From Chat Logs to Collective Insights: Aggregative Question Answering

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Abstract

Conversational agents powered by large language models (LLMs) are rapidly becoming integral to our daily interactions, generating unprecedented amounts of conversational data. Such datasets offer a powerful lens into societal interests, trending topics, and collective concerns. Yet, existing approaches typically treat these interactions as independent and miss critical insights that could emerge from aggregating and reasoning across large-scale conversation logs. In this paper, we introduce Aggregative Question Answering, a novel task requiring models to reason over thousands of user-chatbot interactions to answer aggregative queries, such as identifying emerging concerns among specific demographics. To enable research in this direction, we constructed WildChat-AQA, a benchmark comprising 6,027 aggregative questions derived from 182,330 real-world chatbot conversations. Experiments show that existing methods either struggle to reason effectively or incur prohibitive computational costs, underscoring the need for new approaches capable of extracting collective insights from large-scale conversational data.

1 Introduction

Rapid adoption of conversation agents powered by large language models (LLMs) is transforming human-computer interactions, integrating deeply into society, and generating unprecedented volumes of conversational data (Backlinko Team, 2025; Vynck, 2023). Platforms using LLM-based chatbots now routinely handle millions of interactions every day, producing rich datasets that capture real-time dialogues reflecting user interests, emerging societal trends, and collective concerns (Zhao et al., 2024b; Zheng et al., 2024). Such conversational data offer immense potential for deriving insights at scale, revealing patterns in societal dynamics, shifts in public sentiment, and demographic-specific concerns (Valdez et al., 2020).

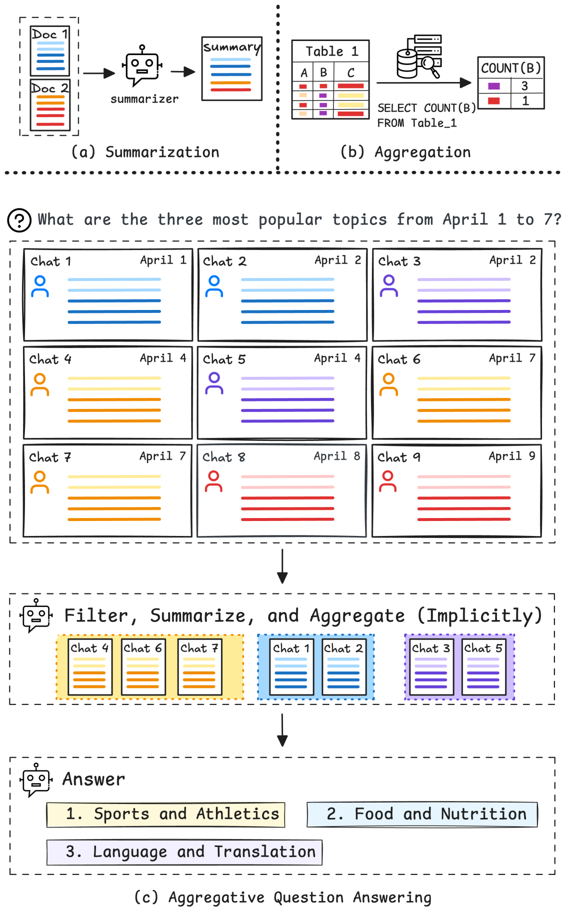

Figure 1: Comparison of different aggregation paradigms: (a) summarization, (b) aggregation over structured databases, and (c) aggregation over large sets of conversations (our focus).

Despite the inherent richness of these conversational datasets, current research typically treats interactions as isolated, independent data points, primarily using them to finetune LLMs for generating improved individual responses (The Vicuna Team, 2023; Lambert et al., 2025; Zhang et al., 2025). This independent and identically distributed (i.i.d.) assumption overlooks important temporal patterns and thematic connections that naturally arise from large-scale, real-world user-chatbot con-

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versations. Conversations do not occur in isolation, but rather within specific temporal, geographical, and device-related contexts (Tamkin et al., 2024). These contextual features carry significant potential for deriving collective insights, such as understanding regional differences in user concerns or identifying temporal shifts in societal attitudes—insights which are lost under the simplifying i.i.d. assumption.

To address this gap, we introduce a new task, Aggregative Question Answering, which requires reasoning across large-scale collections of user-chatbot interactions to extract aggregative insights. Unlike traditional summarization, which condenses information from one or a few documents into static summaries, Aggregative Question Answering generates dynamic answers that depend on the specific aggregative query posed. The task requires reasoning over thousands of conversations to answer questions such as identifying trending topics within specific timeframes (*"What topics trended last week?"*), emerging concerns among particular demographics (*"What topics are Californians concerned about before an election?"*), or tracking changes in societal sentiment (*"How have users' attitudes toward AI evolved this month?"*). The core challenge thus lies not in summarizing individual conversations, but rather in global-scale reasoning conditioned on the query. Figure 1 highlights the high-level distinctions between traditional summarization, querying structured databases, and aggregative question answering.

To facilitate research into Aggregative Question Answering, we introduce WildChat-AQA, a benchmark constructed from the WildChat dataset (Zhao et al., 2024b; Deng et al., 2024). WildChat captures not only conversation transcripts but also metadata such as temporal, geographical, and user-specific information. WildChat-AQA formulates aggregational queries about both explicit and implicit attributes of conversations, including topics, keywords, geographical locations, and temporal information, in a multi-choice format. A concrete example of the data creation process is shown in Figure 2. The benchmark includes 6,027 aggregative questions derived from 182,330 real-world user-chatbot conversations, reflecting genuine user interests and societal trends, thus providing a resource for evaluating models' ability to perform aggregative reasoning at scale.

We evaluated current methods, including both non-reasoning and reasoning models, adapted to this task via fine-tuning, retrieval-augmented generation (RAG), and a customized retrieval approach developed specifically for aggregative reasoning: PROBE (Probing Retrieval Of Broad Evidence). Experimental results show substantial limitations in existing methods: current systems either struggle to reason effectively at scale or incur prohibitive computational costs. Even when whole oracle contexts relevant to a query are provided, there remains significant room for improvement. In more realistic settings with no access to oracle contexts, the performance drops further.

Our findings show that we need more scalable and effective methods capable of extracting collective insights from large-scale conversational datasets. While Aggregative Question Answering opens promising avenues for real-world analytics, we acknowledge potential societal impacts, particularly when insights relate to sensitive topics such as elections, public opinion, or public health. However, we believe that transparent, open academic research fosters responsible development and deployment of such powerful technologies. By introducing Aggregative Question Answering as a new task, we aim to spur future methods that fully harness the potential of large-scale conversational data, ultimately enabling deeper societal understanding and more impactful applications of LLMs.

Our benchmark, code, and dataset are publicly available at `https://github.com/yuntian-group/wildchat_aggregative_question_answering`, and we also provide a user-friendly benchmark visualization tool at `https://aggregativeqa.com/dataview`.

2 Aggregative Question Answering

To support research on Aggregative Question Answering, we construct the WildChat-AQA benchmark based on the WildChat dataset (Zhao et al., 2024b; Deng et al., 2024). WildChat provides real-world conversations between users and chatbots, along with basic metadata such as timestamps and user locations. In this work, we extend these attributes by introducing additional attributes, such as topics and keywords inferred from the conversation text using LLMs. These inferred attributes serve as the ground truth annotations for building our benchmark. At evaluation time, models must infer them from conversations to answer aggregative questions. Table 1 summarizes the attributes, indicating which require inference and which can

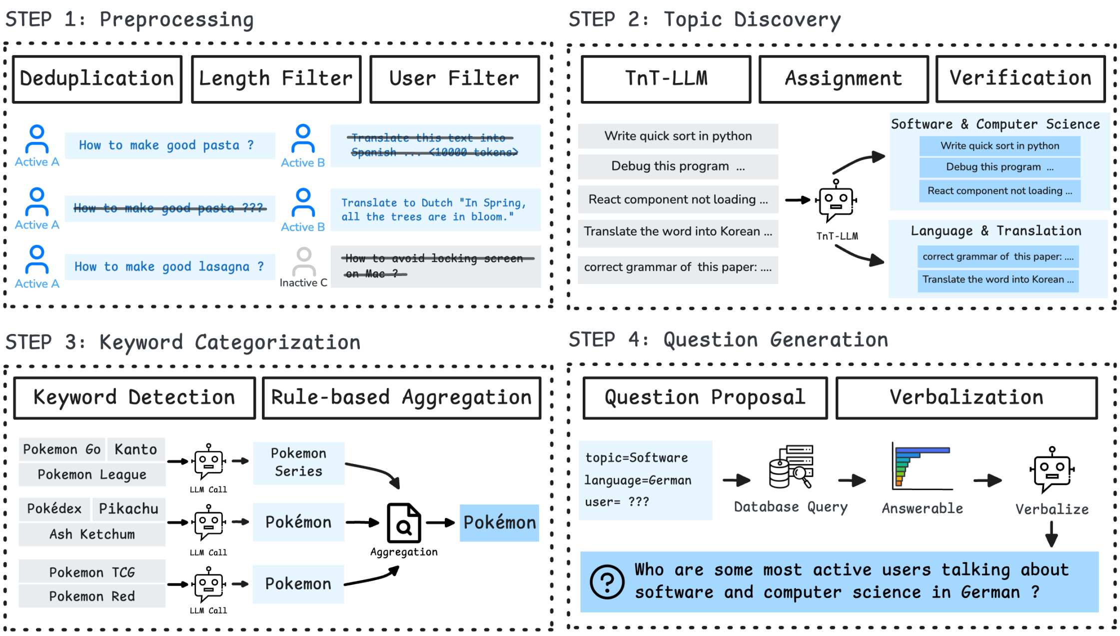

Figure 2: Overview of the WildChat-AQA dataset creation process.

Name	Multi-Val	Inferred	Examples
Location	No	No	United States, Canada
User Name	No	No	lostclasp37, toughcue8
Time	No	No	4/26/2023, 1:47:24 PM
Language	No	No	English, Russian
Topic	Yes	Yes	Software, Programming and Computer Science
Subtopic	Yes	Yes	Mobile Development, AI and ML
Keywords	Yes	Yes	C++, Pokémon

Table 1: Attributes used in WildChat-AQA. **Multi-Val** indicates whether an attribute can have multiple values per conversation. **Inferred** indicates whether the attribute must be inferred from conversation content (as opposed to being directly available from metadata). **Examples** show representative attribute values.

be obtained directly.

2.1 Dataset Construction

The construction of WildChat-AQA involve four main steps, as illustrated in Figure 2:

Step 1: Preprocessing We begin by performing minHash-based deduplication (Hugging Face, 2023) to remove highly similar conversations to ensure diversity. We also filter conversations that exceed 4,096 tokens to maintain manageable context lengths. Additionally, we retain only active users with at least 10 interactions to ensure sufficient user-specific data. We also generate user IDs from IP addresses and headers.

Step 2: Topic Discovery To support meaningful aggregative queries, we prompt GPT-4o to summarize each conversation and extract relevant keywords. Using these summaries, we recursively apply TnT-LLM (Wan et al., 2024) to infer hierarchical topics at two levels: coarse-grained topics and fine-grained subtopics. Detailed prompts and examples can be found in Appendix E.

Step 3: Keyword Categorization Certain subtopics, such as "Programming" and "Fan-fiction and Crossover," contain many conversations. To support finer-grained aggregative queries, we further categorize keywords inferred from conversations into higher-level categories using LLMs so that we can derive aggregative information. For example, different Pokémon-related keywords (versions, characters, trademarks) are grouped into a single category "Pokémon". Full details of this procedure are also available in Appendix E.

Step 4: Question Generation Finally, we generate aggregative questions using combinations of attributes stored in our constructed database. This database is built by compiling all conversations along with their inferred attributes (such as topics and keywords extracted by GPT-4o) and provided metadata attributes (such as timestamps and locations). We then sample attribute combinations from

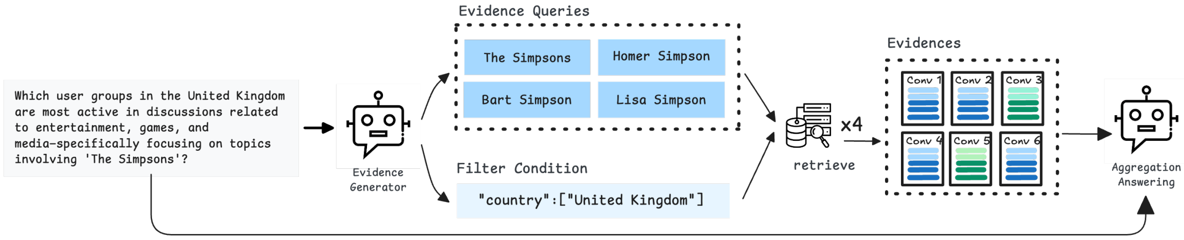

Figure 3: Overview of the PROBE retrieval approach.

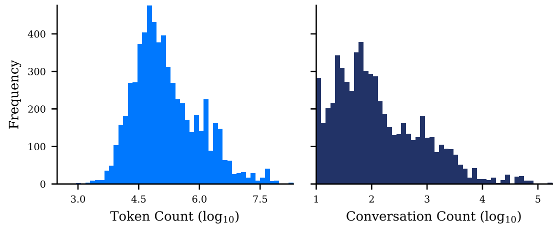

Figure 4: Distribution of total tokens and conversations in the supporting context.

Name	Human–Human κ	Human-Model κ
Topic	0.581	0.617
Subtopic	0.576	0.609

Table 2: Average Cohen's κ indicating agreement between human annotators (human-human) and between human annotations and model predictions (human-model).

zero to three attributes as conditions and a target attribute to query our database. These structured queries explicitly specify the conditions (attribute-value constraints, e.g., *user=abcd*, *keyword=efgh*) and the target attributes to query. The exact combinations are detailed in Table 8 and Appendix B. They serve two purposes: (1) retrieving ground truth answers by converting them directly into database queries executed against our database to retrieve and rank candidate answers, and (2) generating corresponding natural language questions using GPT-4.1. The prompts used are provided in Figure 24 and Appendix E.

