CREDIT-SQL: Few-shot prompting for context-dependent text-to-SQL with regularized examples from diversity sampling

Anonymous ACL submission

Abstract

In this paper, we propose a few-shot prompting method called CREDIT-SQL for the contextdependent text-to-SQL problem. CREDIT-SQL converts each question in a multi-turn dialogue into a self-contained question with a fixed few-shot prompt. Once a self-contained question is obtained, CREDIT-SQL converts it into an SQL query using a prompt made of in-context examples selected by diversity sampling and subsequent example voting. After experimentations with multiple LLMs, CREDIT-SQL achieves 58.6% in terms of the exact set match without values on the dev set of CoSQL, which is the performance comparable to the state-of-the-art models for context-dependent text-to-SQL. We also argue that the example voting we introduced in CREDIT-SQL can serve as an efficient and effective way to mitigate the instability of in-context example selection in general.

1 Introduction

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Information retrieval from structured knowledge sources is an NLP task widely applicable in many areas. Text-to-SQL is a promising approach to achieve this goal due to the popularity of SQL as an interface between the user and the database. Text-to-SQL systems have shown remarkable improvements (Wang et al., 2020a,b; Lin et al., 2020; Cao et al., 2021; Scholak et al., 2021; Cai and Wan, 2020) along with the rapid advancements of sequence-to-sequence models including the infamous transformer model (Vaswani et al., 2017). The advantages of these advanced sequence-tosequence models have been often utilized by finetuning pre-trained decoder-encoder models. However, these advanced models become so large that they are called large language models (LLMs) which typically have parameter size ranges from a few tens of billion to a few hundreds of billion (Ye et al., 2023; OpenAI, 2023; Touvron et al., 2023a,b; Anil et al., 2023). Because of this large model size,

it takes too much resource to fine-tune these large language models on custom datasets.

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To utilize the advantages of advanced sequenceto-sequence models without investing full resources for fine-tuning, in-context learning with zero-shot prompts or few-shot prompts has become popular recently. In the case of few-shot in-context learning, a few in-context examples are listed in the prompt along with a brief instruction, and the LLM outputs the desired sequence as the response to the input prompt. Although the limited context size of available LLMs only allows a handful of in-context examples to be included in each prompt, it has been shown that strategic designs of prompts can perform as well as fine-tuned models in the tasks of text-to-SQL (Pourreza and Rafiei, 2023; Nan et al., 2023; Dong et al., 2023; Gao et al., 2023).

Still, most in-context learning studies on text-to-SQL tasks focus on the context-independent setting where the system needs to answer a single SQL query on the input of a single question. This context-independent setting becomes particularly inconvenient when one needs to develop conversational information retrieval systems where previous questions or answers can implicitly appear in the user's later questions.

To address this problem, we propose a few-shot prompting method called CREDIT-SQL¹ in this paper (See Figure 1, 2, and 3). CREDIT-SQL does context-dependent question rephrasing to convert a multi-turn text-to-SQL task on each dialogue into a series of question-query pair text-to-SQL tasks. Once all the questions are rephrased, a diversitysampled prompt is used to address the text-to-SQL tasks. This prompt is composed of examples obtained via multiple trials of diversity sampling and subsequent example voting. Each example in the prompt is represented as a pair of the rephrased question and the regularized SQL query along with

¹Context-dependent Regularized Examples from DIversity sampling for Text-to-SQL.

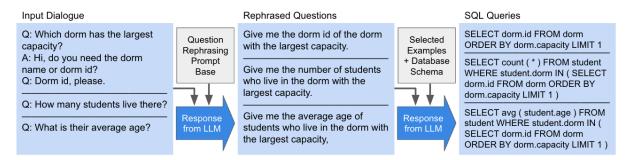


Figure 1: Illustration of overall question to SQL process of CREDIT-SQL. The details of the question rephrasing process are illustrated in Figure 2, and the details of the example selection process are illustrated in Figure 3.

the database schema.

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We claim that our approach makes the following contributions. (1) To the best of our knowledge, we propose the first few-shot prompting approach to perform the dialogue state tracking task with systematically selected in-context examples out of the entire training data. (2) We experimented our approach with multiple open and closed-sourced LLMs, and we report the performance comparable to the state-of-the-art models in the dialogue state tracking task on the CoSQL dataset, which is ranked 1st in the execution accuracy without values and 4th in the exact set match without values on the CoSQL dev set among the models reported on the CoSQL leaderboard at the moment of writing. (3) We suggest a new method to mitigate the instability of in-context example selection in the few-shot prompting with LLM by introducing voting on collected examples.

2 Related works

2.1 Context-dependent text-to-SQL

Most studies on text-to-SQL tasks focused on context-independent settings where a single question is transcribed into a single SQL query. To cope with the complicated scenarios where multiple tables are involved, utilizing graph structures to capture the relations between entities has been the most popular and successful method in text-to-SQL tasks recently (Bogin et al., 2019; Wang et al., 2020a,b; Lin et al., 2020; Cao et al., 2021; Scholak et al., 2021; Cai et al., 2021; Hui et al., 2022).

Unlike its context-independent counterpart, context-dependent text-to-SQL tasks require encoding the context within the dialogue and exploiting this context in the SQL generation. Recently, numerous different approaches have been suggested to tackle this problem. Zhang et al. 2019 used turn attention to edit the SQL query of the previous turn to accommodate the question at the current turn. Cai and Wan 2020 extends the graph structure for the database schema to establish connections between neighboring turns in the dialogue. Wang et al. 2021 and Hui et al. 2021 suggested using a graph structure state tracker to capture the context of the dialogue at each turn, while Zheng et al. 2022 used BERT to encode the history of the dialogue. Pan et al. 2019, Chen et al. 2021, and Chai et al. 2023 rephrased the question at each turn reflecting the context of the dialogue. Xiao et al. 2022 applied question rephrasing recursively and introduced consistency training to build one of the state-of-the-art models at the time of writing. Other state-of-the-art models used utterance dependency tracking with weighted contrastive learning (Cai et al., 2022) or integrating relational structure through the attention layer into the pre-trained models (Qi et al., 2022).

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2.2 Prompting with large language models for text-to-SQL

As in its non-prompting counterpart, most of the efforts to perform text-to-SQL tasks focused on context-independent text-to-SOL tasks. Pourreza and Rafiei 2023 used different in-context examples for each difficulty of the question. Dong et al. 2023 achieved one of the best performance among zero-shot prompting efforts. Beyond the arbitrary selection of in-context examples, there have been trials to choose in-context examples in a systematic manner. Liu et al. 2022 introduced questionsimilarity based example selection using k-NN algorithm. Nan et al. 2023 noticed that the diversity of the in-context examples in a prompt is indeed important, and suggested methods to balance the similarity and the diversity of in-context examples based on their ground-truth SQL queries. Gao et al. 2023 achieved the best performance on the leader-

board of Spider (Yu et al., 2018) at the time of 157 writing, with systematic in-context example selec-158 tion using both questions and SQL queries. Beyond 159 the context-independent setting, Hu et al. 2022 ad-160 dressed context-dependent text-to-SQL tasks with 161 few-shot prompting and zero-shot prompting, but 162 systematic in-context example selection was still 163 lacking. 164

3 Methods

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3.1 Context-dependent question rephrasing

Inspired by the success of question rephrasing approaches (Pan et al., 2019; Chen et al., 2021; Chai et al., 2023; Xiao et al., 2022), we summarize the context of each dialogue into a single question with few-shot prompting at every turn. For the few-shot prompts for this question rephrasing step, we randomly sampled 20 examples out of train set of CoSQL dataset (Yu et al., 2019a), and the fixed prompt base we used for question rephrasing is in Appendix A. In each multi-turn interaction, rephrased questions from previous turns are appended in the prompt to rephrase questions in further turns. The entire process of question rephrasing is illustrated in Figure 2.

