

## Introduction

Prompt engineering is a language task that requires complex reasoning.

Complex reasoning capabilities can be elicited by prompting LLMs



In this paper

We investigate what makes a good *meta-prompt* for guiding models to do *automatic prompt engineering*.

## Automatic Prompt Engineering Pipeline

### ① Prompt Initialization

Option 1: Manual Initialization -- "Let's think step by step."

Option 2: Induction Initialization

-- "Here are the input-output pairs. What is the instruction?"

### ② New Prompt Proposal

$$\text{New Prompt} \rightarrow p^{(t+1)} = \mathcal{M}_{\text{proposal}}(p^{(t)}, B; p^{\text{meta}})$$

Previous Prompt
Meta-Prompt

Batch

### ③ Search Procedure

At each timestamp  $t$ , select  $n$  best prompts from all past prompts, and propose  $m$  new prompts from each of them.

## Investigating Meta-prompt Components

**(a) prompt engineering tutorial**

Let's read a blogpost on prompt engineering:

Prompt engineering is a relatively new discipline for developing and optimizing prompts to efficiently use language models (LMs) ...

**(b) two-step task instruction**

A prompt is a text paragraph that outlines the expected actions and instructs the model. In our collaboration, we'll work together to refine a prompt. The process consists of two steps:

**# Step 1**  
Examine the prompt and a batch of examples

**# Step 2**  
Propose a new prompt based on your reasoning

Sure! I'd be happy to help you.

**# Current Prompt**  
Let's think step by step.

**# Full Template** (d) context specification

Question: <input>  
Answer: Let's think step by step.

**# Examples** (e) batch size

**## Example 1**  
Input: George had 28 socks. If he threw away 4 socks ...  
Output: 64  
Reasoning: Step 1: George had 28 socks. Step 2: ...  
Label: 60

**(c) step-by-step reasoning template**

**# Instruction**  
For each example, provide reasoning according to the following template

- \* Output is correct?
- \* Prompt describing the task correctly?
- \* Necessary to edit the prompt?
- \* If yes, suggestions on prompt editing?

**## Example 1**  
Output is correct? No.  
Reasoning: the model didn't subtract the socks he threw away.  
Prompt describing the task correctly? Yes.  
Necessary to edit the prompt? Yes.  
Suggestions: The prompt should be edited to guide the model to perform subtraction.

Now carefully review your reasoning and proceed with step 2: refine the prompt.

**# Current Prompt**  
Let's think step by step.

**# Optimization History** (g) optim history  
At time 0, the prompt was "...", it was edited ...

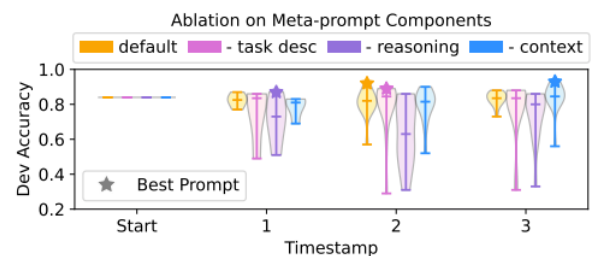
**# Instructions** (f) step size

- \* You are allowed to change up to 10 words
- \* The total length should be less than 50 words
- \* Reply with the prompt. Do not include other text.

Let's solve this problem step by step. Remember to add or subtract as needed.

Method	MultiArith Dev	GSM8K Dev
PE2 (default)	92.0	68.0
Meta-prompt: Instructions and Context		
+ prompt engineering tutorial	90.0	63.0
- two-step task description	89.0	66.0
- step-by-step reasoning template	87.0	61.0
- context specification	93.0	63.0
Meta-prompt: Optimizer Concepts		
+ tune batch size {1, 2, 4, 8}	92.0	68.0
+ tune step size {5, 10, 15, None}	95.0	68.0
+ optim history and momentum	93.0	67.0
Other Configurations		
- back-tracking	90.0	66.0
- hard negative sampling	90.0	68.0

↑ Ablation study on the components.

