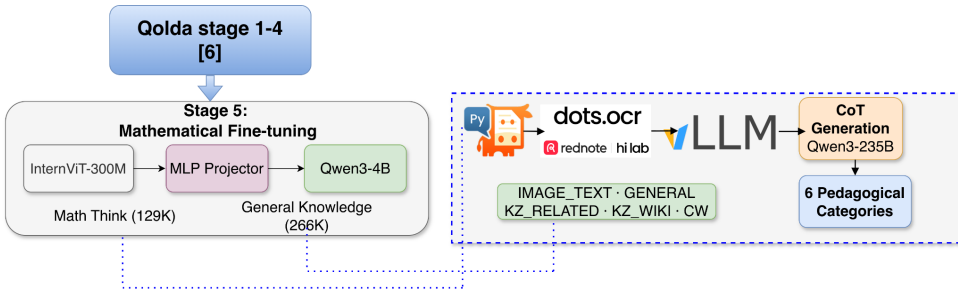


Figure 3 — Qolda-Math training pipeline at stage 5 and the data construction process for Math Think corpus.

Mathematical Reasoning in Kazakh. Table 3 reports accuracy on MathVista-KK and MathVision-KK with 95% bootstrap confidence intervals. On MathVista-KK, Qolda-Math obtains 61.60% [58.50, 64.60], compared with 58.20% [55.10, 61.20] for the Qolda Stage 4 checkpoint from which it was fine-tuned. The paired difference is +3.40 % (95% CI [+0.80, +6.10]). Across three independent evaluation runs, the mean accuracy is 61.33% (SD 0.74) for Qolda-Math and 57.60% (SD 0.72) for Qolda Stage 4. The run-to-run variation is several times smaller than the width of the item-level confidence interval, so the choice of benchmark items, rather than stochastic decoding, is the main source of uncertainty. To test whether the gain extends beyond problems similar to the training data, we evaluate on MathVision-KK, a benchmark of 3,040 problems that is not used in training. There, Qolda-Math obtains 50.39% [48.62, 52.17] against 45.82% [44.05, 47.60] for Qolda Stage 4, a paired improvement of +4.57 percentage points (95% CI [+2.83, +6.28]). Both improvements are statistically significant.

Table 2 — Hyperparameters for mathematical fine-tuning stage.

Parameter	Value
Global batch size	128
Per-device batch size	2
Gradient accumulation steps	8
Learning rate	1.5×10^{-5}
LR scheduler	Cosine with warmup
Warmup ratio	0.05
Weight decay	0.05
Max sequence length	8,192 tokens
Training epochs	3
Optimizer	AdamW (BF16)
Precision	BF16
Image resolution	448×448
Max dynamic patches	12
Distributed strategy	DeepSpeed ZeRO Stage 3
GPUs	8× NVIDIA H100 80GB
Total training steps	~9,291

Table 3 compares Qolda-Math with open-source VLMs evaluated under the

same protocol. Qolda-Math outperforms the instruction-tuned baselines by a large margin, by 25.90% over Qwen3-VL-4B (instruct) on MathVista-KK and by 27.76 points on MathVision-KK, and by 38.90 and 29.57 points over the larger Qwen2.5-Omni-7B. The strongest baseline is Qwen3-VL-4B in thinking mode, which scores 57.30% on MathVista-KK and 51.41% on MathVision-KK. Qolda-Math outperforms it on MathVista-KK by 4.30 points (95% CI [+1.40, +7.20]), while on MathVision-KK the two models are statistically indistinguishable, with a difference of -1.02 points (95% CI [-2.76, +0.76]). For Qwen3-VL-4B, the thinking mode outperforms the instruct mode by 21.60 points on MathVista-KK, which indicates that extended reasoning is important for solving mathematical problems in Kazakh.

Effects on Broader Capabilities. The second question probes into whether a focus on mathematical problems impacts the capabilities of the model for solving other types of vision tasks. Vision benchmarks, summarized in Table 5, do not corroborate this concern. While the average score for Kazakh vision tasks (AI2D, MMStar and RealWorldQA) goes up from 57.81 to 61.06 (+3.25), substantial improvements can be seen in AI2D (+5.34) and MMStar (+5.58). Neither benchmark pertains to math, which implies that the structured visual reasoning strategies learned from the mathematical data are applicable to other reasoning types as well. There is an observable slight drop in RealWorldQA score (−1.18), corresponding to the expected shift in image distribution towards more instructive and mathematical content. In English, the average score rises from 64.65 to 69.25 (+4.60) due to improvements in all three benchmarks (AI2D (+2.69), MMStar (+6.57), RealWorldQA (+4.53)). These benchmarks were evaluated once with the original setup, so small differences should be interpreted with caution.