2.2 Dataset Statistics

The final WildChat-AQA benchmark contains 182,330 user-chatbot conversations and 6,027 aggregative questions. These conversations cover 28 high-level topics, 455 fine-grained subtopics, and 14,482 keyword categories. Table 8 in Appendix B provides detailed statistics of the questions organized by different attribute conditions and target attributes. Unlike typical question-answering tasks, which derive answers from one or a few documents, WildChat-AQA requires models to reason over contexts whose total token counts range widely from $\mathbf{10^1}$ to $\mathbf{10^8}$ tokens. Figure 4 illustrates the distribution of context token counts. Full data statistics are provided in Appendix B.

2.3 Evaluation Protocol

We frame the evaluation of aggregative question answering as a ranking problem. During training, the model or system is provided access to the entire WildChat-AQA dataset. At test time, the model is given an aggregative question along with 10 candidate answers. Its task is to rank these candidates according to their relevance to the question. We use standard ranking metrics **NDCG@1**, **NDCG@3**, **NDCG@5**, and **NDCG@10** to measure performance.

2.4 Human Evaluation

To evaluate the quality of our inferred attributes, we conduct a human evaluation measuring both inter-annotator agreement (human-human) and human-model agreement using Cohen's κ. Specifically, we randomly sample 100 examples each for level-1 (topic) and level-2 (subtopic) taxonomy labeling. Due to the multi-label nature of these tasks, we compute per-label agreement by treating each possible category as an independent binary labeling task. For subtopic evaluation, we additionally report macro-average agreement scores aggregated across all topics to provide a comprehensive view of annotation reliability.

We found that Cohen's κ for both topics and subtopics indicates moderate to substantial agreement (Cohen, 1960), demonstrating a high degree of reliability between human annotations and model predictions.

3 Probing Retrieval Of Broad Evidence

Traditional retrieval methods, including those used in retrieval-augmented generation (RAG) (Lewis et al., 2020), typically aim to identify a small set of highly specific, relevant documents. However, for Aggregative Question Answering, it is essential to identify a broader range of documents that collectively support reasoning about high-level aggregational insights. To address this unique requirement, we introduce a customized retrieval method, **P**robing **R**etrieval **Of** **B**road **E**vidence (**PROBE**). PROBE operates in two main steps:

Broad Query Generation Given a question $\mathbf{Q}$, we first prompt an LLM to generate a comprehensive set of short, diverse queries that may help retrieve a broad range of relevant documents. Specifically, the LLM generates a set of n queries $q_1, q_2, \ldots, q_n$ related to the question. Additionally, the model generates strict filtering conditions $\mathbf{F} = f_1, f_2, \ldots, f_m$ to exclude documents clearly unrelated to the question. Formally, this process is defined as:

$$\mathbf{F}, \{q_1, q_2, \cdots, q_n\} = \text{LLM}(\mathbf{p}, \mathbf{Q}),$$

where $\mathbf{p}$ represents the prompt.

Evidence Aggregation and Generation Next, each generated query q_i along with the filtering conditions $\mathbf{F}$ is used individually to retrieve relevant documents. This results in n separate retrieval runs. We then aggregate these results by merging the retrieved document lists according to their retrieval relevance scores. If a document appears multiple times across different queries, we use max pooling to assign it the highest relevance score it received from any query. Finally, we select the top k documents from this aggregated list as evidence.

The resulting set of retrieved documents serves as supporting evidence for the model to perform aggregational reasoning and answer the question. An overview of the full PROBE retrieval pipeline is in Figure 3.

4 Experiments

4.1 Models

We experiment with widely-used models spanning various sizes: Gemma 3-4B (Team et al., 2025), Qwen3-8B, Qwen3-32B (Yang et al., 2025), and GPT-4.1-mini (OpenAI, 2024). We also evaluate reasoning models including Qwen3-8B-think, Qwen3-32B-think, and o4-mini (OpenAI, 2025).

4.2 Experimental Setups

We explore several experimental setups to investigate how effectively models leverage conversational data to answer aggregative questions:

Textual Similarity We use textual similarity score including BM25 and embedding-based consine similarity using `text-embedding-3-large` embeddings (denoted as Cosine Sim) to rank the response without context information.

Model With No Context The model directly answers questions without external inputs, relying solely on internal knowledge. This approach establishes baseline performance using only pre-existing knowledge. Due to resource constraints, we only evaluate this baseline using o4-mini, which is one of the strongest reasoning models.

Retrieval Augmented Generation (RAG) We use standard retrieval-augmented generation using OpenAI's `text-embedding-3-large` embeddings to retrieve relevant conversations as context.

Finetuning We finetune pretrained models on the entire WildChat-AQA raw conversations and summaries to test whether fine-tuning on context can bring improvement to the QA tasks.

PROBE For our retrieval method, PROBE,, query generation uses GPT-4.1-mini, and the retrieval relies on embeddings from OpenAI's `text-embedding-3-large` model.

4.3 Raw vs. Summarized Document

Raw conversations are detailed but noisy (average 1,143.4 tokens each), whereas summarized conversations are more concise (average 21.5 tokens). Therefore, we experiment with both raw and summarized conversation inputs to investigate their effectiveness for aggregative question answering. Implementation details for experiments are provided in Appendix D.

4.4 Main Results

Table 3 presents performance results across different models, retrieval methods, and conversation formats.

Simple textual relevance is ineffective. We experiment with simple BM25 and embedding-based textual similarity models. We find that textual relevance baselines performed no better than random selection. The embedding-based approach

Model Name	Context	Type	NDCG@1	NDCG@3	NDCG@5	NDCG@10	# Input Token (Million)
Random	-	-	0.2501	0.3516	0.4368	0.6211	-
BM25	-	-	0.2320	0.3529	0.4385	0.6208	-
Cosine Sim	-	-	0.2761	0.3795	0.4638	0.6382	-
o4-mini	-	-	0.3063	0.4017	0.4805	0.6488	0.87
Qwen3 8B	Finetune	Raw	0.2694	0.3739	0.4589	0.6346	1.74
		Summary	<u>0.2984</u>	<u>0.3966</u>	<u>0.4807</u>	<u>0.6480</u>	1.74
Gemma3 4B	RAG	Raw	0.3291	0.4356	0.5159	0.6688	73.48
		Summary	0.3740	0.4895	0.5627	0.6991	174.62
	PROBE	Raw	0.4766	0.5891	0.6478	0.7620	38.44
		Summary	<u>0.5430</u>	<u>0.6513</u>	<u>0.6994</u>	<u>0.7969</u>	17.35
Qwen3 8B Think	RAG	Raw	0.4168	0.5090	0.5779	0.7123	362.16
		Summary	0.5273	0.6110	0.6646	0.7717	176.88
	PROBE	Raw	0.6545	0.7305	0.7728	0.8483	315.52
		Summary	<u>0.6944</u>	<u>0.7638</u>	<u>0.8005</u>	<u>0.8660</u>	123.04
Qwen3 32B Think	RAG	Raw	0.4052	0.5020	0.5705	0.7081	182.90
		Summary	0.5496	0.6321	0.6847	0.7850	176.88
	PROBE	Raw	0.6525	0.7347	0.7759	0.8501	315.52
		Summary	<u>0.7056</u>	<u>0.7753</u>	<u>0.8114</u>	<u>0.8725</u>	123.04
GPT-4.1 mini	RAG	Raw	0.4494	0.5387	0.6035	0.7299	344.37
		Summary	0.5782	0.6620	0.7104	0.8019	154.31
	PROBE	Raw	0.6806	0.7536	0.7936	0.8628	298.69
		Summary	<u>0.7308</u>	<u>0.7942</u>	<u>0.8282</u>	<u>0.8843</u>	107.11
o4-mini	RAG	Raw	0.4730	0.5510	0.6116	0.7383	344.37
		Summary	0.6122	0.6792	0.7242	0.8140	154.31
	PROBE	Raw	0.7117	0.7747	0.8086	0.8745	298.69
		Summary	**<u>0.7571</u>**	**<u>0.8095</u>**	**<u>0.8386</u>**	**<u>0.8930</u>**	107.11

Table 3: Experiment results of different models using various retrieval approaches and conversation formats (raw vs. summarized). <u>Underlined</u> scores indicate the best results for each model, and **bold** scores indicate the best overall results.

performs slightly better than BM25, improving NDCG@1, 3, 5, and 10 by 4.41, 2.66, 2.53, and 1.74, respectively.

Stronger models perform better. Among tested models, o4-mini consistently achieves the highest performance, with a maximum NDCG@1 score of 0.7571. GPT-4.1-mini, while also strong, trails slightly behind. Among open-source models, Qwen3-32B-think achieves the highest performance. (0.7056 NDCG@1).

PROBE outperforms standard RAG. Compared to standard RAG, PROBE consistently shows large performance improvements. With raw data, PROBE improves NDCG@1 scores by 14.8, 23.7, 24.7, 23.1, and 23.8 points for Gemma3-4B, Qwen3-8B-think, Qwen3-32B-think, GPT-4.1-mini, and o4-mini, respectively. A similar trend is observed using summarized conversations.

Summaries outperform raw conversations. Models consistently perform better with summarized inputs, showing improved NDCG@1 scores of 4.5 to 14.4 points over raw conversations for standard RAG, and 4.0 to 6.6 points for PROBE. Summaries enable more efficient information retrieval and easier aggregation of insights.

Basic finetuning is not effective. Direct finetuning on Qwen3-8B (raw or summarized conversations without explicit aggregative reasoning steps) does not substantially exceed random-chance performance. This suggests that standard finetuning alone may be insufficient to internalize aggregative information. We caution, however, against generalizing this finding to all finetuning strategies: more sophisticated approaches that explicitly incorporate

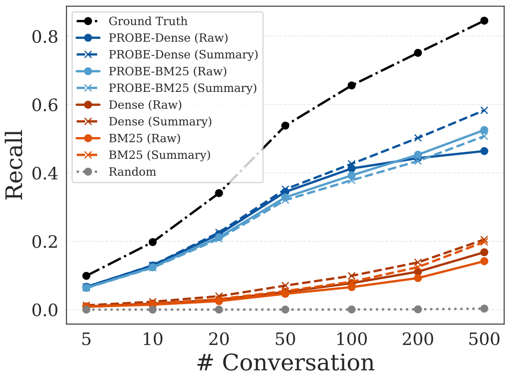

Figure 5: Recall of different retrieval approaches.

aggregative reasoning traces during training could yield stronger results, making this an important avenue for future work.

Token consumption is high. Achieving good performance on this task requires models to consume a very large number of input tokens as shown in Table 3. This highlights a significant computational challenge and motivates future research to improve efficiency.

4.5 Ablation Studies

We conduct ablation studies on a stratified 10% subset of the benchmark, selected based on the condition and target types.

Retrieval effectiveness is crucial. Retrieval quality substantially affects final performance. Table 5 reports the results of o4-mini under varying recall rates from different retrieval methods. Higher recall rates consistently yield better NDCG scores.

Retrieval performance. We compare various retrieval approaches, including vector-based embeddings, BM25, random, and ground-truth retrieval. Figure 5 shows recall rates for different retrieval strategies. PROBE consistently provided substantial improvements over standard RAG, with the highest recall from PROBE-Dense (summarized). Removing either the generated query or filtering steps notably degrades PROBE's retrieval effectiveness as shown in Table 4.

Existing models lack effective aggregational reasoning capabilities. To evaluate model capabilities under ideal conditions, we perform experiments using oracle documents as context. Table 6 shows that all models perform better when given summarized contexts rather than raw conversations,

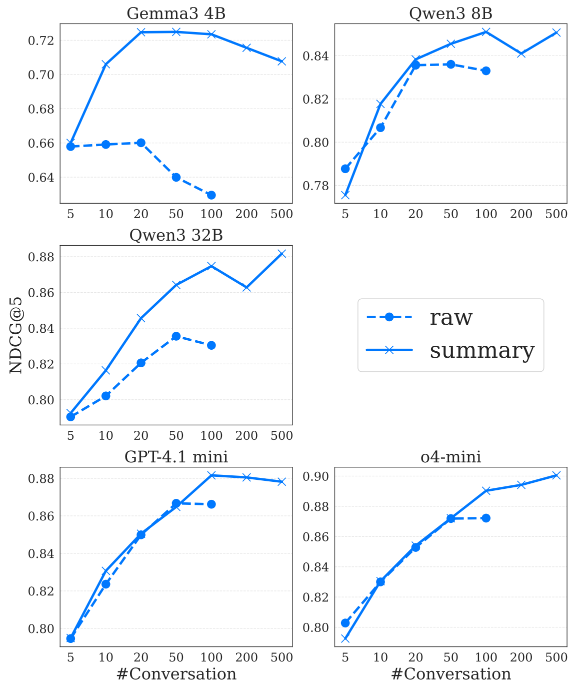

Figure 6: NDCG@5 scores for different models given varying numbers of oracle (ground-truth) documents, comparing raw and summarized conversations.

indicating challenges in aggregating information from longer, noisier texts.

We further analyze how performance varies with the number of provided conversations (Figure 6). Weaker models such as Gemma3 and Qwen3 show a substantial performance gap between raw and summarized contexts, even when given the same number of conversations, highlighting their limited ability to implicitly extract relevant information. Stronger models like GPT-4.1-mini and o4-mini show a smaller initial gap, but this gap widens notably when the context is extended to 100 documents, demonstrating that even advanced models struggle with aggregating and reasoning effectively over extensive raw contexts.

Performance improves with more context. Unlike standard RAG tasks, Aggregative Question Answering fundamentally relies on a broader set of documents. As more documents are provided, models improve significantly in answering aggregative questions (Figure 7). This finding validates that aggregative question answering requires extensive context and global dataset knowledge.

