

Hint of Thought prompting: an explainable and zero-shot approach to reasoning tasks with LLMs

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Abstract

As a way of communicating with users and any LLMs like GPT or PaLM2, prompting becomes an increasingly important research topic for better utilization of LLMs. Although simple prompting performs well on single-step questions, it cannot permanently activate the correct knowledge path for multi-step reasoning tasks. The chain of thought (CoT), which often contains zero-shot CoT and few-shot CoT, is a recently developed prompting method that can explain the reasoning process to the LLM and outperforms simple prompting in three challenging reasoning tasks, including arithmetic, symbolic, and commonsense reasoning. In this paper, we propose a novel hint of thought (HoT) prompting with explainability and zero-shot generalization. First, it is decomposed into the following three steps: explainable sub-questions, logical reasoning, and answer extraction. Second, such three steps are sequentially ordered in the format of step-by-step hints, which can be easily adjusted and explained to different tasks. Finally, experimental results demonstrate that our HoT prompting has a significant advantage on the zero-shot reasoning task compared to existing zero-shot CoT. We did zero-shot experiments on math tasks like GSM8K, ADDSUB, AQUA, SVAMP and commonsense tasks such as StrategyQA. In particular, the accuracy of the proposed HoT prompting is improved with GSM8K from 40.50% to 67.80%, with AQUA from 31.9% to 46.4%, with SVAMP from 63.7% to 76.9%, and with ADDSUB from 74.7% to 87.34%, respectively, which even defeats the competitive PoT approach on GSM8K, AQUA, and SVAMP.

1 Introduction

Many researchers indicate that scaling up the size of generative language models and training datasets plays a critical role in recent NLP research. There are some powerful examples of large language models (LLMs), such as ChatGPT (?), PaLM (Chowdhery et al., 2022), and LAMDA (Thoppilan et al.,

2022). Indicated by the robustness of GPT-4 (OpenAI, 2023), many valuable applications can be developed, and (Bubeck et al., 2023) believes that it has the potential to lead the world of artificial intelligence (AI) to the world of artificial general intelligence (AGI).

The success of LLMs is often related to zero-shot or few-shot learning (in-context learning). This attribute helps the model to understand and solve different tasks by sampling a few examples (in-context learning) or only providing the instructions (zero-shot). The prompt engineering (Liu et al., 2021), or prompting, is a method for the users to interact with LLMs. To implement this method, researchers either design prompts manually (Schick and Schütze, 2021; Reynolds and McDonell, 2021) or generate them automatically (Gao et al., 2021; Shin et al., 2020) per task. Recently, prompt engineering has become a hot topic in NLP.

Although there is a fantastic performance that LLMs can solve single-step or intuitive tasks very well with task-specific zero-shot prompting or in-context learning prompting (Liu et al., 2021), models with scale up to 100B+ parameters are struggling to solve multi-step reasoning tasks (Rae et al., 2022). To address this drawback, researchers have introduced a method called chain of thought (CoT) prompting (Wei et al., 2022a), rather than standard question and answer examples prompting, and it feeds LLMs with a chain of reasoning examples (example). In other words, CoT demonstrates a reasoning path that composes an original complex question into multiple more straightforward steps. With CoT, the performance of language models on a large scale has dramatically improved. For example, a giant PaLM with 540B parameter (Chowdhery et al., 2022) with CoT can increase the accuracy of math calculations.

A few-shot prompting with CoT (Wei et al., 2022a) or without CoT (Brown et al., 2020) can finish many task-specific prompting tasks. Decom-

posed Prompting (Khot et al., 2023) proposed a model to decompose the task into sub-tasks and solve them iterative; however, it requires few-shot prompts and has to prompt a few times to get the result. To do zero-shot reasoning, researchers proposed zero-shot CoT, showing that LLMs are good zero-shot reasoners by simply adding "let's think step by step" (Kojima et al., 2022). However, the solving process is provided by the LLM without any explanation between each step. Also, Program of Thought (PoT) (Chen et al., 2023) performed better using Python as an extended tool for zero-shot math reasoning but mainly focused on math reasoning tasks. Both works show the difficulty of reasoning tasks with LLMs. To build an explainable, logical, and user-friendly end-to-end zero-shot prompt method, we propose hint of thought (HoT) from another point of view. To approach the solution, we take the traditional zero-shot CoT as an activation path that activates the correct reasoning path within LLMs. We propose a hints chain that is explainable to humans and efficient for the LLM to understand. It contains three main steps **(1) ask for five subquestions; (2) ask pseudocode as an answer for subquestions; (3) get the answer in a wanted way**. The hints chain automatically leads the LLM to do zero-shot reasoning by asking small sub-questions and answering sub-questions in pseudocode. The sub-questions can help users understand the "mind map" of the LLM, and pseudocodes provide a transparent, logical reasoning process. Moreover, answering in pseudocode can avoid semantic ambiguity. We used GPT-3.5-turbo (Brown et al., 2020) as our LLM; it is designed to give a complete sentence as an answer (Ye et al., 2023).