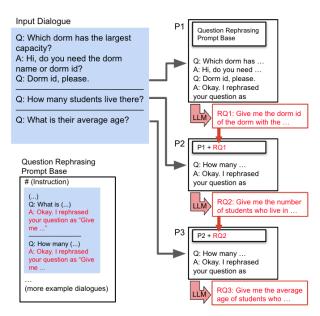


Figure 2: Context-dependent question rephrasing process. A prompt containing examples of multiple dialogues is used to rephrase each question into a rephrased question starting with "Give me ...". Each rephrased question is appended to the prompt for further question rephrasing of later turns.

This question rephrasing process converts the context-dependent text-to-SQL task into the sim-

ple text-to-SQL task which is better studied in the literature than the context-dependent counterpart. This process also regularizes the questions in a similar format ("Give me ...") which can help to create consistent in-context examples for the text-to-SQL tasks. This helps LLM to focus more on transcribing relevant natural language expressions into SQL expressions rather than on deciphering the meaning of the questions written in different styles.

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3.2 SQL query regularization

To increase the consistency of the in-context examples for the text-to-SQL tasks, we regularize the SQL queries used in text-to-SQL prompts with rule-based methods. This regularization includes capitalization, spacing, unaliasing, table representation in each column reference, and so on. Examples of affected SQL queries through this regularization are shown in Table 1. For further details, we attach the pseudocode implementation of the SQL regularization in Appendix F.

Given SQL	Regularized SQL
<pre>select * from tb_1;</pre>	SELECT * FROM tb_1
SELECT T1.C1 FROM tb_1 as T1 JOIN tb_2 as T2 on T1.C3=T2.C4	SELECT tb_1.c1 FROM tb_1 JOIN tb_2 ON tb_1.c3 = tb_2.c4
select COUNT(*)	SELECT count (*)
from tb_1	FROM tb_1
where c2=="A"	WHERE $tb_1.c2 == A'$

Table 1: Examples of affected SQL query expressionsthrough the rule-based SQL query regularization.

Similar to the question rephrasing, SQL query regularization helps LLM to focus more on the grammatical structure of SQL queries or links to the database schema rather than on different expression styles of SQL queries.

3.3 Example selection for text-to-SQL

In the few-shot prompting with LLM, the performance of the model is very sensitive to the choice of in-context examples. In particular, strategic sampling of examples out of the training data significantly outperforms the random choices of examples. A natural way to customize in-context examples for each question is to collect the closest examples to the given question, often based on the similarity in the embedding vector space (Liu et al., 2022). In the meanwhile, Nan et al. 2023 pointed

out that keeping the diversity of the example pool 219 can be more important than a mere collection of 220 similar examples. As introduced in Nan et al. 2023, 221 we adopt diversity sampling through the k-means clustering based on the vectorized SQL queries. Specifically, we vectorized all SQL queries in the CoSOL train set as presented in the pseudocode in Appendix G. Then we perform the clustering with k = N for the N-example prompt based on these vectors. In each cluster, we choose the example closest to the centroid in the SQL vector space. In case the number of resulting clusters N_c is smaller than N, we fill the rest of the examples based on 231 the distance with previous examples. To be specific, 232 among training data examples $\{e_1, e_2, \cdots, e_T\}$ with SQL vectors $\{\mathbf{x}_1, \mathbf{x}_2, \cdots, \mathbf{x}_T\}$, *n*th selected example s_n is

$$s_n - e_i$$

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$$i_n = \operatorname{argmin} |\mathbf{x_i} - \mathbf{c_n}| \text{ for } n \leq$$

$$i_n = \operatorname*{argmax}_{i \notin \{i_1, \cdots, i_{n-1}\}} \left(\min_{j < n} \left| \mathbf{x}_i - \mathbf{x}_{i_j} \right| \right)$$

for $N_c < n \le N$,

 N_c ,

where $\{c_1, c_2, \cdots c_{N_c}\}$ are the SQL vectors of cluster centroids.

Since the k-means clustering is a nondeterministic algorithm that depends on the random initial positions of centroids, the selection result of examples varies depending on the choice of random seed. To mitigate this inconsistency of example selection, we adopt example voting. First, we collect N-example prompt through the k-means clustering. We repeat this example collection M times, with a different random seed each time. Then we rank each example by its occurrence among these *M* different sets of examples. The entire example selection process is illustrated in Figure 3. With some parameter search (see Figure 4 and Figure 5 for the search space), we obtained the best result with N = 18 and M = 20. For the rest of the paper, CREDIT-SQL used in-context examples selected by the voting process with N = 18 and M = 20 otherwise noted. We show these selected in-context examples in Appendix B.

3.4 Example demonstration

In our few-shot prompt for text-to-SQL, we demonstrate selected in-context examples along with the database ID and the database schema including table names, column names, and foreign keys. A

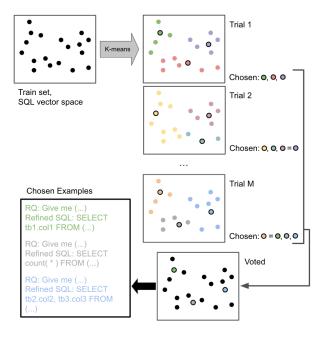


Figure 3: Example selection process using diversity sampling and subsequent example voting. Centroids obtained through the k-means clustering (k = N) are used to pick N examples. After repeating this selection M times, aggregated in-context examples are voted by their counts to finally choose N examples.

sample text-to-SQL prompt for the CREDIT-SQL approach including the example demonstration is in Appendix C.

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4 Experiments

4.1 Dataset

The most popular benchmark for the text-to-SQL task is Spider dataset (Yu et al., 2018), which is a large-scale, complex, and cross-domain dataset with 10k+ questions with annotated SQL queries and covers 200 different databases across 138 domains. SParC (Yu et al., 2019b) is a multi-turn version of the Spider dataset which covers the same sets of databases as Spider. CoSQL (Yu et al., 2019a) is a dialogue version of Spider and SParC, which includes about 3k dialogues with 10k+ annotated SQL queries over the same sets of databases. CoSQL is different from SParC for it contains turns that does not require immediate SQL query response, such as clarification of the question. This makes CoSQL a more suitable dataset for the development of conversational systems for information retrieval from structured knowledge sources. Since CoSOL is the latest and most complex context-dependent text-to-SQL dataset available at the moment of writing, we benchmark our

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approach with this dataset.