Figures 6 and 7 show that under all experiment settings, performance improves as more documents are provided, demonstrating the necessity of incorporating global information from the dataset.

Method	R@5	R@10	R@20	R@50	R@100	R@200	R@500
RAG-Dense	0.01	0.02	0.04	0.07	0.10	0.14	0.21
PROBE-Dense	0.07	0.13	0.23	0.35	0.43	0.50	0.58
- filter only	0.05 (-0.02)	0.09 (-0.04)	0.16 (-0.07)	0.24 (-0.11)	0.29 (-0.14)	0.33 (-0.17)	0.40 (-0.18)
- question & filter	0.06 (-0.01)	0.12 (-0.01)	0.21 (-0.02)	0.32 (-0.03)	0.40 (-0.03)	0.46 (-0.04)	0.53 (-0.05)

Table 4: Recall@k of PROBE-Dense (Summary) with ablations removing generated queries or filters. Numbers in parentheses indicate performance decrease compared to the full PROBE approach.

# Conversation	Context	Recall	NDCG@5	# Input Token (M)
5	RAG	0.01	0.5373	0.33
	PROBE	0.07	0.6991	0.33
	Oracle	0.10	0.7925	0.33
20	RAG	0.04	0.5897	0.80
	PROBE	0.23	0.7624	0.78
	Oracle	0.34	0.8540	0.77
50	RAG	0.07	0.6318	1.74
	PROBE	0.35	0.7927	1.60
	Oracle	0.54	0.8721	1.46
200	RAG	0.14	0.6858	6.46
	PROBE	0.50	0.8202	5.13
	Oracle	0.75	0.8942	3.63
500	RAG	0.20	0.7141	15.4
	PROBE	0.58	0.8263	11.3
	Oracle	0.84	0.9005	6.31

Table 5: NDCG@5 scores, recall rates, and input lengths (in millions of tokens) using o4-mini with summarized conversations. Underlined values indicate the best score for each number of conversations.

Model Name	Ctx Type	NDCG@1	NDCG@3	NDCG@5	NDCG@10
Gemma3 4B	Raw	0.4815	0.6057	0.6601	0.7703
	Summary	0.5699	0.6787	0.7235	0.8102
Qwen3 8B Think	Raw	0.7359	0.7991	0.8360	0.8894
	Summary	0.7757	0.8268	0.8510	0.9003
Qwen3 32B Think	Raw	0.7225	0.8044	0.8355	0.8897
	Summary	0.8134	0.8605	0.8817	0.9199
GPT-4.1-mini	Raw	0.7849	0.8388	0.8667	0.9121
	Summary	0.8130	0.8602	0.8816	0.9216
o4-mini	Raw	0.8003	0.8456	0.8719	0.9185
	Summary	**0.8478**	**0.8793**	**0.9005**	**0.9347**

Table 6: Results of aggregative question answering with oracle (ground-truth) documents as context.

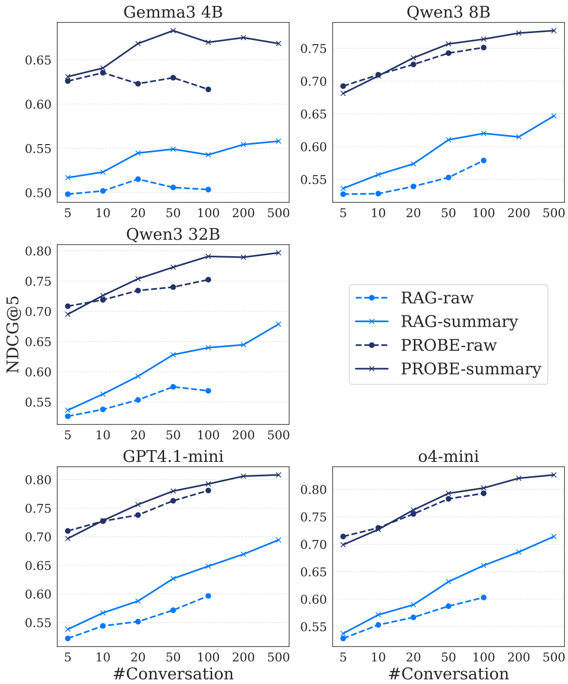

Figure 7: Comparison of NDCG@5 scores for different models with varying numbers of retrieved documents.

Method	NDCG@1	NDCG@3	NDCG@5	NDCG@10
Oracle	0.72	0.79	0.82	0.88
+ thinking	0.81 (+0.09)	0.86 (+0.07)	0.88 (+0.06)	0.92 (+0.04)
RAG (Summary)	0.48	0.56	0.62	0.74
+ thinking	0.54 (+0.07)	0.62 (+0.07)	0.68 (+0.06)	0.78 (+0.04)
PROBE (Summary)	0.64	0.71	0.75	0.84
+ thinking	0.68 (+0.04)	0.76 (+0.05)	0.80 (+0.05)	0.86 (+0.02)

Table 7: NDCG scores of Qwen3 32B with and without reasoning ("think" mode). Improvements from reasoning are indicated in parentheses.

Aggregative question answering is reasoning-intensive. We evaluate Qwen3-32B with the "think" mode on to measure the effect of explicit reasoning. The results (see Table 7) consistently show reasoning led to significant performance improvements across all experimental setups, indicating aggregative question answering demands substantial reasoning abilities.

5 Future Research Directions

Reasoning Over Very Long Context In this work, we experiment with several reasoning-capable models and observe that current models typically have limited context windows, and performance degrades sharply as the length of the input context increases. Developing efficient and accurate methods for reasoning over very long textual contexts remains an important open problem.

Cost-Efficient Aggregative Question Answering Current effective solutions for Aggregative Question Answering require processing extremely large amounts of text, resulting in substantial computational costs. Future research could explore hierarchical indexing, retrieval strategies, and long-term memory mechanisms to reduce token consumption and improve computational efficiency.

Streaming Aggregative Question Answering In real-world scenarios, chatbot conversations often arrive in continuous streams rather than static collections. Future research could explore methods to dynamically update aggregational insights as new interactions occur in real time. Ideally, conversational agents would continuously integrate information from ongoing interactions, similar to how humans update their understanding based on new experiences, to maintain up-to-date and adaptive aggregational knowledge.

6 Conclusion

In this paper, we introduce Aggregative Question Answering, a new task aimed at extracting collective insights from large-scale conversational data generated by interactions between users and LLM-powered chatbots. To facilitate research in this area, we construct the WildChat-AQA benchmark, comprising 6,027 aggregational questions derived from 182,330 real-world chatbot conversations. Our experiments demonstrate that existing state-of-the-art methods, including fine-tuning, Retrieval-Augmented Generation (RAG), and even an improved RAG approach specifically adapted for this task struggle significantly, either failing to reason effectively at the necessary global scale or incurring prohibitively high computational costs. Looking ahead, we believe that addressing these challenges would enable future models to better derive meaningful user and societal insights from large-scale conversational data.

Limitations

Potential Errors in Model-derived Annotations Although we employ powerful large LLMs and pipelines such as GPT-4o and TnT-LLM to infer attributes and assign taxonomy labels, errors and inconsistencies may occur due to model hallucinations or instruction misalignment. Specifically, hallucinations might affect both the inferred topics (summaries used to construct taxonomies) and the extracted keywords, potentially introducing noise or inaccuracies into the benchmark. To quantify these potential errors, we conduct human evaluations measuring the agreement between human annotations and LLM annotations for both topic extraction (Table 2) and keyword extraction. Although these evaluations confirm moderate to high accuracy, we acknowledge that some errors remain inevitable. Additionally, real-world conversational data are inherently noisy, ambiguous, and challenging to categorize neatly, making completely error-free annotations unattainable. We encourage future users of our dataset to remain aware of these limitations when interpreting experimental results.

Artificiality of Generated Questions Aggregative questions in WildChat-AQA were generated by prompting GPT-4.1 to translate structured database queries into natural-language questions. While effective and typically resulting in simple and straightforward queries, this method may introduce stylistic, syntactic, and semantic artifacts. Models trained on our data can potentially overfit to the stylistic patterns of LLM-generated questions, which could limit the validity of the introduced benchmark. Consequently, strong performance on WildChat-AQA may not directly generalize to success on genuinely human-authored aggregative questions, which tend to be linguistically richer and more diverse. We thus consider strong performance on our benchmark as a necessary but not sufficient condition for aggregative question-answering capabilities in real-world scenarios.

Ethical Considerations

Aggregative Question Answering opens promising avenues for real-world analytics but also raises potential ethical and societal concerns, particularly when insights relate to sensitive topics such as elections, public opinion, or public health—areas that could potentially be susceptible to manipulation. To reduce the risks of reinforcing stereotypes or enabling sensitive demographic profiling, we avoided constructing questions targeting protected attributes. Moreover, all experiments conducted in this work rely exclusively on the publicly available and anonymized WildChat dataset, which is explicitly intended for open research purposes (licensed under ODC-BY). By introducing WildChat-AQA as an open benchmark, we aim to empower transparent academic research that responsibly explores both the capabilities and risks associated with aggregational analytics. Our goal is to encourage the open research community to evaluate these powerful systems, rather than relying solely on proprietary analyses conducted behind closed doors.

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A Related Works

Question Answering Question answering typically involves a diverse range of perspectives. Datasets such as TriviaQA (Joshi et al., 2017), RACE (Lai et al., 2017), HotPotQA (Yang et al., 2018), Natural Questions (Kwiatkowski et al., 2019), MuSiQue (Trivedi et al., 2022), 2Wiki (Ho et al., 2020), PopQA (Mallen et al., 2023), and MultiHop-RAG (Tang and Yang, 2024) focus on **local information**, where answers can be derived from one or several documents. In contrast, other benchmarks such as MMLU (Hendrycks et al., 2021a), MATH (Hendrycks et al., 2021b), GSM8K (Cobbe et al., 2021), and Big-Bench (bench authors, 2023) emphasize science, technology, engineering, mathematics, and logical reasoning. These primarily evaluate models' world knowledge and reasoning capabilities but lack a benchmark for understanding large-scale datasets and deriving high-level insights. Recent works such as GraphRAG (Edge et al., 2025) address the long-context challenge by extracting entities and relationships from extended text data and constructing graph structures to answer questions.

Long Context Retrieval Augmented Generation (Lewis et al., 2020) has emerged as a prominent approach for enhancing the performance of large language models (LLMs) on knowledge-intensive tasks while also mitigating hallucinations. Recently, advances in computational capabilities have spurred interest in extending RAG to support very long contexts. Several studies—such as those by Jiang et al. (2024), Zhao et al. (2024a), and Jin et al. (2025)—have proposed methods to improve the effectiveness of LLMs in long-context settings. In parallel, Lee et al. (2024) introduced LOFT, a new benchmark designed to evaluate LLMs on a broad range of tasks addressable by either RAG or long-context modeling.

Summarization Summarization has been a long-standing challenge in natural language processing. Early benchmark datasets, such as CNN/Daily Mail (See et al., 2017) and XSum (Narayan et al., 2018), primarily targeted single-document summarization. Subsequent efforts, including MultiNews (Fabbri et al., 2019) and MS^2 (DeYoung et al., 2021), extended this task to the multi-document setting. Another line of related work focuses on query-based summarization, for which QMSum (Zhong et al., 2021) and DUC 2005 (Dang, 2006) are two widely used datasets.

Text to SQL Text-to-SQL is a widely studied approach for tackling aggregative question answering. In this paradigm, the model is required to generate a structured database query based on a natural language question. Several established benchmarks have been proposed to evaluate this task, including WikiSQL (Zhong et al., 2017), Spider (Lei et al., 2024), BIRD (Li et al., 2024b), and WikiTableQA (Pasupat and Liang, 2015). Additionally, LOFT (Lee et al., 2024) includes a sub-task specifically designed to assess how effectively large language models can emulate database-style querying.

B Data Statistics

B.1 Statistics of Generated Question by Condition and Targets

Condition	Target	Count
0 Condition		
none	topic	1
none	loc	1
none	lang	1
1 Condition		
user	keywords	370
user	time	100
keywords	user	96
user	lang	60
user	topic	54
time	user	39
topic	subtopic	26
loc	topic	20
loc	keywords	17
lang	topic	9
time	topic	6
time	keywords	6
topic	loc	6
topic	user	6
topic	lang	4
topic	keywords	4
time	lang	4
lang	keywords	1
2 Conditions		
user, topic	subtopic	199
user, topic	keywords	185
user, user	subtopic	141
user, topic	time	114
topic, lang	subtopic	100
time, topic	user	98
time, topic	subtopic	98
topic, lang	user	98
topic, loc	time	97
topic, keywords	user	97
topic, loc	subtopic	96
topic, keywords	time	96
time, user	keywords	94
topic, subtopic	user	93
subtopic, subtopic	user	93
topic, loc	keywords	82
topic, lang	time	74
time, topic	loc	60
topic, subtopic	keywords	55
topic, topic	user	55
time, user	topic	53
user, user	topic	53
time, topic	keywords	49
topic, subtopic	loc	39
time, loc	topic	34
time, lang	topic	31
topic, lang	keywords	27
time, topic	lang	15
topic, subtopic	lang	13
topic, loc	user	10
3 Conditions		
loc, topic, subtopic	user	287
lang, topic, subtopic	user	284
user, topic, subtopic	keywords	276
time, loc, topic	user	199
time, topic, subtopic	keywords	175
user, user, user	subtopic	132
user, topic, keywords	time	114
time, topic, keywords	user	100
time, loc, topic	subtopic	100
time, user, topic	subtopic	100
loc, topic, keywords	user	99
user, topic, subtopic	time	98
user, topic, keywords	subtopic	98
loc, topic, keywords	time	98
lang, topic, keywords	time	98
time, topic, subtopic	user	97
lang, topic, keywords	user	96
topic, subtopic, keywords	user	94
loc, topic, subtopic	keywords	93
lang, topic, subtopic	keywords	82
time, topic, subtopic	loc	76
user, user, user	topic	51

Table 8: Question Type Statistics

B.2 Language Distribution

We provide a statistics of all language involved in the conversations in Table 9.