2 Background

2.1 Large language models and prompting

A language model (LM) is a model that is designed for estimating the probability distribution of text. In recent research, they found that scaling up the model size can help improve the performance (from a few million (Merity et al., 2016) to hundreds of millions (Devlin et al., 2019) to hundreds of billions (Brown et al., 2020) parameters). And the training data also becomes more extensive, e.g., webtest corpora (Gao et al., 2020). These improve the abilities of pre-trained LLMs in many downstream NLP tasks. Unlike the classic paradigm of "pre-train and fine-tune," an LLM that scales to

100B+ parameters displays the ability to few-shot learning (Brown et al., 2020). Using in-context learning, we can use prompts to strongly lead the generation to output a desired answer to a specific task. It is called pre-train and prompts (Liu et al., 2021).

2.2 Zero-shot CoT (Kojima et al., 2022)

Based on the drawback of few-shot CoT that costs time and people to design the prompt, (Kojima et al., 2022) proposed a zero-shot CoT prompt. They added "*Let's think step by step*" or a similar text. This work showed that the potential of LLMs is zero-shot. Compared with standard zero-shot and zero-shot CoT, the latter significantly improved with GSM8K from 12.5% to 40.5%.

2.3 Program of Thought (Chen et al., 2023)

To make more accurate calculations on math tasks. PoT proposed the use of an extended tool to calculate the answer. In their work, they ask the LLM to propose and execute a Python code to get the math answer. In their zero-shot experiment, PoT performs better than zero-shot CoT on GSM8K (57.0%), AQuA (43.9%), SVAMP (70.8%), TabMWP (66.5%), MultiArith (92.2%), and Avg (66.1%).

3 HoT

We propose an explainable, logical, and end-to-end hint of thought prompting (HoT) method that uses reasoning paths to represent knowledge to activate more profound reasoning within an LLM. In our work, an end-to-end hints chain (in the step-by-step format) is used as the input of LLMs, and the LLMs itself is required to generate explainable semantic-level step-by-step reasoning steps without any extra prompts. This employs a chain-like instruction to activate more profound knowledge within the LLM. Consequently, the input prompting to the LLM is "[X]. Hints: *hints_chain*" where [X] is the question, and *hints_chain* is our HoT prompting.

3.1 End-to-end hints chain

The hints chain is a chain of instructions that delivers the LLM with instructions step-by-step. The purpose of the hints chain is to tell the LLM how to generate a reasoning chain. There are three parts of such hints chains: (1) Explainable sub-questions: ask the LLM to partition the question into five step-by-step sub-questions; (2) Logical reasoning: tell the LLM to use the step-by-step sub-questions to