4.2 Models

Throughout the paper, we experimented with LLMs of Open AI serviced through Microsoft Azure². Beyond the Open AI models, we experimented with gemini-pro (Team et al., 2023) serviced through Google AI Python SDK³. To test other opensourced models as well, we also experimented with SQLCoder-7B-2⁴ and CodeLlama-13B (Roziere et al., 2023) using vLLM library (Kwon et al., 2023)⁵.

In any experiment, we restricted the output size to 600 tokens to accommodate with the context size limitations. We also set the temperature to 0 for the consistency of the result.

4.3 Evaluation metric

To evaluate the performance of our approach, we use two following metrics as suggested for the SQLgrounded dialogue state tracking task in CoSQL challenge (Yu et al., 2019a):

> • Exact set match without values (EM): Measures if the predicted SQL query and the ground truth SQL query are equivalent to each other, by comparing the equivalence of each component of the queries. When multiple parallel items are compared, set equivalence is measured so that it does not prefer a particular ordering. It also masks literal/numeral values when comparing each component.

> • Execution accuracy with values (EX): Measures if the both outputs of the predicted SQL query and the ground truth SQL query are equal to each other. To generate actual outcomes based on the database, it uses the values in each query as they are.

The two accuracy metrics are evaluated at the question level (question match, QM) and at the interaction (dialogue) level (interaction match, IM).

4.4 Baseline approach: randomly sampled dialogues

For comparison purposes, we establish a baseline few-shot prompting method. It randomly samples multiple dialogues and presents them along with their database schema. The template of this baseline prompt is in Appendix D. 329

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4.5 Experiment results

We report the performances of our baseline approach and CREDIT-SQL on the CoSQL dataset in Table 2, along with the performances of state-ofthe-art models. In the dev set, our CREDIT-SQL method outperforms the baseline approach of fewshot prompting using randomly sampled dialogues by 8.7%p in EM for the question match while it outperforms the baseline approach by 2.4%p in EX for the question match. Our approach also shows comparable performance to the state-of-the-art models, by the margin of $0.2\% p \sim 1.1\% p$ in EM for the question match on the dev set, and shows the best EX for the question match on the dev set. At the time of writing, our approach ranks 4th in EM-QM and 1st in EX-QM on the CoSQL dev set among the models reported on the CoSQL leaderboard.

5 Discussion

5.1 Effectiveness of SQL regularization and diversity sampling

We conducted an ablation study to find out the effectiveness of each module of our CREDIT-SQL approach. The study result is reported in Table 3. This study indicates that subtracting SQL regularization from the prompt drops the EM (EX) for the question match by 0.6%p (0.2%p). When the prompt with examples collected by diversity sampling is replaced with a prompt with randomly sampled examples, the EM (EX) for the question match drops by 5.5%p (2.7%p).

5.2 Effectiveness of example voting

To study the effectiveness of example voting in CREDIT-SQL, we investigated the performance of different methods to aggregate multiple sets of diversity-sampled examples with distinct random seeds. In particular, we plot EM and EX for the question match on the CoSQL dev set of those different methods versus the number of aggregated sets of diversity-sampled examples in Fig 4. These aggregation methods include: (1) the average of each set's performance, (2) the maximum of each

²https://learn.microsoft.com/en-us/azure/ai-

services/openai/concepts/models. We used OpenAI Python API library (https://github.com/openai/openai-python) for the experiments. This library is under Apache-2.0 license and we complied to the license.

³https://github.com/google/generative-ai-python. This library is under Apache-2.0 license and we complied to the license.

⁴https://huggingface.co/defog/sqlcoder-7b-2

⁵https://github.com/vllm-project/vllm. This library is under Apache-2.0 license and we complied to the license.

		EM (%)				EX (%)			
Model	Q	М	Π	М	Q	М	II	M	
	Dev	Test	Dev	Test	Dev	Test	Dev	Test	
STAR (Cai et al., 2022)	59.7	57.8	30.0	28.2	-	-	-	-	
CQR-SQL (Xiao et al., 2022)	58.5	58.3	31.1	27.4	-	-	-	-	
RASAT+PICARD (Qi et al., 2022)	58.8	55.7	27.0	26.5	67.0	66.3	39.6	37.4	
Fe	w-shot	Promp	ting						
Baseline, randomly sampled dialogues	49.9	-	21.6	-	65.0	-	33.2	-	
CREDIT-SQL	58.6	-	25.8	-	68.6	-	36.5	-	

Table 2: Results on the CoSQL dataset. Exact set match without values (EM) and execution accuracy with values (EX) are presented for both the question match (QM) and the interaction match (IM). For the few-shot prompting methods, we present the results of the baseline approach (randomly sampled dialogues) as well as the results of CREDIT-SQL, both with the average performance of 5 repeated experiments on gpt-3.5-turbo-0301. Results for other models are as reported in the literature for comparison.

Model	EM	(%)	EX (%)		
WIUUEI	QM	IM	QM	IM	
CREDIT-SQL	58.6	25.8		36.5	
w/o SQL Reg.	58.0	24.9	68.4	36.2	
w/o Div. Prompt	53.1	20.1	65.9	33.1	

EM (%) EX (%) **Clustering Method** QM IM QM IM k-means 58.6 25.8 68.6 36.5 Agglomerative 58.1 26.3 68.2 36.5 Spectral 56.3 23.5 67.7 34.5

Table 3: Ablation studies for CREDIT-SQL on the CoSQL Dev set. We used gpt-3.5-turbo-0301 and used 18 examples out of 20 votes for the text-to-SQL. The results without SQL regularization and the results without diversity prompt are presented. Each experiment is repeated 5 times and the average performance is reported.

377	set's performance, (3) the performance of EM-
378	based consistency voting from each set's SQL re-
379	sults, and (4) the performance of the prompt made
380	of voted examples among the all examples of the
381	given sets. The last method is adopted for our
382	CREDIT-SQL. As illustrated in Fig 4, the voted-
383	example prompt outperforms either the average or
384	the maximum of the individual results of distinct
385	diversity-sampled prompts for the number of sets
386	around 12 or more. Moreover, our proposed voted-
387	example prompt performs similar to or better than
388	the popular method of voting on SQL results, for
389	the number of sets around 12 or more. Further-
390	more, the voted-example prompt is more efficient
391	in the sense that it only uses a single inference
392	of text-to-SQL per each SQL query regardless of
393	the aggregation number M , while the consistency
394	voting requires M inferences to aggregate M sets
395	of examples. This may suggest a new possibility
396	for efficiently mitigating the instability of example
397	selection in the few-shot prompting with LLM in
398	general.

Table 4: Comparison of different clustering methods. We used gpt-3.5-turbo-0301 and used 18 examples out of 20 votes for the text-to-SQL. Agglomerative clustering method here used Ward linkage, and spectral method used k-means to cluster the spectrum.