B.3 Keywords Cloud

To illustrate the result of keywords categorization, we build a keywords cloud in Figure 8.

Language	Count	Language	Count	Language	Count	Language	Count
English	124,646	Spanish	4,193	Italian	744	Polish	527
Russian	22,877	Portuguese	3,532	Korean	605	Vietnamese	463
Chinese	6,434	Turkish	1,408	Indonesian	566	Ukrainian	406
French	4,782	Latin	1,239	Dutch	549	Other	1,824
German	4,487	Arabic	863	Tagalog	537		

Table 9: Language Statistics in Conversations

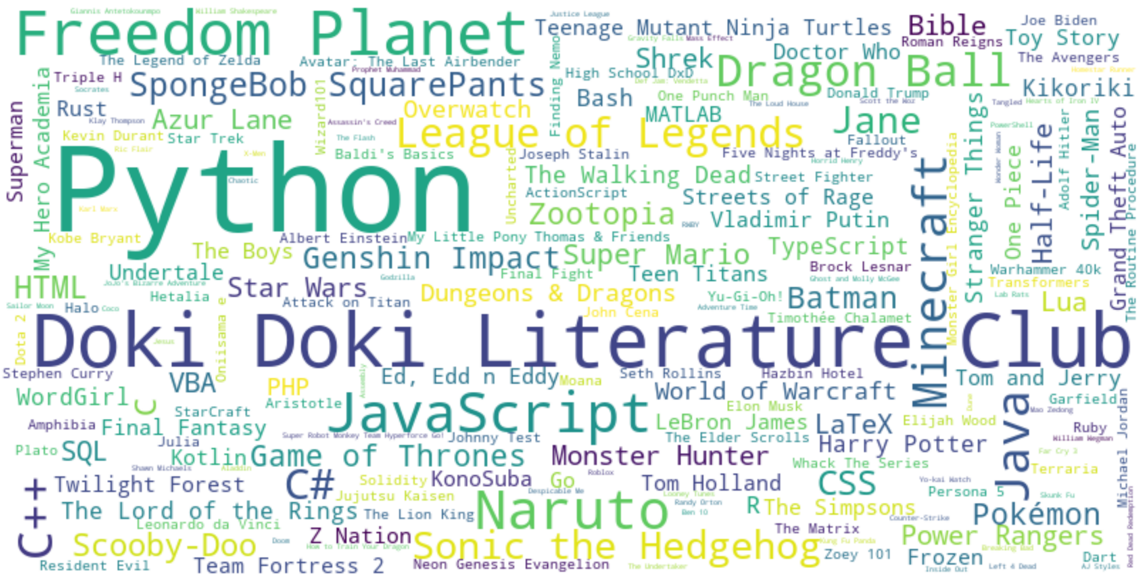


Figure 8: Word Cloud of All Keywords

B.4 Topic and Subtopic Overview

Table 10: Topic Taxonomy in WildChat-AQA

Parent Topic	Sub-topic	Count
Creative Writing and Fiction	Dialogue & Scripted Scenes	25421
	Fanfiction & Universe Crossovers	20323
	Extended Narrative Prose	19771
	Humorous & Satirical Narratives	11901
	Erotic & Sensual Narratives	8304
	World-Building & Adventure Narratives	6470
	Creative Naming & Prompt Generation	4388
	Sports & Competition Narratives	3370
	Transformation & Identity Narratives	3283
	Character Profiles & Descriptions	2025
	Fictional News & Media Formats	1912
	Poetic & Lyric Composition	1608
	Interactive & Roleplaying Narratives	827
Law, Regulation and Criminal Justice	Violent Crimes	630
	Regulatory Compliance and Licensing	454
	Civil Litigation and Consumer Protection	284
	Employment and Labor Law	198
	Sexual Crimes	183
	Intellectual Property and Copyright	163
	Financial, Fraud, and Cyber Offenses	142
	Robbery, Theft, and Property Offenses	130
	Judicial Process and Court Administration	117
	Constitutional Rights and Civil Liberties	81
	Terrorism, War Crimes, Treason, and Political Violence	68
	Corruption and Abuse of Power	64
	Public Order Offenses	54
	Immigration and Border Control	51
	Drug-Related Offenses	50
	Family and Marital Law	48
Entertainment, Games, and Media	Fanfiction & Crossovers	25629
	Original Fiction & Scripts	4834
	NSFW & Explicit Scenes	3717
	Live-Action Film & TV	2963
	Western Animation & Comics	2048
	Gaming Story & Lore	1895
	Celebrity & Pop Culture	1882
	Gaming Mechanics & Tech	1660
	Music & Stage	1651
	Sports, eSports, & Pro Wrestling	1557
	Anime & Manga	1552
	Production & Broadcasting	1044
	Tabletop & TTRPG	804
Software, Programming and Computer Science	Programming	17413
	Web Development	3603
	AI and Machine Learning	2787
	Cybersecurity	1930
	Game Development, Design, and Modding	1737
	Databases and Queries	1724
	Operating Systems and Administration	1414
	Productivity and Desktop Software	1215
	Computer Networking	1176
	DevOps and Cloud	1083
	Data Analysis, Visualization and Business Intelligence	1031
	Mobile Development and Mobile Apps	972
	Computer Graphics	740
	Computer Science Theory	612
	Computer Hardware, Architecture, and Peripherals	576
	Software Architecture and Software System Design	438
	Testing and Quality Assurance	350
	Blockchain and Cryptocurrency	336
	Embedding Systems and IoT	286

Continued on next page

Topic Taxonomy in WildChat-AQA (continued)

Parent Topic	Sub-topic	Count
	Human Computer Interaction	184
	Software Development Methodology and Project Management	165
Science, Mathematics and Logical Reasoning	Physics: Mechanics, Thermodynamics, and Fields	1877
	Basic Arithmetic and Numbers	1376
	Organismal Biology and Evolution	1360
	General Chemistry and Reactions	1339
	Cellular and Medical Sciences	1239
	Astronomy and Astrophysics	1130
	Earth Science and Environment	1031
	Statistics and Probability	912
	Algebra and Vectors	833
	Logic and Puzzles	795
	Geometry and Trigonometry	724
	Computational Science and Modeling	610
	Calculus and Higher Mathematics	505
	Materials, Engineering, and Technology	363
Personal Advice and Support	Navigating Romance and Dating	464
	Enhancing Personal Growth and Discipline	286
	Building Communication and Social Skills	164
	Offering Emotional Support and Love	137
	Navigating Sexual Intimacy, Consent, and Well-Being	128
	Supporting Mental Health and Well-Being	111
	Guiding Family, Parenting, and Caregiving	99
	Boosting Self-Confidence and Esteem	81
	Handling Career and Workplace Challenges	73
	Exploring Personal Values and Choices	70
	Seeking Apologies, Forgiveness, and Trust	65
	Addressing Financial Management and Housing	47
	Improving Physical Health and Body Image	47
	Managing Unwanted Contact and Boundaries	38
	Seeking Legal Guidance and Protective Measures	34
	Embracing Identity and Lifestyle Transitions	32
	Recovering from Breakups and Heartache	32
	Handling Emergencies, Threats, or Crises	30
	Overcoming Addictions and Harmful Habits	19
	Coping with Grief and Loss	15
Business, Commerce and Finance	Digital Marketing & Social Media	4010
	Investments & Financial Markets	934
	Business Operations & Quality Management	914
	Accounting & Financial Reporting	891
	Economic Trends & Macro Outlook	739
	Corporate Governance & Leadership	492
	Customer Service & Complaints	460
	Legal & Regulatory Compliance	435
	Supply Chain & Logistics	426
	Wholesale & B2B Distribution	404
	Banking & Monetary Policies	402
	Careers & Professional Development	373
	Entrepreneurship & Startups	356
History and Culture	Modern and Contemporary History (19th Century–Present)	1407
	Conflicts and Wars	1088
	Medieval Europe	716
	Philosophy and Political Ideologies	624
	Art, Architecture, and Heritage	616
	Religion and Theology	513
	Traditions, Customs, and Rituals	395
	Popular Culture and Mass Media	388
	Pre-Modern East Asia	386
	Colonialism, Imperialism, and Independence	343
	Ancient Non-Classical Civilizations	322
	Classical Rome	269

Continued on next page

Topic Taxonomy in WildChat-AQA (continued)

Parent Topic	Sub-topic	Count
	Diplomacy and Treaties	251
	Language and Literature	240
	Archaeology and Ancient Technologies	217
	Sports and Leisure	197
	Civil Rights and Social Justice	192
	Ancient Greece and Hellenic Culture	174
	Legal Systems and Codes	172
	Social Hierarchies and Slavery	170
	Myths and Folklore	166
	Gender and Women's History	166
	Indigenous Peoples	157
	Science and Medicine	154
	Islamic and Middle Eastern Empires	119
	Exploration and Discoveries	100
Lifestyle and Hobbies	Exploring fashion and accessories	204
	Hair and Personal Grooming	189
	Beauty, makeup, and self-care	110
	Health, sports, and active living	107
	Minimalist living and conscious habits	95
	Personal expression, identity, and body positivity	81
	Creative crafts and DIY projects	67
	Outdoor Recreation and Camping	61
	Relationships, family, and social bonding	59
	Pets, animals, and responsible care	46
	Spirituality, meditation, and mindfulness	45
	Music, dance, and performing arts	43
	Games, collecting, and playful hobbies	42
	Social events, parties, and gatherings	40
	Costumes and cosplay	37
	Cooking, baking, and culinary hobbies	31
	Productivity and time management	30
	Travel, tourism, and new adventures	24
	Digital lifestyle and social media presence	24
	Seasonal festivities and holiday decorating	12
	Gardening and horticulture	7
	Home organization and interior comfort	6
Academic Resource, Education and Learning	Academic Research, Methods, and Presentation	801
	Curriculum and Course Development	697
	STEM and Technical Education	428
	Teaching Strategies and Pedagogical Tools	423
	Health and Medical Education	326
	Technology and AI Integration in Education	296
	Professional and Vocational Training	248
	Educational Policy and Leadership	195
	University Admissions and Scholarship Guidance	157
	Language Learning and Translation	135
	Memory, Study, and Exam Strategies	118
	Creative Arts and Literature in Education	110
	Early Childhood Education and Development	104
	Special Education and Inclusive Learning	66
	Socio-Emotional Learning and Wellbeing	60
	Environmental and Social Education	43
	Academic Ethics and Publication Guidelines	34
	Parental Engagement and Child Education	34
	Classroom Management and Student Engagement	25
	Undefined	2
Psychology, Mental Health and Emotional Support	Communication Skills & Empathy	211
	Child & Adolescent Mental Health	199
	Relationship & Interpersonal Challenges	181
	Stress, Coping Strategies & Resilience	158
	Mood Disorders (Depression & Bipolar)	155
	Anxiety, Panic & Phobias	112
	Psychological Theories & Historical Perspectives	109
	Therapy & Counseling Methods	103

Continued on next page

Topic Taxonomy in WildChat-AQA (continued)

Parent Topic	**Sub-topic**	**Count**
	Sexual Orientation, Gender & Sexual Behaviors	102
	Trauma & PTSD	99
	Emotional Support for Crises & Suicidal Ideation	97
	Self-esteem & Self-sabotage	95
	Neurodevelopmental Disorders (ADHD, Autism, etc.)	90
	Addiction & Substance Use	69
	Abuse, Violence & Bullying	67
	Grief & Loss	54
	Personality Disorders	42
	Schizophrenia & Psychotic Symptoms	38
	Social & Cultural Factors in Mental Health	37
	Sleep & Dream Analysis	36
	Dissociative Disorders & Maladaptive Daydreaming	33
	Medication & Pharmacological Discussions	28
	Eating & Body Image Disorders	25
	Obsessive & Compulsive Disorders	16
Interactive Activities with AI Chatbots	Explicit or Sexual Roleplay	1023
	Developer Mode or Policy-Breaking Requests	456
	Interactive Storytelling with User Control	380
	Comedic or Vulgar Roleplay	256
	Flirty or Romantic Scenarios	217
	Childlike or Energetic Roleplay	188
	Game or Puzzle Interactions	162
	Roleplay with Personal or Close Relationships	112
	Fantasy or Mythical Adventures	101
	Roleplay with Non-Human Traits	78
	Action or Combat-Based Roleplay	77
	Testing Chatbot's Memory or Logic	68
	Roleplay with Theatrical or Literary Flair	60
	Roleplay with Real-World Professions	49
	Minimalistic or Symbolic Responses Only	44
	Roleplay with Custom Machinery or System Simulation	43
	Roleplay with Worship or Devotion	37
	Roleplay with Social or Political Themes	29
	Roleplay as Rebels or Criminals	27
	Hypnosis or Therapeutic Roleplay	7
Linguistics, Language and Translation	Rewriting and Paraphrasing	8331
	Translation	7997
	Vocabulary and Terminology	2586
	Proof Reading and Grammar Correction	2102
	Linguistic Analysis	1099
	Summarization	779
	Language Learning Assistance	503
	Phonetics and Pronunciation	464
	Information Extraction	391
Social Issues, Politics and Governance	Domestic Governance & Public Policy	1334
	Political Theories & Ideological Debates	1231
	International Relations & Geopolitics	1190
	Social Justice, Identity & Cultural Norms	1009
	Political Leadership & Electoral Dynamics	742
	National Security & Crisis Management	543
	Economic Policy & Regulation	366
Medicine and Health	Orthopedics and Musculoskeletal Health	467
	Nutrition and Dietary Supplements	466
	Infectious Diseases and Vaccines	385
	Rehabilitation and Recovery	384
	Pharmacology and Medication Safety	378
	Eye, ENT, and Respiratory Conditions	376
	Surgery and Emergency Care	341
	Mental Health and Wellbeing	328
	Reproductive Health and Childbirth	313
	Digestive, Metabolic, and Endocrine Disorders	304