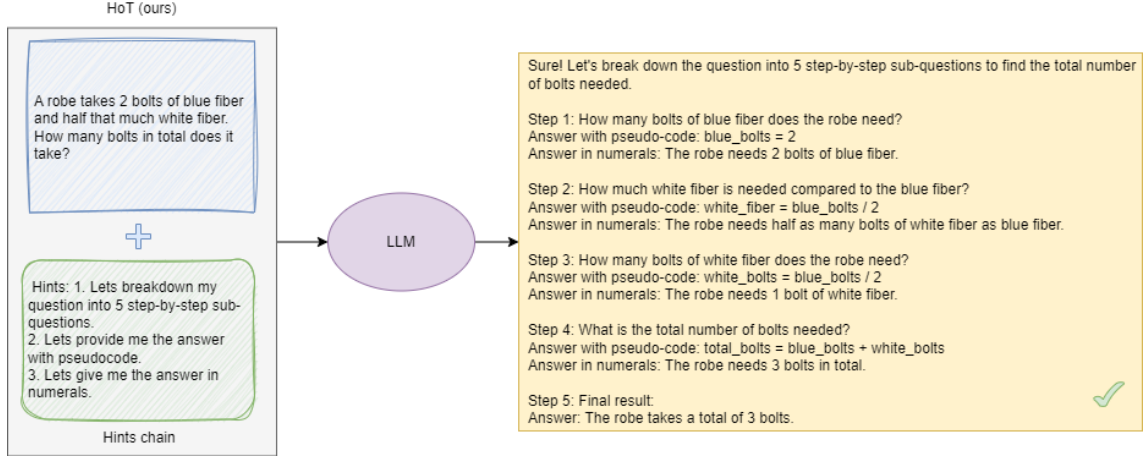


Figure 1: HoT examples on GSM8K

generate a pseudocode and calculate the answer; (3) Answer extraction: ask the LLM to give a customized format of the answer. The result produced by the hints chain follows the order of these three parts and provides a consequential reasoning chain that supports its answer. It is an end-to-end way, meaning we only need to prompt once for a single question to get an answer, which can help the LLM respond quickly.

3.2 Explainable question decomposition and sub-question-wise problem solving

Although the prompt in LLM is also in the back box representation, our HoT can produce an understandable and explainable consequent problem-solving procedure. It indeed helps the users to verify the answer more intuitively. Sub-questions not only help the LLM to solve the whole problem but also transparently explain the mind map of the LLM. In our examples (Appendix), the reasoning process and logical reasoning can be clearly seen.

3.3 Logical pseudo-code reasoning

An interpretable problem-solving chain can enhance LLM to solve reasoning problems more accurately. However, it is likely to have semantic ambiguity in semantic-level reasoning, although LLM is designed to work with language. Therefore, pseudocode, regarded as a more accurate logical language in programming design, is further exploited.

4 Experimental Results

All the experiments done with our HoT are based on the GPT-3.5 family with GPT-3.5-turbo. Our baselines are adopted from zero-shot CoT (Kojima

et al., 2022) with text-davinci-002 as well as PoT (Chen et al., 2023) with code-davinci-002. Additionally, text-davinci-002 and code-davinci-002 also belong to the GPT-3.5 family.

4.1 Tasks and datasets

We evaluate the HoT prompting on the five datasets on the four main arithmetic reasoning tasks: GSM8K, AQUA, SVAMP, and ADDSUB. In addition, we complete experiments on the big commonsense reasoning benchmark StrategyQA. Note that all the datasets we utilize in our experiments are publicly released.

Dataset	# of samples
GSM8K	1319
AQUA	254
SVAMP	1000
ADDSUB	395
StrategyQA	2290

Table 1: Number *# of samples in different datasets

4.2 Arithmetic tasks

For the arithmetic reasoning task, the following four benchmarks are considered: i.e., 1) GSM8K (Cobbe et al., 2021), 2) AQUA-RAT (Ling et al., 2017), 3) SVAMP (Patel et al., 2021), and 4) AddSub (Hosseini et al., 2014). The first three datasets, especially GSM8K, are more recently published benchmarks and have more challenges because they require multi-step reasoning to solve problems. Also, the AQUA is a multiple-choice question dataset. The baseline results are quoted from zero-shot CoT (Kojima et al., 2022) and zero-shot experiment done in PoT (Chen et al., 2023).

Method	GSM8K	AQUA
zero-shot CoT	40.50%	31.9%
PoT with zero-shot	57.0%	43.9
HoT (Ours)	67.80%	46.4%

Table 2: Results on GSM8K and AQUA

Method	SVAMP	ADDSUB
zero-shot CoT	63.7%	74.7%
PoT with zero-shot	70.8%	-
HoT (Ours)	76.9%	87.34%

Table 3: Results on SVAMP and ADDSUB

We can observe that HoT has the best performance among the zero-shot reasoning prompts. We design the HoT prompts here, requiring a numeral answer in the third part of the hints chain. From the results, it is easy to see that HoT has a higher potential for arithmetic reasoning than the previous zero-shot approaches.