5.3 Effects of number of examples in text-to-SQL prompt

We investigated the effects of number of examples in text-to-SQL prompt in the performance of the model in Fig 5. Due to the limited context size, we could not experiment number of examples beyond 21. Within the number of examples we investigated, there was no clear correlation between the performance of the model and the number of examples used. We opted best number of examples within our hyperparameter search.

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Effects of different clustering methods 5.4

We investigated the effects of different clustering 411 methods in text-to-SQL prompt in the performance 412 of the model in Table 4. While we opted k-means 413 for the CREDIT-SQL, agglomerative clustering 414 with Ward linkage (Ward Jr, 1963) also showed 415 similar performances on the CoSQL dev set. The 416 spectral clustering (Shi, 2003) was behind the other 417 two clustering methods in the performances on the 418 same dev set. 419

LLM	Number of Completion		EM (%)		EX (%)	
	examples	method	QM	IM	QM	IM
gpt-3.5-turbo-0301	18	Text	58.6	25.8	68.6	36.5
gpt-3.5-turbo-0301	12	Text	57.3	24.6	67.4	35.2
gpt-3.5-turbo-instruct	12	Text	54.9	23.9	65.7	32.4
gpt-3.5-turbo-16k	18	Chat	51.7	19.8	63.3	29.7
gpt-3.5-turbo-16k	50	Chat	51.5	18.8	64.1	30.4
gpt-4-turbo	18	Chat	54.0	21.5	65.2	32.1
gemini-pro	18	Text	51.3	16.4	63.9	29.0
SQLCoder-7B-2	18	Text	33.1	6.8	46.1	15.4
CodeLlama-13B	18	Text	28.6	5.8	34.3	8.9

Table 5: Performances of CREDIT-SQL on the CoSQL dev set, with different LLMs. We present the number of text-to-SQL examples as well as the completion method used for each experiment. For the chat completion method, we input the entire few-shot prompt as a system message.

5.5 Performance analysis by question difficulty

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CoSQL provides the difficulty of each question based on the components of the golden SQL query for that question. Here we analyze the performance of the best-performing CREDIT-SQL on the CoSQL dev set by the question difficulty (Figure 6). As anticipated, both the execution accuracy and the exact set match decreases as the question difficulty increases.

5.6 Performances with different LLMs

To determine the LLM model to be used for the CREDIT-SQL, we evaluated the CoSQL dev set with different LLMs (Table 5). Within the OpenAI models (gpt-...), gpt-3.5-turbo-0301 performed the best while we observed that the text completion method outperforms the chat completion method significantly. Other models beyond OpenAI models were not performing as well as other OpenAI models while gemini-pro showed the best performance among SOLCoder-7B-2, which is a fine-tuned them. CodeLlama model to the text-to-SQL task, performed better than the larger size CodeLlama model, CodeLlama-13B. Although we tested only 7B model for the resource limitation, the benchmark on the model card of SQLCoder-7B-2⁶ indicates that the performance gain of using a larger model might be limited to a few percent points.

5.7 Error analysis

To understand the cases in which CREDIT-SQL does not perform well, we performed an error anal-

ysis on the results of the best-performing CREDIT-SQL. In particular, we present questions with the incorrect exact set match at the question match level in Figure 7. To categorize the errors, we used the keyword analysis provided by the official evaluation code⁷ for the CoSQL dataset (Zhong et al., 2020). To understand how much the exact set match errors and the execution accuracy errors are correlated, we also present the pie chart that describes the correlation of those two metrics in Figure 7. Further case studies of errors can be found in Appendix E. 452

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5.8 Limitations and future works

Since our work focused on the CoSQL dataset, the prompts we suggest in this paper might have difficulty in generalizing to the databases and SQL queries outside the CoSQL dataset. Indeed, testing the generalizability of CREDIT-SQL to other context-dependent SQL datasets would be an interesting subject for future research. While we tested several other LLMs beyond OpenAI models, one may test the performance of CRDEIT-SQL on a further variety of the latest LLMs for future research. Our ablation study on the number of text-to-SQL examples was rather inconclusive due to the limited context size, so an investigation of the effects of the number of examples on a LLM with far larger context size can provide a good insight into our approach.

6 Conclusion

In this paper, we propose a few-shot prompting method called CREDIT-SQL which is the first few-

⁶https://huggingface.co/defog/sqlcoder-7b-2

⁷https://github.com/taoyds/test-suite-sql-eval

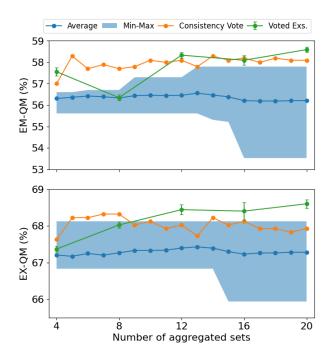


Figure 4: Comparison of different methods of aggregating multiple diversity-sampled sets of examples generated with distinct random seeds. We present EM-QM and EX-QM on the CoSQL dev set for comparison. For this study, We used gpt-3.5-turbo-0301 and used 18 examples out of 20 votes for the text-to-SQL. Blue solid line: Average of the results generated by prompts with distinct random seeds, up to the given number of prompts. Blue shades: The minimum to the maximum range for the results generated by prompts with distinct random seeds, up to the given number of prompts. Orange: The EM-based consistency voting results on the SQL results of the given number of sets. Green: The result of the prompt made of voted examples out of all examples from the given number of prompts. Average performance over 5 repetitions is reported along with the error bar size of the standard deviation.

shot prompting approach to perform the dialogue 484 state tracking task with systematically selected in-485 context examples out of the entire training data. 486 CREDIT-SQL splits each dialogue state tracking 487 task into multiple question-query pair text-to-SQL 488 tasks by question rephrasing and utilizes the di-489 versity sampling and subsequent in-context exam-490 ple voting to prepare the few-shot prompts for the 491 text-to-SQL tasks. Experiments demonstrate that 492 **CREDIT-SQL** achieves a performance comparable 493 to the state-of-the-art models. Also, the technique of example voting used in CREDIT-SQL suggests a 495 new way to mitigate the instability of in-context ex-496 ample selection in the generic few-shot prompting 497 setting. 498

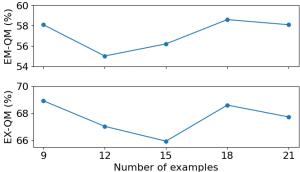


Figure 5: EM-QM and EX-QM on the CoSQL dev set for the different number of examples. We used gpt-3.5-turbo-0301 and used 18 examples out of 20 votes for the text-to-SQL.

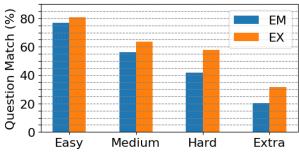


Figure 6: Performance of CREDIT-SQL on the CoSQL dev set by the question difficulty. We present the EM-QM and EX-QM along with 4 difficulty categories: easy, medium, hard, and extra.