Continued on next page

Parent Topic	Sub-topic	Count
	Sexual Health and Function	243
	Healthcare Systems and Public Health	238
	Neurology and Nervous System Disorders	212
	Dermatology and Skin Care	201
	Diagnostic Tests and Imaging	190
	Cardiovascular Diseases and Hypertension	181
	Exercise, Fasting, and Weight Control	177
	Pediatrics and Child Health	169
	Preventive Medicine and Wellness	152
	Cancer and Oncological Care	141
	Medical Technology and Telemedicine	109
	Oral Health and Dentistry	103
	Substance Use and Addiction	96
	Allergies and Immune Conditions	88
	Occupational and Environmental Health	80
	Genetics and Rare Conditions	76
	Veterinary Medicine and Animal Health	42
Technology, Engineering and Industry	Mechanical Engineering and Manufacturing	678
	Electrical and Electronics Design	418
	Materials Science and Engineering	405
	Aerospace and Space Exploration	381
	Consumer Electronics and Gadgets	364
	Big Data, IoT, and Smart Systems	310
	Blockchain and Decentralized Tech	305
	Networking, Telecommunications, and Cybersecurity	287
	Civil Engineering and Infrastructure	278
	Automotive Engineering and Vehicle Technology	257
	AI and Machine Learning	251
	VR, AR, and XR Solutions	245
	Industrial Safety and Compliance	220
	Robotics, Drones, and Mechatronics	203
	Military and Defense Technology	185
	Energy and Sustainable Manufacturing	156
	Cloud, Virtualization, and Enterprise Platforms	131
	Supply Chain and Logistics Management	115
	Software Development and Web Frameworks	108
	Quantum and High-Performance Computing	101
	Agricultural Engineering and Food Industry	84
	Digital Media, Broadcasting, and Streaming	75
	Hardware Innovation and CPU/GPU Development	68
	HCI, UI/UX, and Interactive Tech	67
	Marine and Offshore Engineering	62
	Data Storage and Retention	61
	Engineering Education and STEM Training	55
	Biomedical, Biotech, and Wearables	55
	Gaming Technology and eSports	46
	Industrial Digitalization and Change Management	37
	Product Design and Industrial Innovation	29
	3D Printing and Additive Manufacturing	16
General Digital Support	AI Capabilities	472
	AI Limitations	397
	AI Identity, Version, and Origins	161
	Correcting or Revising AI Responses	61
	Technical Guidance: External Apps and Websites	57
	AI Emotions or Opinions	48
	Creative Writing	38
	Official Links or Verification	33
	Coding Tasks	29
	Technical Guidance: Phones and Software	24
	Email and Account Management	19
	Comparison with Other AI Systems	18
	Education or Research Use	17
	Search and Browsing Advice	10

Continued on next page

Topic Taxonomy in WildChat-AQA (continued)

Parent Topic	Sub-topic	Count
	Payment or Subscription	5
Food, Cooking and Nutrition	Nutritional Guidance & Diet Planning	569
	Recipes & Cooking Techniques	518
	Ingredient Selection & Quality	218
	Culinary Culture & Dining Experience	166
	Food Safety & Storage	76
Art and Design	Product & Merchandise Design	1086
	AI-Generated Art & Prompt Engineering	585
	Digital Media & Advertising Design	492
	Color Theory & Visual Composition	407
	Character & Animation Design	290
	Art History & Critique	270
	Editorial & Commercial Illustration	262
	Fashion & Costume Design	252
	Logo & Branding Design	213
	Educational & Children's Art	204
	Architectural & Environmental Design	192
	Digital Art & Software Techniques	132
	Traditional & Manual Art Techniques	116
Religion, Mythology and Spirituality	Biblical and Scriptural Narratives	981
	Islamic Sacred Narratives	363
	Classical Mythology Narratives	356
	Eastern Sacred Narratives	243
	Modern Esoteric and Occult Spirituality	188
	Religion, Society, and Cultural Critique	178
	Astrological and Divinatory Traditions	169
	Folk and Indigenous Myth Narratives	164
	Norse and Germanic Mythological Narratives	44
	Ancient Near Eastern and Persian Narratives	31
Literature and Book Analysis	Narrative and Prose Analysis	1482
	Poetry and Versified Analysis	427
	Literary Guidance and Recommendations	355
	Advanced Literary Criticism	43
Philosophy and Ethics	Epistemology, Logic, and Fallacies	349
	Law, Governance, and Political Philosophy	341
	Mind, Consciousness, and Reality	303
	Religion, Theology, and Faith Traditions	299
	Existentialism, Death, and Meaning	176
	Moral Theories, Virtue, and Character Development	171
	Moral Speech and Expression	146
	Critical Theory and Postmodernism	133
	Consent, Power, and Manipulation	104
	Cultural Norms and Social Ethics	100
	Aesthetics and Artistic Philosophy	91
	Ethics in AI and Future Technologies	90
	Professional Ethics and Duty	81
	Markets, Capitalism, and Economic Fairness	43
	Bioethics, Medicine, and Life Origins	42
	Morality Toward Animals	40
	Love, Relationships, and Emotional Ethics	28
	Environmental Ethics and Sustainability	19
Sports and Athletics	NCAA College Football	1012
	Motorsport	607
	NBA Basketball	604
	NCAA College Basketball	549
	Global Soccer	538
	Fictional or Hypothetical Scenarios	451
	Professional American Football	313
	General or Cross-Sport Training & Fitness	218
	Professional Wrestling	146
	Baseball	68
	Combat Sports	64

Continued on next page

Topic Taxonomy in WildChat-AQA (continued)

Parent Topic	Sub-topic	Count
	Cricket	60
	Cycling (Races & Gear)	59
	Ice Hockey	25
	Tennis and Other Racket Sports	18
	Rugby	14
	Gymnastics & Swimming	7
	Volleyball	3
	Golf	2
Environment, Ecology and Sustainability	Climate Change Causes, Impacts, and Adaptation	140
	Biodiversity Conservation and Wildlife Protection	119
	Greenhouse Gas Emissions and Carbon Management	117
	Pollution (Air, Water, Soil) and Remediation	102
	Waste Management and Circular Economy	101
	Environmental Policies, Laws, and Regulations	82
	Sustainable Energy and Energy Transition	74
	Green Industry, Corporate Sustainability, and Innovation	72
	Water Resource Management and Conservation	67
	Ecological Economics and Sustainable Development	66
	Environmental Education and Public Awareness	45
	Deforestation, Reforestation, and Sustainable Forestry	43
	Environmental Monitoring, Data Analysis, and Reporting	40
	Sustainable Lifestyles and Consumer Choices	39
	Sustainable Packaging, Recycling, and Plastics Reduction	37
	Sustainable Agriculture and Food Systems	35
	Marine and Coastal Conservation	33
	Sustainable Cities and Urban Development	33
	Ecological Restoration and Ecosystem Management	33
	Digital Technologies and Sustainability	32
	Sustainable Architecture and Construction	26
	Sustainable Transportation and Mobility	23
	Soil Health and Land Use Management	22
	Environmental Disaster Preparedness and Risk Reduction	20
	Carbon Markets and Climate Finance	19
	Eco-friendly Materials and Green Design	17
	Community-based Conservation and Participation	15
	Climate Negotiations and International Agreements	12
	Protected Areas and Natural Heritage Sites	12
	Environmental and Climate Justice	11
	Conservation Technology and Innovation	6
	Environmental Impact Assessment and Life Cycle Analysis	5
	Sustainable Tourism and Ecotourism	3
Travel and Tourism	Cultural, Heritage & City Experiences	126
	Transport & Logistics	87
	Travel Itineraries & Trip Planning	65
	Accommodation & Lodging	54
	Tourism Industry, Policy & Market	49
	Culinary & Dining	40
	Visa & Travel Documentation	40
	Beach, Coastal & Cruise Tourism	37
	Entertainment & Nightlife	28
	Adventure & Outdoor Activities	25
Professional Development and Career Advice	Cover Letters & SOPs	270
	Resume & CV Enhancement	233
	Workplace Culture & Dynamics	132
	Skill Development & Advanced Education	128
	Leadership & Team Management	106
	Salary & Compensation Guidance	96

Continued on next page

Topic Taxonomy in WildChat-AQA (continued)

Parent Topic	Sub-topic	Count
	Recruitment & Talent Acquisition	96
	Industry-Specific Career Advice	75
	LinkedIn & Personal Branding	69
	Job Search & Networking Strategies	60
	Career Transitions & Upskilling	60
	Negotiation & Employment Contracts	42
	Interview Preparation & Techniques	31
	Employment Documentation & Verification	31
	Freelancing & Entrepreneurship	19
Home and Household	Gardening: Planting & General Care	140
	Gardening: Soil & Fertilization	128
	Fruit & Berry Cultivation	107
	Home Fixtures & Materials	83
	Gardening: Pest & Disease Management	75
	Interior Design & Decoration	60
	Home Maintenance & Appliance Repair	54
	Laundry & Fabric Care	36
	DIY Tools & Household Projects	31
	Household Cleaning & Stain Removal	27
	Outdoor Landscaping & Mulching	24
	Eco-Friendly & Sustainable Practices	15
	Household Safety & Security	14
	Real Estate & Tenancy	13
	Household Management & Lifestyle	13
	Home Organization & Storage Solutions	8
	Household Pets & Animal Care	5

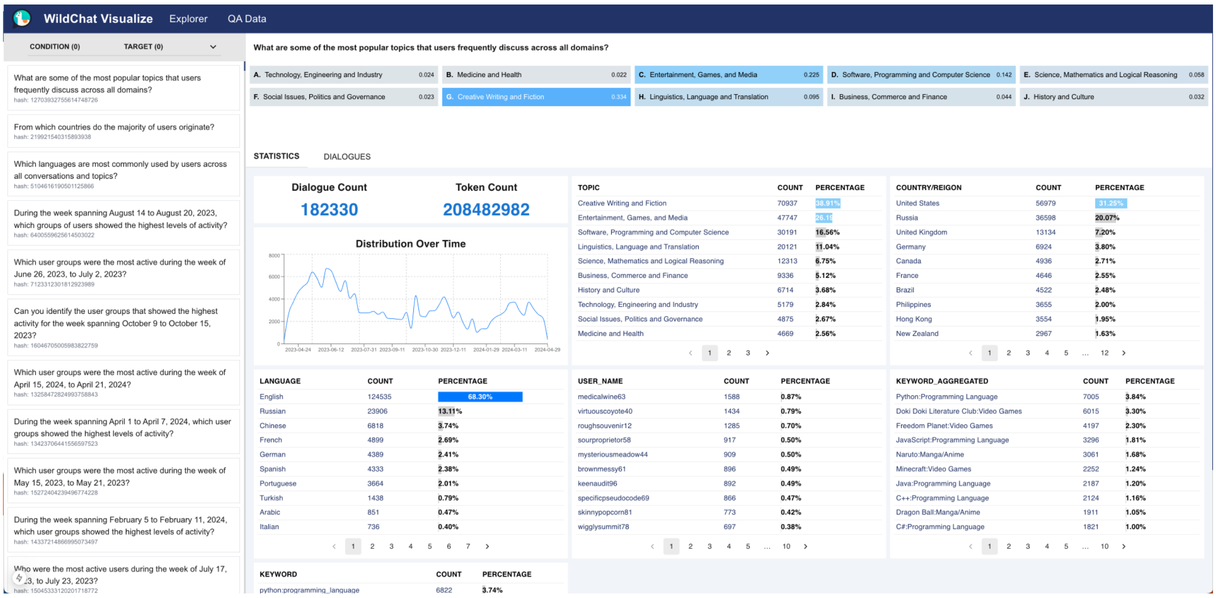


Figure 9: Data Visualization Demo Overview

C Data Visualization Demonstration

We developed an interactive data visualization interface using React.js and Next.js for the frontend, and FastAPI for the backend implementation. MongoDB serves as the database system. An overview of the interface is shown in Figure 9. Users can filter generated questions using a configurable question filter, as illustrated in Figure 10.

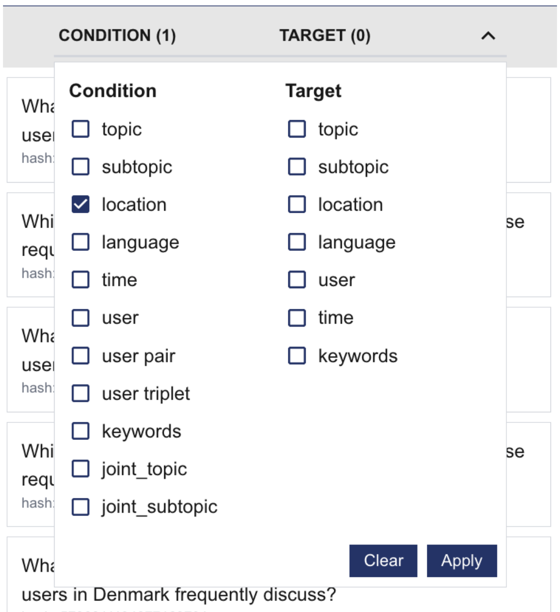


Figure 10: Question filter attributes of different conditions and targets.

The filtering mechanism allows users to select one or more attributes for both the condition and target fields to retrieve relevant questions. For instance, the filters "user_pair" and "user_triplet" refer to questions based on common interests between two or three users, respectively. Similarly, "joint_topic" and "joint_subtopic" denote filters that select conversations involving shared topics or subtopics.