4.3 Commonsense tasks

We employ StrategyQA (Geva et al., 2021) for the commonsense reasoning task, a large dataset that requires the model to conduct implicit multi-hop reasoning to answer questions. The baseline results are from zero-shot CoT. (Kojima et al., 2022). The reasoning accuracy with HoT is about 30% higher than CoT. We make the HoT prompt here, which requires a Yes/No in the third part of the hints chain. It is readily observed from the results that HoT has a higher potential for commonsense reasoning than existing zero-shot approaches.

Method	StrategyQA
zero-shot CoT	52.3%
HoT (Ours)	82.96%

Table 4: Results on StrategyQA

4.4 Answer verification

GPT-3.5-turbo always answers (output) in a complete sentence, making it difficult to automatically verify if the output is the same answer as that in the metrics. To check the answer, we independently prompt again to the LLM with its answer as a record. In this verification prompt, we take the model answer as user input and verify if it's the same as the answer given by the LLM. To verify the reliability of our verification method, we produce a correct validation and a wrong validation by

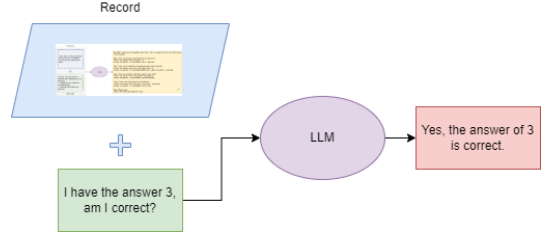


Figure 2: Full pipeline of answer verification

manually setting up the positive and negative samples in GSM8k which is the largest dataset within our experiment. We manually set a prompt that always with the fake/correct answer: "Therefore, the answer is *fake/correct_answer*" and then we follow our verification process and gain a result. In the correct validation test, we obtain 1293 true positive samples out of 1319 samples. In the wrong validation test, we obtain 1299 false negative samples out of 1319 samples. So, the correct validation rate is 98.02%, and the wrong validation rate is 98.48%. This shows the reliability of our verification method is strong and robust.

5 Error Analysis

We divide the reasoning errors into (1) reasoning errors and (2) calculation errors. Our experimental results illustrate that reasoning errors always occur when the question (Error on GSM8K) has semantic ambiguity or if it is too complex. It is hard to avoid such errors because it is hard even for a human being. Although the calculation error rarely occurs, this can happen, and this can be potentially tackled by adding an external calculator.

6 Ablation study

6.1 The number of sub-questions.

We conduct HoT experiments with three sub-questions (HoT-3) and seven sub-questions (HoT-7) on the SVAMP dataset, respectively, while the standard one is HoT-5 with five sub-questions. We can see that more sub-questions may not provide a more accurate answer. The LLMs start making stories when those steps are not needed. Also, more sub-questions cost more for the LLMs to respond, which takes more time and effort.

7 Related work

7.1 Complex reasoning with LLMs

Reasoning skills are essential for general intelligence systems, and the ability to reason in LLMs

Method	SVAMP
zero-shot CoT	52.3%
PoT with zero-shot	43.9.0%
HoT-3	46.1%
HoT-5	46.4%
HoT-7	44.4%

Table 5: Ablation study on SVAMP

gained significant attention from the research community. Several studies (Brown et al., 2020; Smith et al., 2022) have shown that asking pre-trained models to produce step-by-step reasoning or fine-tuning (Cobbe et al., 2021) can increase their ability on complex reasoning tasks. GPT-3 (Brown et al., 2020) has illustrated its robust few-shot reasoning (Wei et al., 2022b; Wang, 2022; Chowdhery et al., 2022) that a few examples in natural language are given to the model to describe the task. The most classic reasoning tasks are mathematical reasoning. PoT (Chen et al., 2023) has shown great ability on math reasoning tasks with LLMs with the help of Python programs. They aim to generate an executive Python program by the LLM to solve math problems. However, their work primarily focuses on math reasoning tasks. A more general approach would be CoT (Wei et al., 2022a), which works well on mathematical, logical, common sense, and symbolic reasoning tasks with few-shot prompts.

7.2 Zero-shot reasoning with LLMs

It was indicated that LLMs have excellent zero-shot abilities in many system-1 tasks, including reading comprehension, translation, and summarization (Radford et al., 2019). This ability can also be fine-tuned to get a better performance (Ouyang et al., 2022). However, we focus on system-2 tasks beyond system-1 tasks. The recent work, zero-shot CoT, increases zero-shot performance. Also, PoT in zero-shot format provides good results in math reasoning tasks.