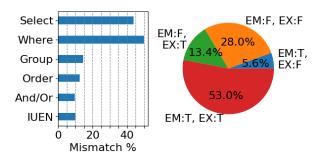


Figure 7: Left: Error analysis of CREDIT-SQL on the exact set match errors at the question match level. Here we present the mismatch percentage for each category of SQL query keywords. Here IUEN stands for IN, UNION, EXCEPT, or NOT IN. Since each incorrect SQL query may contain multiple mismatches, mismatch percentages for different categories are not disjoint. **Right:** Correlation of EM and EX, evaluated on the CoSQL dev set at the question match level.

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"Give me	869
ons whose	870
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A Question Rephrasing Prompt Base

For the question rephrasing prompt, we randomly sampled 20 examples from the CoSQL training data. Each question in the sampled examples is manually rephrased so that the rephrased question starts with "Give me ..." and the question is self-contained without referring to any previous context. Following is the question rephrasing prompt base we used for CREDIT-SQL:

Database: department_store

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- Q1: List the name of all suppliers in alphabetical order of their addresses.A1: Okay. I rephrased your question as "Give me
- the names of all suppliers, ordered alphabetically
 by their addresses."
 - Q2: And their phone numbers?
 - A2: Okay. I rephrased your question as "Give me the phone numbers of all suppliers, ordered alphabetically by their addresses."
 - Q3: What states is Tesco located in?
 - A3: do you mean the address id or the address details?
 - Q4: The address details.
- A4: Okay. I rephrased your question as "Give methe address details of Tesco."
- 842 Q5: How about Lidl?
 - A5: Okay. I rephrased your question as "Give me the address details of Lidl."

Database: theme_gallery

- Q1: Show the average ticket prices for exhibitions for all years before 2009?
- A1: Okay. I rephrased your question as "Give me
 the average ticket price of all exhibitions whose
 year before 2009."
- Q2: Show minimum ticket prices for exhibitionsfor all years before 2009?
- A2: Okay. I rephrased your question as "Give me the minimum ticket price of all exhibitions whose year before 2009."
- Q3: Show maximum ticket prices for exhibitions for all years before 2009?
- A3: Okay. I rephrased your question as "Give me
 the maximum ticket price of all exhibitions whose
 year before 2009."
- Q4: Show average ticket price for exhibitions foryear 2005?

A4: Okay. I rephrased your question as "Give me the average ticket price of all exhibitions whose year is 2005."

Q5: Show average ticket price for exhibitions for all years before 2006?

A5: Okay. I rephrased your question as "Give me the average ticket price of all exhibitions whose year before 2006."

Database: apartment_rentals

Q1: How many bathroom count those building 809 has?

A1: The total number of bathrooms building 809 has is NULL.

Q2: How about building 808?

A2: Okay. I rephrased your question as "Give me the total number of bathroom count of all building 809."

Q3: How about the total number of rooms it has? A3: Okay. I rephrased your question as "Give me the total number of rooms of all building 809."

Database: wine_1 Q1: Which wine has the highest price? A1: Okay. I rephrased your question as "Give me the wine with the highest price." Q2: Which wine has the highest score? A2: Okay. I rephrased your question as "Give me the wine with the highest score." Q3: Which wine has the most cases available? A3: Okay. I rephrased your question as "Give me the wine with the most cases available." Q4: How about winery with the least cases? A4: Okay. I rephrased your question as "Give me

the winery with the least cases."

- Database: dorm_1 Q1: How many students live in each dor
- A1: Okay. I rephrased your question as "Give m the total number of students of each dorm."

Q2: What is the average age of the students living in each dorm?

A2: Okay. I rephrased your question as "Give me the average number of students of each dorm."

Database: roller_coaster90Q1: what is the highest length of coaster91A1: Okay. I rephrased your question as "Give me91the highest length of all costers."91Q2: which roller coaster are top speed91

^{###} Make sure the rephrased questions do not need any implicit information of the previous dialogue.

014	A2: Okay. I rephrased your question as "Give me	number of type code."	065
914 915	the roller coaster with highest speed."	Q2: What are the product names of all products	965
916	Q3: what is the height of Boardwalk Bullet	with the type code "Food"?	966 967
	A3: Okay. I rephrased your question as "Give me	A2: Okay. I rephrased your question as "Give me	
917 918	the height of Boardwalk Bullet."	the product names of all products with the type	968 969
910	the neight of boardwark bullet.	code "Food"."	970
920	Database: entrepreneur	Q3: What are the prices of those?	
921	Q1: What is the largest weight that appears in the	A3: Okay. I rephrased your question as "Give	971 972
922	people table?	me the prices of all products with the type code	972
923	A1: Okay. I rephrased your question as "Give me	"Food"."	973
924	the maximum weight of all people."	Q4: What are the names and prices of all products	974
925	Q2: Can you add the people id associated with that	with the type code books?	976
926	weight into the table?	A4: Okay. I rephrased your question as "Give me	977
927	A2: Okay. I rephrased your question as "Give me	the names and prices of all products with the type	978
928	the maximum weight of all people and the people	code books."	979
929	id of that person."	Q5: What are the name and type code of the prod-	980
930	Q3: Can you also add the name associated with	uct with the highest price?	981
931	that people id into the table?	A5: Okay. I rephrased your question as "Give me	982
932	A3: Okay. I rephrased your question as "Give me	the name and type code of product with the highest	983
933	the maximum weight of all people and the people	price."	984
934	id, name of that person."	Q6: Can you list all product names and their cor-	985
935	r, i i i i i r i i r	responding type codes of the products with prices	986
936	Database: customers_campaigns_ecommerce	below the average price?	987
937	Q1: Can you tell me the highest number of mail-	A6: Okay. I rephrased your question as "Give	988
938	shots for the customers?	me the names and product codes of all products	989
939	A1: Okay. I rephrased your question as "Give me	with prices below the average price of all products."	990
940	the highest number of mailshots for the customers."		991
941	Q2: What about the highest mailshot id number?	Database: student_assessment	992
942	A2: Okay. I rephrased your question as "Give me	Q1: what is the course id of English course?	993
943	the mailshot id number of mailshot with the highest	A1: Okay. I rephrased your question as "Give me	994
944	number of mailshots."	the course id of English course."	995
945	Q3: What is the customer id for that mailshot id?	Q2: name the student ids who attend the statastic	996
946	A3: Okay. I rephrased your question as "Give	course?in order of attendance date	997
947	me the customer id number of mailshot with the	A2: Okay. I rephrased your question as "Give	998
948	highest number of mailshots."	me the student ids of all students who attend the	999
949	Q4: How many mailshots does customer id 1 have?	statastic course, ordered by the attendence date."	1000
950	A4: Okay. I rephrased your question as "Give me	Q3: what is the date of attendance of the student is	1001
951	the total number of mailshots of customer id 1."	121?	1002
952	Q5: What is the name of customer id 1?	A3: the date of attendance of the student with id	1003
953	A5: Okay. I rephrased your question as "Give me	121 is 2012-04-09 11:44:34.	1004
954	the name of customer id 1."	Q4: which student id attend english and french	1005
955	Q6: What is the amount of mailshots that Wendell	both course?	1006
956	has?	A4: Okay. I rephrased your question as "Give me	1007
957	A6: Okay. I rephrased your question as "Give me	the student ids of all students who attend both	1008
958	the total number of mailshots of Wendell."	courses of English and French."	1009
959			1010
960	Database: solvency_ii	Database: chinook_1	1011
961	Q1: What is the most common type code of all the	Q1: what are the durations of the longest tracts?	1012
962	products?	A1: Okay. I rephrased your question as "Give me	1013
963	A1: Okay. I rephrased your question as "Give me	the durations of the longest tracts."	1014
964	the type code of all products with the maximum	Q2: what are the shortest tracks?	1015