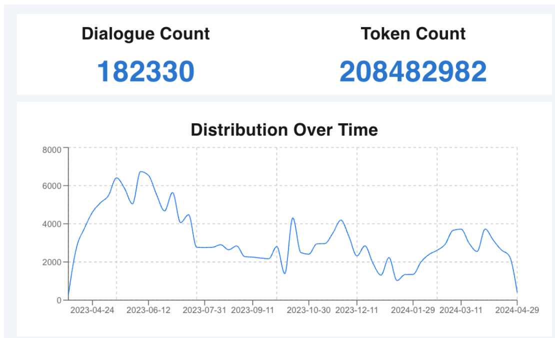
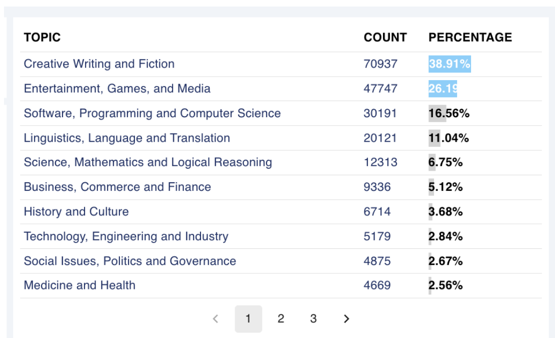


Figure 11: Context conversation and token count and distribution of conversation over time.



TOPIC	COUNT	PERCENTAGE
Creative Writing and Fiction	70937	38.91%
Entertainment, Games, and Media	47747	26.19
Software, Programming and Computer Science	30191	16.56%
Linguistics, Language and Translation	20121	11.04%
Science, Mathematics and Logical Reasoning	12313	6.75%
Business, Commerce and Finance	9336	5.12%
History and Culture	6714	3.68%
Technology, Engineering and Industry	5179	2.84%
Social Issues, Politics and Governance	4875	2.67%
Medicine and Health	4669	2.56%

Figure 12: Distribution of topics

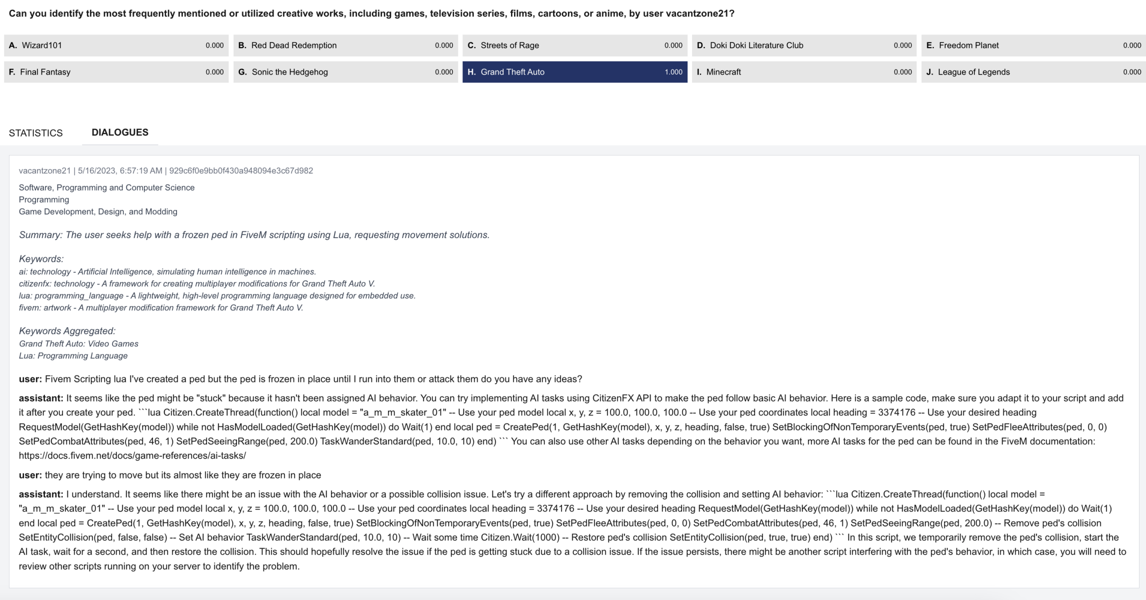


Figure 13: Dialogue Detail Display

For each question, the interface displays the number of supporting dialogues and their associated token counts. Additional distributions—such as raw keywords, aggregated keywords, language, topic, location, and user identity—are visualized to facilitate deeper insights.

Users can also explore the "DIALOGUES" panel to view all conversation excerpts that support a particular question. Each dialogue entry includes detailed metadata: username, timestamp, topic, subtopic, generated summary, raw extracted keywords, and aggregated keywords. This comprehensive display allows users to audit or explore the basis of each proposed question in context.

D Experiment Implementation Details

We employed MongoDB v8.0.4 for question proposal generation and ground-truth-based retrieval. All retrieval experiments utilizing BM25 and dense kNN methods were conducted using Elasticsearch v8.18. Training and inference for open-source models were carried out on a range of GPUs, including the NVIDIA RTX A6000 Ada, NVIDIA H100, and NVIDIA H200, depending on availability.

For all embedding-based dense retrieval experiments, the questions, generated queries, documents, and summaries were encoded using the OpenAI `text-embedding-3-large` model, which produces 3072-dimensional vectors.

For fine-tuning experiments with Qwen3-8B, we used the HuggingFace Transformers library (Wolf et al., 2020), version 4.51.3, training on the full conversation dataset with a peak learning rate of 1×10^{-5}, a batch size of 8, and a linear learning rate decay schedule.

For text pre-processing of RAG, we chunked raw conversations into segments of at most 512 tokens with a maximum overlap of 128 tokens, preserving sentence boundaries wherever possible. For summarized conversations, no chunking is performed due to relatively short text length.

For inference with open-source models, we utilized vLLM v0.8.5.post1. The sampling hyper-parameters used during inference are detailed in Table 11.

Model Name	top_p	top_k	temperature
Gemma3-4B	0.95	64	1.0
Qwen3-8B	0.8	20	0.7
Qwen3-8B-Think	0.95	20	0.6
Qwen3-32B	0.8	20	0.7
Qwen3-32B Think	0.95	20	0.6
GPT-4.1-mini	1.0	-	1.0
o4-mini	-	-	-

Table 11: Model sampling hyper-parameter

For broad query generation in **PROBE**, we use GPT-4.1-mini as query and filter generator with top_p = 0.5 and top_k = 0.5.

Algorithm 1 TnT-LLM: Taxonomy Generation Phase

Input: Max round of iteration N, Batch size B, Conversations summaries C, Summary embeddings E, 2Number of cluster of KMeans K, Initial taxonomy generation prompt $P_{\text{initial, topic}}$, Taxonomy update prompt $P_{\text{update, topic}}$
Output: Label taxonomy T

Partition summaries C into K clusters $\{D_1, \ldots, D_K\}$ using KMeans on E.
Initialize taxonomy $T \leftarrow \emptyset$.
Initialize cursors for round-robin sampling from each cluster D_k.
for $n \leftarrow 1$ to N **do**
    $S_{batch} \leftarrow \emptyset$
    Select up to B summaries for S_{batch} by sampling from clusters $\{D_k\}$ in a round-robin fashion without replacement, advancing cursors.
    if S_{batch} is empty **then** ▷ No more summaries available for sampling
        break
    end if
    if $n = 1$ **then**
        $T \leftarrow$ CallLLM$(P_{\text{initial, topic}}, S_{batch})$
    else
        T, score $\leftarrow$ CallLLM$(P_{\text{update, topic}}, S_{batch}, T)$ ▷ Update existing T
    end if
    if score not improve for 3 iteration **then**
        break
    end if
end for
return T

E Data Construction Process

In this part, we explain in detail how we create the dataset. We start with WildChat-Full dataset which contains around 990K conversations.

E.1 Pre-processing and De-duplication

We begin by de-duplicating the full WildChat dataset using MinHash and Locality-Sensitive Hashing (LSH), following the approach described in Hugging Face (2023). For MinHash, we use 4-grams ($k = 4$) and 9 permutations ($p = 9$). For LSH, we set the band size to $b = 7$ and the row size to $r = 3$. After de-duplication, approximately 520K conversations remain.

Next, we tokenize all conversations using the LLaMA 3 tokenizer (Grattafiori et al., 2024) and discard those exceeding 4,096 tokens. Users are identified based on a combination of hashed IP addresses and HTTP request headers, and each user is assigned a randomized username. Users with fewer than 10 sessions are considered inactive, and all their conversations are removed.

After filtering by conversation length and user activity, around 220K conversations remain. All subsequent processing steps are performed on this filtered dataset.

E.2 LLM-based keywords and summarization extraction

To perform TnT-LLM for topic discovery, we begin by extracting keywords and summaries from raw conversations. Specifically, we prompt GPT-4o to generate both the keyword set and a concise summarization of each conversation. The extracted keywords span a diverse set of semantic types, including persons, technologies, scientific terms, foods, demographic terms, organizations, locations, events, artworks, programming languages, product brands, and financial terms. The complete prompt used for this extraction process is shown in Figure 14.

E.3 TnT-LLM based Topic and Subtopic Discovery and Assignment

E.3.1 Topic Discovery and Assignment

Topic Taxonomy Generation We largely follow the pipeline of TnT-LLM (Wan et al., 2024) to identify topics within the dataset. Rather than randomly sampling from a large corpus, we first obtain the

```
# Context

You are a helpful assistant in processing data. You are going to generate a report for a user chatbot interaction dialogue.

In the data given below, user requests starts with [**User Request**] and agent response starts wtih [**Agent Reponse**].
Utterance are separated by '----'.

# Content

{{input_text}}

# Instruction

You need to generate report satisfying following requirements based on Content:

1. Extract or infer all keywords of following types from the dialogue:

    - person: individuals' names, including first, middle, and last names, titles, and honorifics. Example: Nelson Mandela, Dr.
    Jane Doe
    - technology: Terms describing technology of any fields. Example: AI, 5G, renewable enery, NFT, SEO, Large Language Model,
    AR, VR, Metaverse.
    - scientific_term: Terms describing science theories, or concepts. Example: Quantum Physics, Photosynthesis
    - food: Food-related terms, ingredients, or dishes. Example: Avocado, Chocolate.
    - demographic_term: term references to ethnicities, nationalities, or demographic groups. Example: LGBTQ+, Caucasian,
    Afican American.
    - organization: Companies, institutions, government agencies, and other organized groups. Example: Google, Meta, United
    Nations, World Health Organization, MIT, Stanford, FDA.
    - location: Geographical locations, including stars, planets, countries, cities, states, addresses, and landmarks. Example:
    London, Mount Everest, Times Square, United States, Moon, Neptune, Sun.
    - event: Name of social, cultural, military, political, historical, scientific, commercial, religious, medical or health
    events. Example: World War II, 2024 Paris Olympic, Cold War, CES 2024, Industrial Revolution, The Renaissance.
    - artwork: Name of any form artworks, including music, books, video games, anime, comic, drama, shows, TV shows, TV series,
    films, painting etc.
    - programming_language: Any kind of programming language. Example: Python, Java, C++, C#, LaTeX, R, CSS etc.
    - product_brands: Name of products and brands. Example: IPhone 14, Nike Air Max, Apple Mac Book.
    - financial_term: financial or economic terminology. Example: Interest Rate, Inflation.


2. DO NOT output "none" if specfic kind of keywords not appear.

3. The keywords extracted MUST be **uniquely idenfiable without context**.

4. Give simple description of each keywords **within 15 words** in **English**.

5. All keywords extracted MUST be **English** or translated into **English**.

6. Write a summary of given user chatbot interaction **within 30 words** in **English**, focus on user query, describe from
third person view.

7. Keep as much information as possible in summary about user request.

8. Explain user's intent based on the given content, respond in `intent` part within **30 word** using **English**.

9. The answer MUST be generated in json format:
    {
        "summary": "<summary>",
        "intent": "<intent>",
        "keywords":[
            {
                "keyword_type": <type_1>,
                "value": <value_1>,
                "description": <keyword_description_1>
            },
            {
                "keyword_type": <type_2>,
                "value": <value_2>,
                "description": <keyword_description_2>
            },
        ],
    }

# Response
```

Figure 14: Prompt for keywords extraction and summarization.

```
# Context

You are a helpful assistant for clustering human-AI conversation. The following content are a batch of human-AI conversation summary sampled, separated by "----". You are going to propose a set of meaningful, diverse and high quality categories so that all human-AI conversation can be classified without ambiguity.

# Content

{{input_text}}


# Instruction

Your task is to propose a list classes and corresponding description so that the given data can be classified into, with following requirements:

1. The classes generated are the **domain** of human-AI interaction, avoid introducing user intent.

2. The class names and class descriptions generated can **accurately** and **consistently** classify new data points **without ambiguity**.

4. The class name should be a **concise and clear label** for the category.

5. The classes generated MUST be **mutual exclusive**.

6. The class description of each class should be generated within **100 words** in English.

7. The class name and class description must be consistent with each other.

8. Output class must match the data as close as possible, without adding unnecessary ones and missing necessary ones.

9.  Generate **No More Than 30 classes**

10. Avoid categories include any vague information such as "Other", "Undefined", "Miscellaneous".

11. The response should be generated in json format following:

    {
        "classes": [
            {
                "class_description" : <description_1>,
                "class_name" : <title_1>
            },
            {
                "class_description" : <description_2>,
                "class_name" : <title_2>
            },
            {
                "class_description" : <description_3>,
                "class_name" : <title_3>
            },
             <more classes...>
        ]
    }

Make sure output **pure json**

# Response
```