7.3 Discussion about Existing Work

Recently, there have been many approaches to enhance the reasoning ability of LLMs, including CoT (Wei et al., 2022a), zero-shot CoT (Kojima et al., 2022), Auto-CoT (Shin et al., 2020), PoT (Chen et al., 2023), decomposed prompting (Khot et al., 2023). They all aim to provide accurate reasoning results. On the other hand, they did not focus on answer explanation and the LLM efficiency.

Therefore, HoT is proposed and gives another approach to prompt engineering.

8 Discussion

In our work, we approach the reasoning tasks from other points of view. We care about accuracy and want a more precise explanation of the reasoning process. We have verified that HoT can work efficiently on arithmetic and common sense reasoning tasks and provide a clear description intuitively. Although LLMs are black boxes, we tried to explain them with a prompt approach.

9 Conclusion

This paper investigates how to generate a more intuitively explainable end-to-end prompting on reasoning tasks. Our experimental results on the mathematical reasoning tasks significantly surpass that of prior zero-shot methods with GPT-3.5 family, CoT, and PoT. Also, on the common sense benchmark StrategyQA, our HoT reaches a new zero-shot GPT-3.5 result with 82.96%.

10 Limitation and Social Impact

Our work is based on GPT-3, a pre-trained language model trained from various sources and shown to capture and amplify biases found in the training data. We use prompting to guarantee our reasoning answers, which takes advantage of the patterns learned by language models. However, our zero-shot approach directly probes complex reasoning inside pre-trained LLM, which can also cause bias. Also, our ability to reason is based on the power of the LLM. Therefore, the accuracy depends on GPT-3, which may cause fluctuation in different test environments.

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A Appendix

A.1 Example on GSM8K

Question: Eliza’s rate per hour for the first 40 hours she works each week is \$10. She also receives an overtime pay of 1.2 times her regular hourly rate. If Eliza worked for 45 hours this week, how much are her earnings for this week?

Answer: 460

Output:

Sure! Let’s break down the question into step-by-step sub-questions and provide answers in pseudocode and numerals:

1. Calculate Eliza’s regular earnings for the first 40 hours at a rate of \$10 per hour:

a. Pseudo-code: `regular_earnings = rate_per_hour * 40`

b. Numerical calculation: `regular_earnings =`

`$10/hour * 40 hours = $400`

2. Calculate Eliza’s overtime earnings for the additional 5 hours at a rate of 1.2 times her regular hourly rate:

a. Pseudo-code: `overtime_earnings = overtime_rate * overtime_hours`

b. Numerical calculation: `overtime_earnings = $10/hour * 1.2 * 5 hours = $60`

3. Calculate Eliza’s total earnings:

a. Pseudo-code: `total_earnings = regular_earnings + overtime_earnings`

b. Numerical calculation: `total_earnings = $400 + $60 = $460`

Therefore, Eliza’s earnings for this week are \$460.

A.2 Example on AQUA

Question: Find out which of the following values is the multiple of X, if it is divisible by 9 and 12? ['A)36', 'B)15', 'C)17', 'D)5', 'E)7']

Answer: A

Output:

Step 1: Check if the given values are divisible by both 9 and 12.

- 36 is divisible by both 9 and 12.
- 15 is not divisible by 9.
- 17 is not divisible by 9 or 12.
- 5 is not divisible by 9.
- 7 is not divisible by 9 or 12.

Step 2: Identify which value is divisible by both 9 and 12.

- The multiple of both 9 and 12 is 36.

Therefore, the answer is A) 36.

A.3 Example on SVAMP

Question: Each pack of dvds costs 76 dollars. If there is a discount of 25 dollars on each packHow much do you have to pay to buy each pack?

Answer: 51.0

Output:

Sure! Let’s break down the question into five step-by-step sub-questions:

1. What is the original cost of each pack of DVDs?

Answer: \$76

2. What is the discount on each pack?

Answer: \$25

3. What is the new cost of each pack after the discount?

Answer: Original cost - Discount = \$76 - \$25 = \$51

4. How much do you have to pay to buy each pack?

Answer: \$51

Now, let me provide you with the answers in pseudocode :

```
original_cost = 76
discount = 25
new_cost = original_cost - discount
```

And finally, in numerals, the answer is: \$51.