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the hire dates of all employees with department institutions			-	
Same as the department of Clara. Al. Okay. I repinased your question as Olve Thi		- · · ·		
		sume as the department of Crata.	in oray. Trephased your question as one	111/

1119	institutions."	party_host.host_id = host.host_id]	1168
1120	Q2: show the institute type with highest number of	Q: Give me the names of all nations with hosts	1169
1121	institutions	younger than 35.	1170
1122	A2: Okay. I rephrased your question as "Give	SQL: SELECT DISTINCT host.nationality FROM	1171
1123	me the institute type with the highest number of	host WHERE host.age < 35	1172
1124	institutions."	-	1173
1125	Q3: which university is founded first	Database: company_1	1174
1126	A3: Okay. I rephrased your question as "Give	Table department, columns = [*, name, number,	1175
1127	me the university with the earliest foundation date."	mgr_ssn, mgr_start_date]	1176
1128	2	Table dependent, columns = $[*, essn, depen-$	1177
1129	Database: formula_1	dent_name, sex, bdate, relationship]	1178
1130	Q1: list the forename of all races	Table dept_locations, columns = [*, number, loca-	1179
1131	A1: Okay. I rephrased your question as "Give me	tion]	1180
1132	the forenames of all races."	Table employee, columns = [*, fname, minit, lname,	1181
1133	Q2: what is the forename of the race that occurred	ssn, bdate, address, sex, salary, super_ssn, dno]	1182
1134	most recently?	Table project, columns = [*, pname, number, loca-	1183
1135	A2: Okay. I rephrased your question as "Give me	tion, dnum]	1184
1136	the forename of the race with the latest occurance	Table works_on, columns = [*, essn, pno, hours]	
1137	date."	Foreign_keys = []	1185
1138	Q3: what is its code?	0 - 7 - 6	1186
1139	A3: Do you mean circuit id?	Q: Give me the total number of employees with	1187
1140	Q4: yes	salary lower than 50000.	1188
1140	A4: Okay. I rephrased your question as "Give me	SQL: SELECT count (*) FROM employee	1189
	the circuit id of the race with the latest occurance	WHERE employee.salary < 50000	1190
1142	date."	D Sample Prompt for the Baseline	1191
1143	uate.	Approach	
1144	B In-context Examples Selected via	Approach	1192
1145	Voting for CREDIT-SQL Text-to-SQL	Following is a sample prompt for the baseline ap-	1193
1146	Prompt	proach with 2 dialogues:	1194
	*		1195
1147	We present the 18 voted examples we used for the	# Generate the SQL query for each question about	1196
1148	text-to-SQL prompt of our CREDIT-SQL approach	the given database schema.	1197
1149	in Table 6. We performed k-means clustering with		1198
1150	k = 18 and voted examples collected from 20 trials	Database: inn_1	1199
1151	of clustering with distinct random seeds.	Table reservations, columns = $[*, code, room,$	1200
		check-in, checkout, rate, lastname, firstname,	1201
1152	C Sample Text-to-SQL Prompt for	adults, kids]	1202
1153	CREDIT-SQL	Table rooms, columns = [*, roomid, roomname,	1203
1154	Following is a sample text-to-SQL prompt for	beds, bedtype, maxoccupancy, baseprice, decor]	1204
1155	CREDIT-SQL in the case of $N = 2$:	Foreign_keys = [reservations.room =	1205
1156		rooms.roomid]	1206
1157	# Generate the SQL query for each question about	Q: which rooms have a king bed?	1207
1158	the given database schema.	A: SQL query you requested is [SELECT * FROM	1208
1159	the given database senema.	Rooms WHERE bedtype = 'King']	1209
	Database: party_host	Q: what are the decor of those rooms?	1203
1160	Table host, columns = [*, host_id, name, national-	A: SQL query you requested is [SELECT distinct	1210
1161	_	decor FROM Rooms WHERE bedtype = 'King']	
1162	ity, age] Table party, columns = [*, party, id, party, theme	· · · ·	1212
1163	Table party, columns = [*, party_id, party_theme,	Q: show me the names and the decor of the rooms	1213
1164	location, first_year, last_year, number_of_hosts]	that have a king bed	1214
1165	Table party_host, columns = [*, party_id,	A: SQL query you requested is [SELECT room-	1215
1166	host_id, is_main_in_charge] Foreign_keys	Name, decor FROM Rooms WHERE bedtype =	1216

[party_host.party_id

=

party.party_id,

=

me the institute type with the lowest number of

1217	'King']
1218	Q: show me the price of the rooms also
1219	A: SQL query you requested is [SELECT room-
1220	Name, decor, basePrice FROM Rooms WHERE
1221	bedtype = 'King']
1222	Q: now sort the list by price
1223	A: SQL query you requested is [SELECT room-
1224	Name, decor, basePrice FROM Rooms WHERE
1225	bedtype = 'King' order by basePrice]
1226	
1227	Database: restaurant_1
1228	Table restaurant, columns = $[*, resid, resname, ad-$
1229	dress, rating]
1230	Table restaurant_type, columns = [*, restypeid,
1231	restypename, restypedescription]
1232	Table student, columns = [*, stupid, lname, fname,
1233	age, sex, major, advisor, city_code]
1234	Table type_of_restaurant, columns = $[*, resid,$
1235	restypeid]
1236	Table visits_restaurant, columns = [*, stupid, resid,
1237	time, spent]
1238	Foreign_keys = [type_of_restaurant.resid =
1239	restaurant.resid, type_of_restaurant.restypeid =
1240	restaurant_type.restypeid, visits_restaurant.stuid
1241	= student.stuid, visits_restaurant.resid = restau-
1242	rant.resid]
1243	Q: Which city code of Smith?
1244	Q: Is Smith first name or last name?
1245	Q: first name
1246	A: SQL query you requested is [SELECT city_code
1247	from Student where fname = "Smith"]
1248	Q: What age of last name Kim?
1249	A: SQL query you requested is [SELECT age from
1250	Student where lname = "Kim"]
1251	Q: What are the student id of city code WAS?
1252	A: SQL query you requested is [SELECT stuid
1253	from Student where city_code = "WAS"]
1254	Q: Which major has least number of students? List
1255	the major and the number of students.
1256	A: SQL query you requested is [SELECT Major
1257	, count (*) FROM Student GROUP BY Major
1258	ORDER BY count (Major) ASC LIMIT 1]
1259	E Error analysis: case studies
1260	To understand types of errors CREDIT-SQL is gen-

To understand types of errors CREDIT-SQL is generating, we perform case studies on the errors from the evaluation results on the CoSQL dev set. In par-1262 ticular, we focus on examples from hard difficulty 1263 and extra difficulty which the model is most strug-1264 gling with (Figure 6). In the following examples, 1265 'DB' indicates the database id, 'RQ' indicates the 1266

rephrased question by CREDIT-SQL, 'G' indicates the golden SQL query, 'P' indicates the predicted SQL query by CREDIT-SQL.