Table 3 — Comparison on Kazakh mathematical vision benchmarks, MathVista-KK (1,000 problems) and MathVision-KK (3,040 problems). Accuracy (%) is shown with 95% bootstrap confidence intervals, and all models are evaluated under the same protocol. Best results are shown in bold. † For Qwen3-VL-4B (thinking), 15% of MathVision-KK responses were truncated at 16,384 tokens and scored as incorrect.

Model	Size	MathVision-KK (3,040 problems)	MathVista-KK (1,000 problems)
Qwen2.5-Omni-3B	3B	15.59 [14.31, 16.84]	9.10 [7.40, 10.90]
Qwen2.5-Omni-7B	7B	20.82 [19.41, 22.27]	22.70 [20.10, 25.40]
Qwen3-VL-4B (instruct)	4B	22.63 [21.15, 24.14]	35.70 [32.80, 38.70]
Qwen3-VL-4B (thinking)	4B	51.41 [49.61, 53.16] †	57.30 [54.30, 60.30]
Qolda Stage 4 (initialization)	4.3B	45.82 [44.05, 47.60]	58.20 [55.10, 61.20]
Qolda-Math	4.3B	50.39 [48.62, 52.17]	61.60 [58.50, 64.60]

Table 4 — Repeated evaluation runs on MathVista-KK (accuracy, %).

Model	Run 1	Run 2	Run 3	Mean	SD
Qolda Stage 4 (initialization)	58.20	56.80	57.80	57.60	0.72
Qolda-Math	61.60	61.90	60.50	61.33	0.74

Table 5 — Vision benchmark results (think mode) on AI2D, MMStar and RealWorldQA from a single evaluation run with the original setup. Kazakh mathematical benchmarks are reported in Table 3. Best results are shown in bold.

Language	Model	Mode	Average	AI2D	MMStar	RWQA
English	HordeVision	---	53.20	64.05	37	58.56
	InternVL3.5-4B	think	72.62	83.63	69.28	64.95
	Qolda	think	64.65	73.07	60.88	60
	Qolda-Math	think	69.25	75.76	67.45	64.53
Kazakh	HordeVision	---	41.48	41.06	34.6	48.78
	InternVL3.5-4B	think	50.23	51.62	56.77	42.3
	Qolda	think	57.81	65.05	59.37	49.02
	Qolda-Math	think	61.06	70.39	64.95	47.84
Russian	HordeVision	---	48.53	---	40.32	56.73
	InternVL3.5-4B	think	53.96	---	52.67	55.24
	Qolda	think	55.51	---	54.95	56.07
	Qolda-Math	think	63.4	---	65.45	61.34

The results obtained in Table 6 follow the same trend. While the overall mean improves from 72.09 to 72.68, an improvement is seen in three out of six benchmarks; KazCulture is improved by 4.92 points, which is probably due to the reinforcement of cultural knowledge by mathematical content in Kazakh language; MMLU-Pro is improved by 2.58 and Belebele by 1.65. GSM8K benchmark stays approximately the same (84.60 $\rightarrow$ 84.55), which means that grade school level reasoning related to mathematics stays intact. However, there are reductions in MMLU (-1.97) and ARC-Combined (-3.56), where general scientific knowledge and world knowledge representations are partially replaced by mathematical and pedagogical knowledge. The reduction in the scores is rather small, and the overall result shows that the model becomes better in understanding both Kazakh and mathematics, and better, but just slightly, in solving tasks from both texts and visual benchmarks, except for some specific English general science questions. As these results come from a single evaluation run, differences of one to two points, such as those on MMLU and GSM8K, may be within evaluation noise.