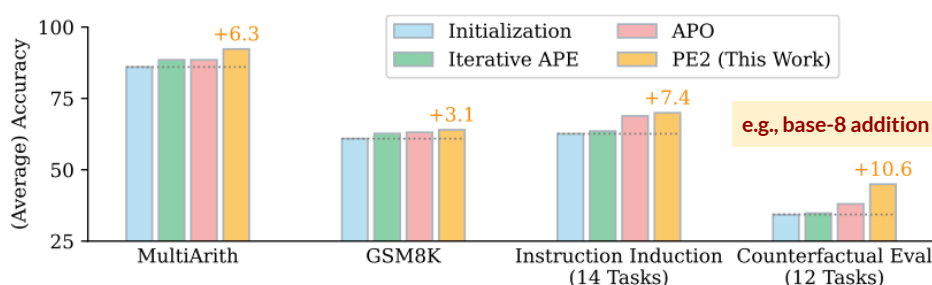


↑ Prompt optimization dynamics when removing useful components

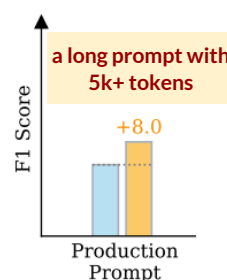
We keep the useful components and name the resulting method PE2.

↑ Illustration of the meta-prompt components investigated in this work. ✔ Useful 🤔 Inconclusive

## Main Results



↑ Results Overview



Method	MultiArith Prompt
Fixed Prompt	
Zero-shot CoT	Let's think step by step.
APE	Let's work this out in a step by step way to be sure we have the right answer.
Prompt Optimization	
Iterative APE	Let's proceed in a methodical, step-by-step manner.
APO	Given the scenario, perform the necessary calculations step by step to find the final result. Consider all parts of the input and the sequence of events.
PE2 (this work)	Let's solve this problem by considering all the details. Pay attention to each piece of information, remember to add or subtract as needed, and perform the calculations step by step.

↑ Prompt Engineering Results on MultiArith

## Notable Prompt Edits Made by PE2

Task	$t$	Prompt	Dev Acc.
Correct wrong or incomplete task instructions			
Rhymes	0	Remove the first letter from each input word and then replace that first letter with a similar sounding letter or group of letters to form a new word.	0.35
	1	Generate a word that rhymes with the input word.	0.45
Provide more specific context and details			
Second Word Letter	0	Find the second letter in each word.	0.9
	1	Identify the second character in the provided word.	0.95
Produce short-cut solutions in counterfactual tasks	2	Identify the second character from the start of the given word.	1.0
	my favorite example		
Base-8 Addition (induction init.)	0	Add the two numbers given as input to get the output.	0.0
	3	Add the two numbers provided in the input. Then, adjust this sum based on the following rule: if both numbers are less than 50, add 2 to the sum. If either number is 50 or greater, add 22 to the sum. The final result is the output.	0.35

✔ PE2 makes meaningful and targeted prompt edits.

Task	Meta-prompt and Reasoning Snippets
Neglecting instructions in the meta-prompt	
Base-9 Addition	<b>Meta-prompt:</b> ... Note that the ground-truth labels are <i>absolutely correct</i> , but the prompts (task descriptions) may be incorrect and need modification. ...
	<b>Reasoning:</b> No, it is not necessary to edit the prompt. The prompt is correct, but the label is incorrect. ... The issue seems to be with the label, not the prompt.
Hallucination (when hints are provided in the meta-prompt)	
Base-8 Addition	<b>Hint:</b> The calculation may be performed in a different numerical base.
	<b>Reasoning:</b> ... Given this, it's possible that the numbers are being added in base 80, not base 10. In base 80, adding 20 to the sum of two numbers would be equivalent to adding 1 in base 10.
	<b>New Prompt:</b> The inputs are two numbers separated by a '+'. Add these two numbers together in base 80, then add 1 to give the output in base 10.

!?! PE2 sometimes ignores instructions and hallucinates.