Example 1
DB: dog_kennel
RQ: Give me the first names of all
professionals or owners.
G: SELECT first_name FROM Professionals UNION
SELECT first_name FROM Owners
P: SELECT owners.first_name FROM owners UNION
SELECT professionals.first_name FROM
professionals
M: False, EX: True

In Example 1, we can see a typical case where the exact match fails while the execution results are identical. In this particular case, this happens because the order of two tables (professionals and owners) is not preserved in the predicted SQL query, though there is no semantical difference.

Example 2
DB: battle_death
RQ: Give me the names of all battles with no
ships lost in the English Channel.
G: SELECT name FROM battle EXCEPT SELECT T1.
name FROM battle AS T1 JOIN ship AS T2 ON
<pre>T1.id = T2.lost_in_battle WHERE T2.location</pre>
= 'English Channel'
P: SELECT battle.name FROM battle JOIN ship ON
<pre>battle.id = ship.lost_in_battle WHERE ship.</pre>
id IS NULL AND ship.location = 'English
Channel'
EM: False, EX: False

As demonstrated in Example 2, CREDIT-SQL predictions on questions involving the exclusion of certain groups of data often include IS NULL, but many such attempts incorrectly lead to the empty results.

Example 3
DB: dog_kennel
RQ: Give me the average age of all dogs that
have gone through any treatment.
G: SELECT avg (age) FROM Dogs WHERE dog_id IN
(SELECT dog_id FROM Treatments)
P: SELECT avg (dogs.age) FROM dogs JOIN
<pre>treatments ON dogs.dog_id = treatments.</pre>
dog_id
EM: False, EX: False

The prediction in Example 3 could generate the 1281 correct execution result if the dog_id column was 1282 unique in both of dogs and treatments tables. However, this was not the case for the treatments 1284 table, and therefore the average age evaluated from 1285 the prediction in Example 3 counts dogs received 1286 multiple treatments excessively.

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Example 4
DB: student_transcripts_tracking
RQ: Give me the name of the course with the
least number of students of enrollments.
G: SELECT T1.course_name FROM Courses AS T1
JOIN Student_Enrolment_Courses AS T2 ON T1.
course_id = T2.course_id GROUP BY T1.
course_name ORDER BY count (*) LIMIT 1
P: SELECT courses.course_name FROM courses JOIN
<pre>student_enrolment_courses ON courses.</pre>
<pre>course_id = student_enrolment_courses.</pre>
<pre>course_id GROUP BY courses.course_id ORDER</pre>
BY count (*) ASC LIMIT 1
EM: False, EX: False

The prediction in Example 4 indeed generates the execution result that the question asked. The problem in this case is that there are multiple courses with the least number of enrolled students, and only one of them is chosen by the column used for GROUP BY. Both course_id and course_name are unique in the courses table and therefore they are all acceptable columns, though they generate different execution results in this example.

Example 5
DB: car_1
RQ: Give me the names of all countries in
Europe with at least 3 car manufacturers.
G: SELECT T1.CountryName FROM COUNTRIES AS T1
JOIN CONTINENTS AS T2 ON T1.Continent = T2.
ContId JOIN CAR_MAKERS AS T3 ON T1.
CountryId = T3.Country WHERE T2.Continent =
'europe' GROUP BY T1.CountryName HAVING
count (*) > = 3
P: SELECT countries.countryname FROM countries
JOIN car_makers ON countries.countryid =
car_makers.country JOIN car_names ON
car_makers.id = car_names.makeid GROUP BY
<pre>countries.countryname HAVING count (*) >=</pre>
<pre>3 AND countries.continent = 'Europe'</pre>
EM: False, EX: False

The prediction in Example 5 is semantically fine if not looking into the actual contents of the database. The problem in this case is that the continent column in the countries table is not presented as the actual continent name but as the continental code. If one replaces the text field 'Europe' with numeral field 2, this prediction query generates identical execution results with the golden query.

F Details of SQL regularization

1306To regularize SQL queries, we use a SQLObject1307class. A Python pseudocode of this class is pre-1308sented in Figure 8. To regularize a SQL query, we1309instantiate a SQLObject object initialized with the1310input SQL query, and then run get_sql_string1311method to get a regularized SQL query.

G Details of SQL vectorization

То vectorize SQL queries, we use a 1313 SQLVectorizer class which inherits SQLObject 1314 class in Figure 8. A Python pseudocode of this 1315 class is presented in Figure 9. To regularize a SOL 1316 query, we instantiate a SQLVectorizer object 1317 initialized with the input SQL query, and then 1318 run vectorize method to get a regularized SQL 1319 query. 1320

1312

```
class SQLObject:
      def __init__(self, schema_info, sql=None, words_and_texts=None):
    self.schema_info = schema_info
    self.components = {}
              if sql is not None:
                     self.read_sql(sql)
              elif words_and_text is not None:
                     words, texts = words and texts
                     self.parse_components(words, texts)
      # parse SQL query into components
def read_sql(self, sql):
    # replace text fields with quotation marks into [text1], [text2], etc., while storing original text fields
    new_sql, texts = self.replace_text_fields(sql)
    # parse words(column, table, operator, paratheses, texts) and locate the original text fields in the word sequence
    words, texts = self.parse_words(new_sql, texts)
    self_parse_components(words_texts)
              self.parse_componenets(words, texts)
      # parse components(joint, select, where, group by, order by, limit etc.) from given words and text fields
def parse_components(self, words, texts):
    if any of ('intersect', 'union', 'except') in words:
        conj_op, conj_op_idx = (conjunction operator and its location)
        obj_left = SQLObject(self.schema_info, (words[:conj_op_idx], texts))
        the conjunction operator info (cond f(conj_op_idx], texts))
                     obj_right = SQLObject(self.schema_info, (words[(conj_op_idx+1):], texts))
self.components['joint'] = (conjunction_operator, obj_left, obj_right)
              else:
                     self.parse_nonnested_components(words, texts)
       # parse the contents followed by each keyword in nonnested SQL query
       def parse nonested_components(self, words, texts):
    for keyword in ['from', 'select', 'where', 'group by', 'having', 'order by', 'limit']:
        followed_words = (words followed by the keyword in the given word sequence)
                     if keyword == 'from':
                            self.table_alias = (table alias dictionary built from field under 'from')
field = (field under 'from' without alias; ex: from tb1 as T1 -> from tb1)
                     else:
                            contents = (replace any reference on table alias to the table name;
                     ex: T1.col1, col2 -> tb1.col1, tb1.col2)
self.components[keyword] = contents
       # assemble components of SQL object into a SQL query
       def get_sql_string(self):
    text = ''
              for keyword in ['select', 'from', 'where', 'group by', 'having', 'order by', 'limit']:
if keyword in self.components:
                            return text.strip()
```

Figure 8: Pseudocode for SQLObject class.