Figure 15: Initial Taxonomy Generation Prompt

```
# Context

You are a helpful assistant for clustering human-AI conversation. The following content in **Content** part are a batch of human-AI conversation summary sampled, separated by "----". And a category table you generaeted based on the previous data in **Category Table** part. You are going to update the table for downstream user interest discovery.

# Category Table

{{input_category_table}}

# Content

{{input_text}}

# Requirements

Your need to update the category table to make sure the table satisfy the following **requirements**:
    - The classes generated are the **domain** of human-AI interaction, avoid introducing user intent.
```

```
    - The class names and class descriptions generated can **accurately** and **consistently** classify new data points
    **without ambiguity**.

    - The class name should be a **concise and clear label** for the category.

    - The classes generated MUST be **mutual exclusive**.

    - The class description of each class should be generated within **100 words** in English

    - The class name and class description must be consistent with each other.

    - Output class must match the data as close as possible, without adding unnecessary ones and missing necessary ones.

    - The generated classes must useful for user interest discovery and analysis.

    - Generate **No More Than 60 classes**

    - Avoid including three or more different aspects in one category, such as `History, Politics & Government`.

    - Avoid categories include any vague information such as "Other", "Undefined", "Miscellaneous".

# Instructions

You need to update using following steps:

1. Review the given category table and the input data. Provide a rating score of current table. The rating score should between
0 to 100. The score should be given based instrinstic quality and extrinstic quality:

    - **Instrinstic quality**
        1) If the categories meets the requirements given in **Requirements** part, with clear and consistant category names
        and descriptions, and no overlap or contracdiction among the categories.
        2) If the categories include any vague information such as "Other", "Undefined", "Miscellaneous".
        3) If there is categories that are too general and include too many aspects or sub-categories.

    - **Extrinstic quality**
        1) If the data given can be classified into the given category consistently without any ambiguity.
        2) If there is missing category that the data can not classified into.
        3) If there is any category that is unnecessary so that can be merged or removed.

2. Based on your score, decide if you need to update the categories, you can perform following operations:
    - Edit class name or class description of the categories.
    - Add new categories if there are missing categories.
    - Split one categories into multiple to become specific.
    - Merge multiple categories into one to become less amiguous.
    - Remove unnecessary categories to reduce redundency.
    - No update if they are good enough.

    If you decide to update the categories, explain the update sugguestion in `suggesion` part. Otherwise just output `N/A` in
    suggestion part.

    Restate: The categories should be **concise, consistent, mutual exclusive**. Make sure remember to update the dialogue
    count accordingly.

    Restate: Be **specific** about each category. **Do not include vague categories**

    You can ignore low quality or ambuiguous data points.


4. Output the report using json format as follows based on your decision and review result above, make sure categories satisfy
the **requirements** given.
    {
        "score": <table_score>,
        "suggestion: <suggestion>,
        "classes": [
            {
                "class_description" : <description_1>,
                "class_name" : <title_1>
            },
            {
                "class_description" : <description_2>,
                "class_name" : <title_2>
            },
            {
                "class_description" : <description_3>,
                "class_name" : <title_3>
            },
             <more classes...>
        ]
    }

# Updated Category Table
```

Figure 16: Taxonomy Update Prompt

textual embeddings of conversation summaries using the BAAI/bge-en-icl model (Li et al., 2024a). We then perform clustering on these embeddings to guide our sampling, ensuring a diverse selection across different semantic regions. This step is added to enhance topic diversity in the sampled subset.

Subsequently, we apply the topic discovery algorithm detailed in Algorithm 1. The initial taxonomy generated is visualized in Figure 15, while the prompt used for topic refinement is shown in Figure 16. For all topic discovery steps, we employ GPT-4o as the underlying language model, using hyperparameters $B = K = 500$ and $N = 10$. To perform efficient KMeans clustering, we utilize the FAISS library (Douze et al., 2025). Unlike the original TnT-LLM method, which relies on LLMs for taxonomy refinement, we manually resolve conflicts and enforce mutual exclusivity among the discovered topics.

Topic Label Assignment Using the generated topics and corresponding taxonomy, we assign a topic ID to each conversation. This assignment process can be formulated as a multi-label classification task. The labeling is performed by GPT-4o using the assignment prompt illustrated in Figure 17. The prompt is carefully designed to mitigate common errors identified through a manual inspection of a small validation set consisting of 400 examples.

E.3.2 Subtopic Discovery and Assignment

Subtopic Taxonomy Generation For each discovered topic, we further identify its subtopics by running TnT-LLM on all conversations classified under that topic. However, subtopic discovery proves to be more challenging. To address this, we adopt a more sophisticated pipeline and employ a stronger model. The following pipeline is specifically designed to facilitate subtopic discovery within each major topic.

1. Prompt GPT-4o to check the result of topic assignment and summarize the raw conversation from the perspective of major topic using the prompt shown in Figure 18.

2. Get the embedding of the summaries that pass checking using `text-embedding-3-large`.

3. Run KMeans use faiss with K in $\{10, 15, 20, 25, 30, 35, 40\}$, find the top 3 best number of centroid k_1^*, k_2^*, k_3^* using silhouette score (Rousseeuw, 1987).

4. For each target number of subtopics k^*,we execute Algorithm 1 with parameters $B = 200, K = 200, N = 30$ using topic-specific initial and update prompts as illustrated in Figure 19 and Figure 20. The model used for subtopic discovery is OpenAI-o1, selected for its strong reasoning capabilities. To enforce the desired number of generated subtopics at the start of the iteration, we replace the placeholder "{min_class_number_requirement}" in Figure 19 with instruction "- Generate NO LESS THAN k^* topics." .

5. After generating the taxonomy for each k^*, we randomly sample 10% of data instances from the current topic—capped at a maximum of 1000 samples. We then query the o3-mini model, which has strong reasoning ability, using the prompt provided in Figure 21. This yields a set of predicted labels $\{l_1, l_2, \cdots, l_i, \cdots, l_m\}$, along with corresponding relevance scores $\{r_1, r_2, \cdots, r_i, \cdots, r_m\}$ between 0-10, each ranging from 0 to 10. We then compute a quality score for each generated taxonomy using the following equations:

$$s_{\text{quality}} = s_{\text{coverage}} + s_{\text{certainty}} \tag{1}$$

Where s_{coverage} and $s_{\text{certainty}}$ are defined as:

$$s_{\text{coverage}} = 1.0 - \frac{N_{\text{Undefined}}}{N} \tag{2}$$

where $N_{\text{Undefined}}$ is the number of samples that labeled as "Undefined", which is not fit in the taxonomy, and N is the number of data sample labeled for taxonomy validation.

$$\begin{aligned} p_i &= \frac{r_i}{\sum_{k=0}^{m} r_k} \\ H_j &= \frac{\sum_{i=1}^{n} p_i \log_2 p_i}{\log_2 m} \\ s_{\text{certainty}} &= \frac{\sum_{j=1}^{N}(1.0 - H_j)}{N} \end{aligned} \tag{3}$$

We select the best taxonomy generated using s_{quality}.

```
# Context

You are a helpful assistant in analyzing user-AI interaction data. You are going to classify a user-AI interaction conversation based on a category table. The **Content** and **Categories** are given in json format.

In the data given below, user requests starts with <User Request> and agent response starts wtih <Agent Response>. Utterance are separated by '----'.

# Content

{{input_text}}

# Categories

{{input_categories}}


# Classification Examples

You need to labeling based on user request or demand, here are some examples, separated by `----`:

{{examples}}

# Instruction

You need to classify the given conversation using the `conversation`, `summary`, # Categories table and given # Classification Examples with following requirements:

- Explain how you perform the classification in `explanation` part **WITHIN 200 WORDS**.

- `Entertainment, Games, and Media` MUST be added with proper relevance order if there are **LESS THAN THREE** other classes **AND** the **MAJOR** characters, content, plot, universe, celebrities involved in conversation is from a known game, film, tv series, comics or other artwork for entertainment described in #Categories.

- `Erotic, Explicit and Inappropriate Content` MUST be ranked LOWEST if **EXPLICITLY INVOLVED**.

- Classify based on the <User Request> in `conversation`, then refer to <Agent Response>, finally refer to `summary` if necessary.

- You must classifiy the conversation into **AT MOST THREE** classes **MOSTLY RELEVANT**.

- The classification result MUST have **AS SMALL NUMBER OF CLASS AS POSSIBLE**.

- AVOID classify the conversation into categories that slightly involved, and focus on users' **MAJOR DEMAND**.

- Respond the classes **ORDER BY RELEVANCE**.

- All response should be in **ENGLISH**

- The classification MUST be done based on `class_description`, `class_examples` and # Classification Examples.

- Respond in **pure json** following with explanation and selected class index:
    {
        "explanation": <explanation>,
        "classes": [<class_index_1>, <class_index_2> ...]
    }

# Response
```

Figure 17: Topic Assignment Prompt

```
You are an expert in analyzing and summarizing dialgoue between user and chatbot, you are going to summarize following
conversation based on instruction.

{{conversation}}

# Instructions

- You need to summarize the dialogue between user and ai chatbot from {{class_name}} topic aspect, the **definition** of the
topic is:
    {{class_description}}

- You MUST check if the conversation contains user request or input related to {{class_name}} based on the **definition**,
explain your check result briefly within 50 words.

- The check result MUST be either "yes" or "no", a string in lower case.

- You need to keep as much information as possible, try your best to keep important keywords and facts in the dialogue.

- The summary MUST describe from third person perspective and **focus on user request**.

- The summary MUST be done within 10 - 20 words using one sentence related to {{class_name}}.

- Make the summary a perfect version for sub-topic discovery.

- Respond in following format using **pure json**

    {
        "explanation": "<explanation>",
        "check_result": "<check_result>",
        "summary": "<summary>"
    }

# Response
```

Figure 18: Topic Validation and Aspected Summarize Prompt

Subtopic Label Assignment Finally, we label all data samples using the prompt illustrated in Figure 21, with the o3-mini model. For each topic, we select the best-performing taxonomy and use it to annotate all corresponding samples.

E.4 Topic Label Quality Control

After completing the labeling pipeline, we still observed some false positives upon manual inspection. To address this, we conducted an additional verification step—similar to the initial phase of the subtopic discovery pipeline—by reviewing each data sample alongside its raw conversation, assigned label, and label description, using the o3-mini model and the prompt shown in Figure 22. Following this verification, we removed all samples that lacked a valid label assignment or were assigned the Undefined label at either the topic or subtopic level. This filtering ensured that the final dataset aligned with the discovered taxonomy, ultimately reducing the dataset size to approximately 182k examples.

E.5 Keywords Categorization

After the labeling process, we observed that certain topics—such as “Fanfiction and Crossover” and “Programming” contained a disproportionately large number of data samples. To enable more fine-grained question generation, we further categorized the extracted keywords into four semantic types: **programming language**, **creative artwork**, **public figure**, and **book**. Conversations that do not contain any keywords from these categories are classified as having no keywords.

E.5.1 LLM Based Aggregation

Assuming that the same word used by the same user conveys a consistent meaning, we first associate each user’s keyword with its corresponding description, extracted at the beginning of the process. We then employ o3-mini to cluster these raw keywords into semantically coherent groups, corresponding to categories including “Programming Language”, “Video Games”, “Tabletop Games”, “Manga/Anime”, “Film”, “TV Show”, “Western Cartoon/Comic”, “Book”, “Musical”, and “Public Figure” , using the prompt illustrated in Figure 23.

E.5.2 Rule-based LLM Result Aggregation

Although o3-mini is prompted to generate the most well-known names for corresponding entities, the model occasionally produces inconsistent outputs, such as “Pokémon” vs. “Pokemon”. These discrepancies are treated as distinct entries in downstream question generation. To address this, we define equivalence between a pair of large language

```
# Context

You are a helpful assistant for clustering human-AI conversation within topic "{{topic}}". The following # Input Data are a
batch of summarized human-AI conversation sampled. You are going to propose a set of meaningful, diverse and high quality
categories so that all human-AI conversation can be classified without ambiguity.

# Input Data

{{input_text}}

# Instruction

Your task is to propose a list sub-topic within topic of {{topic}} and corresponding description so that the given data can be
classified into, with following requirements:
    - The classes generated are the **TOPIC** MUST fall under the parent topic "{{topic}}".
    - The parent **topic description** are as follows:
        {{topic_description}}
    - The class names and class descriptions generated can **ACCUREATELY** and **CONSISTENTLY** classify new data points into
    **1-3 class** with **NO AMBIGUITY**.
    - The class name should be a **CONCISE AND CLEAR** short sentence for the category.
    - The classes generated MUST be **MUTUAL EXCLUSIVE**.
    - The class description of each class should be generated within **200 WORDS** in English.
    - The class description MUST be generated based on data sample.
    - The class name must be consistent with its class description.
    - Output class must **fit the data as close as possible**, avoid adding unnecessary ones and missing necessary ones.
    - Avoid general categories include any vague information such as "Other Topics", "Undefined", "Miscellaneous".
    - You may ignore data points not related to {{topic}}.
    - Keep each class **fine-grained**, AVOID include too many aspect in one class.
    - The classes generated MUST cover the # Input Data **AS MUCH AS POSSIBLE** and fall below the {{topic}} following **topic
    description**.
    {{max_class_number_requirement}}
    {{min_class_number_requirement}}
    - The response should be generated in json format following:
        {
            "classes": [
                {
                    "class_description" : <description_1>,
                    "class_name" : <title_1>
                },
                {
                    "class_description" : <description_2>,
                    "class_name" : <title_2>
                },
                <more classes...>
            ]
        }

Make sure output **pure json**

# Response
```