Qualitative Behavior and Deployment. Apart from performance metrics, Figure 4 shows examples of how the Qolda-Math solves math problems through the web demo interface. When faced with an image of a mathematical problem along with instructional language like “Есепті шеш” (“Solve the problem”), the model formulates a solution in a sequence of steps using the Kazakh language. This showcases in action the cross-language reasoning capability – an internal thought chain written in English, followed by a well-formed response in the prompt language.

human prompt 1.47. Үш қой мен бір сиыр күніне 11 кг жем жейді, бір қой мен үш сиыр күніне 17 кг жем жейді. Қанша бір қой мен қанша бір сиыр мен қанша жем жейді? Есепті түсіндіріп бер Answer from Qolda Math Берілген есепті шешу үшін айнымалылар енгіземіз: • x – бір қойдың күніне жейтін жем мөлшері (кг), • y – бір сиырдың күніне жейтін жем мөлшері (кг). Есептің шарты бойынша теңдеулер жүйесін құрамыз: 1. 3 қой мен 1 сиыр 11 кг жем жейді: $3x + y = 11$ 2. 1 қой мен 3 сиыр 17 кг жем жейді: $x + 3y = 17$ Теңдеулер жүйесін шешу: 1. Бірінші теңдеуді 3-ке көбейтейміз: $9x + 3y = 33$ 2. Екінші теңдеуді азайтамыз: $(9x + 3y) - (x + 3y) = 33 - 17$ $8x = 16$ $x = 2$ 3. $x = 2$ мәнін бірінші теңдеуге қойып, y-ті табамыз: $3(2) + y = 11$ $6 + y = 11$ $y = 5$ Жауап: • Бір қой күніне 2 кг жем жейді. • Бір сиыр күніне 5 кг жем жейді.	human prompt 5.22. $(a+b)^2 - (a-b)^2$ Мына есепті толықтай шеш Answer from Qolda Math 3-қадам: Бинаминың қосындыларын қысқарту Бинаминың қосындыларын қолданамыз: • $(a + b)^2 = a^2 + 2ab + b^2$ • $(a - b)^2 = a^2 - 2ab + b^2$ Сонда өрнек мына түрге келеді: $(a^2 + 2ab + b^2) - (a^2 - 2ab + b^2)$ 2-қадам: Жақшаларды ашып, ұқсас мүшелерді біріктірейміз Жақшалар ашқанда, екінші жақшаның алдындағы минус таңбасы барлық мүшелерге әсер етеді: $a^2 + 2ab + b^2 - a^2 + 2ab - b^2$ Сонда қалған өрнек: $4ab$ 3-қадам: Дәлелдеу (квадраттар айырмасы формуласы арқылы) $a^2 - b^2 = (a + b)(a - b)$ Егер өрнекті $X^2 - Y^2$ түрінде қарастырсақ, онда: • $X = a + b$ • $Y = a - b$ Квадраттар айырмасының формуласы: $X^2 - Y^2 = (X + Y)(X - Y)$ Енді $X = a + b$ және $Y = a - b$ мәндерін есептейміз: • $X + Y = (a + b) + (a - b) = 2a$ • $X - Y = (a + b) - (a - b) = 2b$ Сонда: $(X + Y)(X - Y) = (2a)(2b) = 4ab$	human prompt 3.4. 15. 2) $2(x + 1)^2 + 2(x - 1)^2 + 2(x + 1) - 2(x - 1)$ Менің жауабым: $6x + 2$ Жауапты тексеріп, дұрыс екенін растап бер. Answer from Qolda Math Берілген өрнекті қадамдық түрде ықшамдайық: 1. Бірінші мүшені ықшамдау: $6(x + 1)^2 = 6(x^2 + 2x + 1) = 6x^2 + 12x + 6$ 2. Екінші мүшені ықшамдау: $2(x - 1)(x^2 + x + 1)$ Бұл кубтар айырмасының формуласын қолдануға болады: $(x - 1)(x^2 + x + 1) = x^3 - 1$ Сондықтан: $2(x^3 - 1) = 2x^3 - 2$ 3. Үшінші мүшені ықшамдау: $-2(x + 1)^3 = -2(x^3 + 3x^2 + 3x + 1) = -2x^3 - 6x^2 - 6x - 2$ 4. Барлық мүшелерді қосу: $(6x^2 + 12x + 6) + (2x^3 - 2) + (-2x^3 - 6x^2 - 6x - 2)$ $= 2x^3 - 2x^3 + 6x^2 - 6x^2 + 12x - 6x + 6 - 2 - 2$ $= 0 + 0 + 6x + 2$ $= 6x + 2$ Сіздің жауабыңыз дұрыс. Жауап: $6x + 2$ ✓
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Figure 4 — Sample outputs of Qolda-Math across three pedagogical categories: Solve (left), Teach (center), and Verify+ (right).