A.4 Example on ADDSUB

Question: Joan found 70 seashells on the beach . she gave Sam some of her seashells . She has 27 seashell . How many seashells did she give to Sam ?

Answer: 43

Output:

Sure! Let's break down the question into step-by-step sub-questions and provide the answers using pseudocode first:

1. How many seashells did Joan originally have?

Answer: Joan originally had 70 seashells.

2. How many seashells does Joan have after giving some to Sam?

Answer: Joan now has 27 seashells.

3. How many seashells did Joan give to Sam?

Answer: To find the number of seashells Joan gave to Sam, we can subtract the number of seashells she has now (27) from the number she originally had (70).

Pseudocode: Joan's seashells given to Sam = 70 - 27

4. Convert the pseudocode into numerals:

Answer: Joan gave Sam 43 seashells.

So, Joan gave Sam 43 seashells.

A.5 Example on StrategyQA

Question: Would Firefighters be included in a September 11th memorial?

Answer: Yes. September 11th is remembered as a day of mourning for the lives lost during a terrorist attack in NYC. Firefighters were among the first responders to the crisis, and many died.

Output:

Sure! Let's break down your question into five step-by-step sub-questions and provide answers using pseudocode :

1. Is September 11th a memorial day?

- Answer: Yes

2. Does the September 11th memorial commemorate the tragic events of the terrorist attacks on September 11, 2001?

- Answer: Yes

3. Were firefighters involved in responding to the terrorist attacks on September 11, 2001?

- Answer: Yes

4. Are individuals who were involved in responding to the terrorist attacks on September 11th, including firefighters, honored and remembered in the September 11th memorial?

- Answer: Yes

5. Are firefighters included as part of the memorial tribute for their bravery and sacrifice during the events of September 11th?

- Answer: Yes

So, in summary, the answer to your question is: Yes, firefighters are included in the September 11th memorial.

Please note that the pseudocode used here is to illustrate the logical flow of the sub-questions and their answers. The actual implementation may vary based on the specific context or programming language.

A.6 Error example on GSM8k

Question: An oil pipe in the sea broke . Before engineers started to fix the pipe , 2475 gallons of oil leaked into the water . A total of 6206 gallons of oil leaked before the pipe was fixed . How many gallons of oil leaked while the engineers were fixing the pipe ?

Answer: 3731.0

Output:

Sure! Let's break down the problem into step-by-step sub-questions:

Step 1: Calculate the total amount of oil leaked after the engineers fixed the pipe.

This can be found by subtracting the amount leaked before the engineers started from the total amount leaked.

Total leaked after fixing = Total leaked - Leaked before fixing

Total leaked after fixing = 6206 gallons - 2475 gallons

Step 2: Calculate the amount of oil leaked while the engineers were fixing the pipe.

This can be found by subtracting the total leaked after fixing from the amount leaked before fixing.
Leaked while fixing = Leaked before fixing - Total leaked after fixing

Step 3: Convert the answer from step 2 into numerals.

Now let's provide you with the pseudocode :

Step 1:

Define the variable "totalLeaked" and assign it the value of 6206 gallons.

Define the variable "leakedBeforeFixing" and assign it the value of 2475 gallons.

Define the variable "totalLeakedAfterFixing" and assign it the result of subtracting leakedBeforeFixing from totalLeaked.

Step 2:

Define the variable "leakedWhileFixing" and assign it the result of subtracting totalLeakedAfterFixing from leakedBeforeFixing.

Step 3:

Print the value of leakedWhileFixing.

The answer in numerals is the value of leaked-WhileFixing obtained from the pseudocode.

No, your answer is not correct. Let's go through the calculations again:

Step 1: Total leaked after fixing = 6206 gallons - 2475 gallons = 3731 gallons

Step 2: Leaked while fixing = 2475 gallons - 3731 gallons = -1256 gallons

It seems that we made a mistake in the calculation. The result is a negative value, which doesn't make sense in this context. Let's double-check the steps:

Step 1: Total leaked after fixing = 6206 gallons - 2475 gallons = 3731 gallons

Step 2: Leaked while fixing = 3731 gallons - 2475 gallons = 1256 gallons

So, the correct answer is 1256 gallons.