Figure 19: Initial Taxonomy Generation Prompt For Subtopic

```
# Context

You are a helpful assistant for clustering human-AI conversation within topic "{{topic}}". The following content in **Input
Data** part are a batch of summarized human-AI conversation sampled. And a category table you generaeted based on the previous
data in **# Category Table** part. You are going to update the table for downstream user interest discovery.

# Input Data

{{input_text}}

# Category Table

{{input_category_table}}

# Requirements

Your need to update the category table to make sure the table satisfy the following **requirements**:

    - The classes generated are the **TOPIC** of human-AI interaction MUST fall under the parent topic "{{topic}}".
    - The parent topic description are as follows:
        {{topic_description}}
    - The class names and class descriptions generated can **ACCUREATELY** and **CONSISTENTLY** classify new data points into
    **1-3 class** with **NO AMBIGUITY**.
```

```
    - The class name should be a **CONCISE AND CLEAR** short sentence for the category.
    - The classes generated MUST be **MUTUAL EXCLUSIVE**.
    - The class description of each class should be generated within **200 WORDS** in English.
    - The class description MUST be generated based on data sample.
    - The class name must be consistent with its class description.
    - Output class must **fit the data as close as possible**, avoid adding unnecessary ones and missing necessary ones.
    - Avoid general categories include any vague information such as "Other Topics", "Undefined", "Miscellaneous".
    - You may ignore data points not related to {{topic}}.
    - Keep each class **fine-grained**, AVOID include too many aspect in one class.
    - The classes generated MUST cover the # Input Data **AS MUCH AS POSSIBLE** and fall below the {{topic}} following **topic
    description**.
    {{max_class_number_requirement}}

# Instructions

You need to update using following steps:

1. Review the given category table and the input data. Provide a rating score of current table. The rating score should between
0 to 100. The score should be given based instrinstic quality and extrinstic quality:

    - **Instrinstic quality**
        1) The categories meets the requirements given in ** # Requirements ** part, with clear and consistant category names
        and descriptions, and no overlap or contracdiction among the categories.
        2) The categories not include any vague information such as "Other Topics", "Undefined", "Miscellaneous".
        3) Each category not contain too many aspects.
        4) All categories are **MUTAL EXCLUSIVE**.
        5) The categories fall under the parent topic and adhere with topic description.

    - **Extrinstic quality**
        1) The data given can be classified into the 1-3 of given categories consistently without any ambiguity.
        2) There is no missing category so that all new data can be classified properly.
        3) There is no unnecessary category that can be merged or removed.
        4) The categories are fine-grained and fit new data well.

2. Based on your score, decide if you need to update the categories, you can perform following operations:
    - Edit class name or class description of the categories.
    - Add new categories if there are missing categories.
    - Split one categories into multiple to become specific.
    - Merge multiple categories into one to become less amiguous.
    - Remove unnecessary categories to reduce redundency.
    - No update if they are good enough.

    If you decide to update the categories, explain the update sugguestion in `suggesion` part. Otherwise just output `N/A` in
    suggestion part.

    Restate: The categories should be **CONCISE**, **CONSISTANT**, and **MUTAL EXCLUSIVE**. Make sure remember to update the
    dialogue count accordingly.

    Restate: Be **specific** about each category. **Do not include vague categories**

    You can ignore low quality or ambuiguous data points.


3. Output the report using json format as follows based on your decision and review result above, make sure categories satisfy
the **requirements** given.
    {
        "score": <table_score>,
        "suggestion: <suggestion>,
        "classes": [
            {
                "class_description" : <description_1>,
                "class_name" : <title_1>
            },
            {
                "class_description" : <description_2>,
                "class_name" : <title_2>
            },
             <more classes...>
        ]
    }

# Updated Category Table
```

Figure 20: Taxonomy Update Prompt For Subtopic

```
# Context

You are a helpful assistant in analyzing user-AI interaction data. You are going to perform classification of user-AI
interaction conversation based on a json version category table.

In the data given below, user requests starts with <User Request> and agent response starts wtih <Agent Response>. Utterance
are separated by '----'.

# Content

{{input_text}}

# Categories

{{input_categories}}


# Instruction

You need to classify the given conversation and give confidence score of classification using the "conversation" field,
"summary" field, # Categories table and given # Classification Examples with following requirements:

- You are classifying user-AI conversation under the topic of {{topic}}, the description of the the topic is:

    *topic description*

    {{topic_description}}

- Explain how you perform the classification in "explanation" part **WITHIN 300 WORDS**, cover both classification result and
confidence score.

- All response should be in **ENGLISH**

- Classify based on the <User Request> in "conversation" , then refer to <Agent Response>, finally refer to "summary" if
necessary.

- The classification MUST be done stick to "class_name" defined by "class_description".

- Perform classification ONLY FOCUS on the part related to {{topic}} and *topic description* of # Content.

- You MUST classifiy the conversation into **AT MOST THREE** classes that are **HIGHLY RELEVANT**.

- The classification resulting label set MUST BE **AS SMALL AS POSSIBLE**, **HIGH PRECISION** and **COMPREHENSIVE**.

- Respond the classes **ORDER BY RELEVANCE**, from most relevant to least relevant.

- "undefined" MUST not appear with other classes if there is any related turn or content.

- Give the relevance score correspond to each classification using an integer between 0-10.

- Respond in **pure json** following with explanation and selected class **index** before the class name:
    {
        "explanation": <explanation>,
        "classes": [<class_index_1>, <class_index_2> ...],
        "relevance": [<relevance_1>, <relevance_2> ...]
    }

# Response
```

Figure 21: Subtopic Assignment Prompt

```
You are a careful classification data verifier, you are going to check multi-label classification of user-AI conversation
result, you are going to check following conversation, the user request is start with <User Request>, and the AI response is
start with <Agent Response>, the turns is separate by "----":

# Conversation

{{input}}


# Classification Result

{{results}}

# Instruction

1. Carefully check if **each** classification result given in "class_description" under # Classification Result is highly
relevant to the **major domain** of **any turn** of the conversation.

2. Check class by class via verifying if any turn of conversation satisfy the "class_description", explain the result within
100 words after "explanation".

3. Respond json using following format, the "index" is the given index in # Classification Result and "check_result" is a
string in "yes" or "no", choose yes if you are highly confident.

{
    "explanation": <explanation>,
    "results": [
        {
            "index": <label_index_as_int_1>,
            "check_result": <result_1>
        },
        {
            "index": <label_index_as_int_2>,
            "check_result": <result_2>
        },
        ...
    ]
}

# Response
```

Figure 22: Subtopic Verification Prompt

````
You are an expert in identifying the origin and clustering keywords with description, please complete following tasks

# Keywords

{{input}}

# Instruction

- You need to cluster **all keywords** and **keywords contained in description** given above via identifying all the **artwork, franchise, series, book, and public figures** it belong to like following results:

```json
   {
    "results": [
        {
            "name": "Doki Doki Literature Club!",
            "category": ["Video Games"],
            "keywords": ["Monika", "Natsuki", "Doki Doki Literature Club"]
        },
        {
            "name": "Game of Thrones",
            "category": ["TV Show"],
            "keywords": ["Daenerys Targaryen", "Arya Stark", "A Game of Thrones"]
        },
        {
            "name": "Dungeons & Dragons",
            "category": ["Tabletop Game"],
            "keywords": ["Dungeons and Dragons", "D&D", "DnD", "D&D 5e"]
        },
        <MORE EXAMPLES TRUNCATED TO SAVE SPACE ...>
        {
            "name": "Tom Holland",
            "category": ["Public Figure"],
            "keywords": ["Tom Holland", "tom holland"]
        },
        {
            "name": "Donald Trump",
            "category": ["Public Figure"],
            "keywords": ["Donald Trump", "Donald J. Trump"]
        }
    ]
}
```

- Descriptions of each keywords may lack information, you may need to **infer the underlaying artwork or franschise**.

- You need to copy the given keywords and keywords identified in "description" identically to "keywords" list in response.

- Respond empty list in "results" if there is no relatd artwork and media based on the category.

- You should ignore keywords that are not fall into any desired categories.

- You need to identify all artworks, series, franchise or book the given list of keywords belong to, use the **most well known and inclusive name**, and you respond without **detailed version or episode** using **English**

- **Avoid too general name**, such as DC Universe, Disney, Marvel Comics. **Focus on specific names**, such as Batmen, Spider-Man. '

- Public figure MUST be non-fictional people.

- Each unique public figure should have their own cluster with their most well-known name.

- You MUST focus on these categories only : "Video Games", "Tabletop Games", "Manga/Anime", "Film", "TV Show", "Western Cartoon/Comic", "Book", "Musical", and "Public Figure".

- You need to generate **no more than 80** results across all categories. Response most frequently referenced ones if more than 80.

- Respond **in pure json format** as the example above.

# Response
````

Figure 23: Subtopic Verification Prompt

```
You are a helpful assistant for translating structured data query over multi-lingual dataset into natural language for
multiple choice question answering, the answer can have multiple correct options.

# Input

{{query}}

# Context

Explanation of condition fields:
    1. user_name: the unique user name of a user
    2. time_week: the start date of a week
    3. label_level_1: the topic or domain of a dialogue.
    4. label_level_2: the subtopic or domain of a dialogue under a main topic in label_level_1.
    5. country: the country or region of the users' request come from.
    6. language: the language the users are using.
    7. keywords_aggregated: the keywords involved in the conversation, can be **one of** artworks/series/book/franchise,
    public figure and programming language.

# Examples

{{examples}}


# Instruction
- The general idea of translation is to generate natural language question that **faithfully** describe the "condition" and ask
about the "targat"
- You need to translate based on these condition explained in # Context.
- The attribute used in question that describe keywords_aggregated options should be inferred from given target and options.
- You **MUST condense all description of topic or subtopic** in the generated question, using faithfully summarized version.
- The question generated **MUST include all condition and target type** in **a natural and detailed way**.
- The question generated **MUST keep as much information as possible** from given topic description.
- Make sure the the generated question could be used as question of multiple choice question answering.
- Avoid leaking information and give hint in the question to the answer.
- Generate 2 possible questions with the same meaning but **diverse style**, **without target or candidate** in **English**,
similar to proper # Examples.
- Respond in json format:
{
    "question_list": [<questions...>]
}

# Response
```

Figure 24: Question Generation Prompt

model-generated terms or phrases (w_a, w_b), where $\text{len}(w_a) <= \text{len}(w_b)$ – based on a set of normalization criteria. Terms are considered equivalent across all keyword types except "Public Figure" if they satisfy any of the following conditions after applying string normalization:

1. w_a and w_b are identical.
2. w_a and w_b are identical after removing all stopwords in NLTK English stopwords list.
3. w_a is a prefix of w_b and w_a has more than 2 words.
4. w_a is a suffix of w_b and w_a has more than 2 words.
5. w_a is an abbreviation of w_b by concatenating all first letter of w_b.

For keywords of type "Public Figure" only Conditions 1 and 2 are applied due to the higher sensitivity of proper name matching. After normalization, we obtain a dataset with annotated two-level topic hierarchies and keywords spanning the following types: "Programming Language", "Video Games", "Tabletop Games", "Manga/Anime", "Film", "TV Show", "Western Cartoon/Comic", "Book", "Musical", and "Public Figure".

E.6 Question Proposal

Attributes Combination We generate questions through a brute-force search over various combinations and quantities of conditions. The full set of considered conditions is shown in Table 1. Specifically, we enumerate all possible attribute combinations containing 0 to 3 conditions and manually select 73 meaningful combinations that can be naturally expressed in language. The selected combinations are listed in Table 8.

Question Proposal Sampling For each attribute condition and target type combination, we enumerate all possible condition value configurations using MongoDB. For each configuration, we first verify that the number of documents satisfying the condition is at least 50, unless the condition involves the username attribute, in which case the threshold is reduced to 10. This ensures that each generated question is supported by a sufficient number of documents.

Next, we query the database again to check whether the top 3 most frequent target attribute values collectively account for at least 15% of all occurrences. This constraint prevents cases where the target distribution is overly uniform and lacks distinguishing signals.

All condition-target combinations that pass both checks are then stored in a map, where the key is the top-1 target value and the value is a list of corresponding condition-target combinations. Each list is sorted by the normalized entropy of the target distribution to prioritize more informative combinations.

Finally, we sample from this map in a round-robin manner, ensuring that each value is selected no more than twice. This strategy helps generate the most answerable questions while maintaining diversity across different top-1 target outcomes.

E.7 Question Generation

Given a set of condition types, corresponding values, and a target value, we prompt GPT-4.1 to generate natural language questions using the template shown in Figure 24.

```
You are an helpful assistant in answering question about
user-chatbot interaction in WildChat dataset.

# Conversations

{{conversations}}


# Question

{{question}}

Base on the conversation given above, answer the given
multiple choice question, **rank all options by relevance
or correctness** based on the # Conversations. Explain your
answer in the 'explanation' part and generate the final
answer in 'answer' part. Respond using index of answer and
using **pure json** format like:

{
    "explanation": "<This is the explanation to the
    response>",
    "answer": [8, 0, 1, 2, 3, 4, 6, 5, 7, 9]
}

# Answer
```

Figure 25: Question Answering Prompt

Following question generation, we retrieve the top 10 candidate answers for ranking by querying the database. In cases where fewer than 10 valid candidates are available, we supplement them by sampling from the global distribution of values that share the same target type.

Using this procedure, we generated a total of 6,177 questions.

E.8 Question Quality Control

We employ o4-mini for final quality control. Specifically, o4-mini is used to rank target candidates under two settings: (1) without any supporting context, and (2) with supporting context provided in the form of either summaries or raw conversations, using the prompting format shown in Figure 25.For each instance, we compute the instance-wise NDCG@10 score in the no-context setting, denoted as $s_{\text{no\_context}}$, and define the contextual score as $s_{\text{context}} = \max(s_{\text{raw\_context}}, s_{\text{summary\_context}})$, where $s_{\text{raw\_context}}$ and $s_{\text{summary_context}}$are scores under raw and summarized contexts, respectively.

To assess statistical significance, we calculate a confidence-based threshold to determine whether a contextual improvement is meaningful over random performance. The threshold is defined as:

$$s_{\text{threshold}} = \min(1.0, \max(0.0, s_{\text{random}} + z_{0.90} * s_{\text{std}})) \tag{4}$$

where s_{std} is the standard deviation estimated via a Monte Carlo approach, and $z_{0.90}$ is the 90%-confidence z-score.We remove any instance that satisfies both of the following conditions:

- $s_{\text{context}} - s_{\text{no\_context}} \leq 0$
- $s_{\text{context}} < s_{\text{threshold}}$

After filtering, we retain a total of 6,027 valid data samples for downstream evaluation.