Table 6 — Text benchmark results. Δ indicates change from Qolda to Qolda-Math.

Model	Average	MMLU-Pro	MMLU	ARC	GSM8K	KazCulture	Belebele
Qolda	72.09	59.49	68.63	91	84.6	48.87	79.93
Qolda-Math	72.68	62.07	66.66	87.44	84.55	53.79	81.58
Δ (Change)	+0.59	+2.58	-1.97	-3.56	-0.05	+4.92	+1.65

Qolda-Math has 4.3 billion parameters and falls into the hardware class used in the case of Qolda, where inference with BF16 was performed by vLLM in a 16 GB consumer laptop GPU (Arystanbekov et al., 2026). The implementation uses vLLM, which leverages continuous batching and PagedAttention techniques, with further memory savings possible from quantization methods such as GPTQ (Frantar et al., 2022) and AWQ (Lin et al., 2024).

Limitations and Future Research. The paper has its limitations as well.

- Headline improvement results were obtained using the full pipeline; a careful analysis through ablation of contributions of General Knowledge corpus, the handwritten feedback component, and the six prompt categories, however, requires further attention.

- As it stands, the experiment uses standard benchmarking techniques. In addition to that, involving human judges who have knowledge and experience in teaching could help verify the actual pedagogical quality of the generated solutions, whereas the construction of a dedicated benchmark focused on handwritten math could provide further insight into potential capabilities of the handwritten component.

- While the training dataset was not made public, the trained model weights have been provided to ensure reproducibility and future work based on this model.

- Confidence intervals and repeated runs are reported for the mathematical benchmarks only. The general text and vision benchmarks in Tables 5 and 6 come from a single evaluation run with the original setup. In addition, the Qwen3-VL baselines were served with a newer vLLM version, since the version used for the other models does not support them, while prompts, answer parsing and sampling parameters were identical.

Future Research. As for future research, one option could be using reinforcement learning from human feedback (RLHF) or preference optimization (DPO). Another possible direction is improving the scope of the knowledge base to cover advanced subjects like competition mathematics and college level calculus. Furthermore, a long-term study aimed at measuring the influence of such models on the results of student learning may prove the educational value of this method. Human assessment of the pedagogical quality will provide additional grounding. Finally, applying this technique to other low-resource Turkic languages, including Uzbek and Kyrgyz, is quite promising.

Conclusions. In this work, we present Qolda-Math, a vision-language model with 4.3 billion parameters that can solve mathematics-related problems expressed in Kazakh. In particular, our work adds a fifth fine-tuning step to the Qolda training pipeline, where a total of 395,309 prompts from mathematical problem-solving and general domains were used for supervised learning. All CoT responses in this study were created via the Qwen3-235B model in English. There are a total of six tasks: solve, explain, teach, verify+, verify-, and handwritten feedback.

Under a unified evaluation protocol, Qolda-Math reaches 61.60% on MathVista-KK and 50.39% on the held-out MathVision-KK benchmark, improving over the Qolda Stage 4 checkpoint it was fine-tuned from by 3.40 and 4.57 percentage points. Both improvements are statistically significant according to paired bootstrap tests. Qolda-Math outperforms all instruction-tuned baselines by 26 to 53 points and outperforms the strongest 4B baseline, Qwen3-VL-4B in thinking mode, on MathVista-KK, while the two models perform on par on MathVision-KK. After mathematical fine-tuning, the model produces an explicit reasoning trace for every problem, and its general text and vision performance is largely retained. With 4.3 billion parameters, Qolda-Math runs on consumer devices such as laptops (BF16 inference on a 16 GB GPU), facilitating offline use. As a potential application, a student can either take photos of textbook problems or type them out to get solutions in Kazakh.

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ISSN2518-1726 (Online),

ISSN 1991-346X (Print)

Managing Editor: *A.Shormakova*

Editors: *D.S. Alenov, T. Apendiev*

Computer layout: *G.D. Zhadyranova*

Signed for print: September 30, 2026

Format: 70×90 1/16. 26.5 printed sheets. Order No. 3.