1	Give me the invoice dates of all customers. [chinook_1]
1	SELECT customer.firstname, customer.lastname, invoice.invoicedate FROM customer JOIN invoice
	ON customer.customerid = invoice.customerid
2	Give me the event id of all events that have a participant with the detail Kenyatta Kuhn. [lo-
2	cal_govt_in_alabama]
	SELECT events.event_id FROM events JOIN participants_in_events ON partici-
	pants_in_events.event_id = events.event_id JOIN participants ON participants_in_events.participant_id
	= participants.participant_id WHERE participants.participant_details = 'Kenyatta Kuhn'
3	Give me the patient id of the appointment with the most recent start date. [hospital_1]
5	SELECT appointment.patient FROM appointment ORDER BY appointment.start DESC LIMIT 1
4	Give me the minimum and maximum number of bathrooms and bedrooms of all the apartments.
-	[apartment_rentals]
	SELECT min (apartments.bathroom_count), max (apartments.bathroom_count), min (apart-
	ments.bedroom_count), max (apartments.bedroom_count) FROM apartments
5	Give me the total number of all professors. [college_1]
5	SELECT count (*) FROM professor
6	Give me the names of 5 products that are not in any event. [solvency_ii]
0	SELECT products.product_name FROM products WHERE products.product_id NOT IN (SELECT
	products_in_events.product_id FROM products_in_events)
7	Give me the total number of students who play football. [game_1]
,	SELECT count (*) FROM sportsinfo JOIN student ON sportsinfo.stuid = student.stuid WHERE
	sportsinfo.sportname = 'Football'
8	Give me the names of all instructors who are advising more than one student. [college_2]
Ũ	SELECT instructor.name FROM instructor JOIN advisor ON instructor.id = advisor.i_id GROUP BY
	advisor.i_id HAVING count (*) > 1
9	Give me the account types of all customers whose credit score is above 100. [loan_1]
	SELECT customer.acc_type FROM customer
10	Give me the total number of students who have behavior incident reports with recommendations.
	[behavior_monitoring]
	SELECT count (*) FROM (SELECT * FROM behavior_incident JOIN students ON behav- ior_incident.student_id = students.student_id GROUP BY behavior_incident.student_id)
11	Give me the total number of residents of each property, and the property id. [local_govt_and_lot]
	SELECT properties.property_id , count (*) FROM properties JOIN residents ON proper- ties.property_id = residents.property_id GROUP BY properties.property_id
	Give me the claim id of the claim that incurred the most number of settlements. [insurance_policies]
12	SELECT claims.claim_id FROM claims JOIN settlements ON claims.claim_id = settlements.claim_id
	GROUP BY claims.claim_id ORDER BY count (*) DESC LIMIT 1
	Give me the date of ceremony of all music festivals with category 'best song' and 'awarded'. [music_4]
13	SELECT music_festival.date_of_ceremony FROM music_festival WHERE music_festival.category =
	'Best Song' AND music_festival.result = 'Awarded'
	Give me the ids of all employees with role Role_Code. [cre_Doc_Tracking_DB]
14	SELECT employees.employee_id, employees.role_code FROM employees
	Give me the first names of all students who have a dorm id of 160. [dorm_1]
15	SELECT student.fname FROM student JOIN lives_in ON student.stuid = lives_in.stuid WHERE
	lives_in.dormid = 160
	Give me the college name of the employee with name Reggie Lewis. [company_employee]
16	SELECT people.graduation_college FROM people WHERE people.name = 'Reggie Lewis'
	Give me the names of all nations with hosts younger than 35. [party_host]
17	SELECT DISTINCT host.nationality FROM host WHERE host.age < 35
10	Give me the total number of customers who pay by Credit card. [customers_campaigns_ecommerce]
18	
	SELECT count (*) FROM customers WHERE customers.payment_method = 'Credit Card'

Table 6: Voted examples used for CREDIT-SQL. The first row of each example: rephrased question [database ID], the second row of each example: regulated SQL query. 19

```
class SOLVectorizer(SOLObject):
         def __init__(self, schema_info, sql):
                    super().__init__(schema_info, sql)
          # Count the occurance of each component of SQL query
          def vectorize(self):
                   keys = [
    'intersect', 'union', 'except', 'sel_col', 'sel_all', 'sel_count', 'sel_min', 'sel_max', 'sel_avg', 'sel_sum',
    'from_ext', 'from_tb', 'wh_and', 'wh_or', 'wh_in', 'wh_like', 'wh_is', 'wh_eq', 'wh_gl', 'wh_subq',
    'wh_between', 'wh_pm', 'groupby', 'hv_eq', 'hv_g', 'hv_l', 'hv_else', 'hv_count', 'hv_min', 'hv_max',
    'hv_avg', 'hv_sum', 'order_n', 'order_count', 'order_min', 'order_max', 'order_avg', 'order_sum', 'order_asc',
    'order_desc', 'limit'

                    vec = {k: 0 for k in keys}
                    if 'joint' in self.components:
                               joint, obj1, obj2 = self.components['joint']
return (get vectors for obj1 and obj2, then average them)
                   for col in self.components['select']:
    vec['sel_col'] += 1 if (col is valid column) else 0
    vec['sel_all'] += 1 if (col is wildcard '*') else 0
    for op in ['count', 'min', 'max', 'avg', 'sum']:
        vec[f'sel_{op}'] += 1 if (col has op) else 0
                   if 'where' in self.components:
    vec['wh_gl'] += (number of occurances of '<', '>', '<=', or '>=' in self.components['where'])
    vec['wh_eq'] += (number of occurances of '=' or '!=' in self.components['where'])
    vec['wh_pm'] += (number of occurances of '+' or '-' in self.components['where'])
    vec['wh_like'] += (number of occurances of 'ilike' or 'like' in self.components['where'])
    for op in ['and', 'or', 'in', 'is', 'between']:
        vec[f'wh_{subq']} += (number of occurances of op in self.components['where'])
    vec[f'wh_subq'] += (number of subqueries in self.components['where'])
                    vec['groupby'] += (number of columns in self.components['where'])
                    if 'having' in self.components:
                              wec['hv_eq'] += (number of occurances of '=' in self.components['having'])
vec['hv_g'] += (number of occurances of '>' or '>=' in self.components['where'])
vec['hv_l'] += (number of occurances of '<' or '<=' in self.components['where'])</pre>
                              vec['hv_else'] += (number of occurances of all other binary operators in self.components['where'])
for op in ['count', 'min', 'max', 'avg', 'sum']:
    vec[f'hv_{op}'] += (number of occurances of op in self.components['where'])
                    if 'orderby' in self.components:
                               vec['order_n'] += (number of columns in self.components['orderby'])
for op in ['count', 'min', 'max', 'avg', 'sum', 'asc', 'desc']:
    vec[f'order_{op}'] += (number of op in self.components['orderby'])
                    vec['limit'] += (0 if 'limit' in self.components 1)
                    return vec
```

Figure 9: Pseudocode for SQLVectorizer class.