LLMs for Literature Review: Are we there yet?

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Abstract

Literature reviews are an essential component of scientific research, but they remain time-intensive and challenging to write, especially due to the recent influx of research papers. This paper explores the zero-shot abilities of recent Large Language Models (LLMs) in assisting with the writing of literature reviews based on an abstract. We decompose the task into two components: (1) Retrieving related works given a query abstract and (2) Writing a literature review based on the retrieved results. We analyze how effective LLMs are for both components. For retrieval, we introduce a novel two-step search strategy that first uses an LLM to extract meaningful keywords from the abstract of a paper and then retrieves potentially relevant papers by querying an external knowledge base. Additionally, we study a prompting-based re-ranking mechanism with attribution and show that re-ranking doubles the normalized recall compared to naive search methods while providing insights into the LLM's decision-making process. In the generation phase, we propose a two-step approach that first outlines a plan for the review and then executes steps in the plan to generate the actual review. To evaluate different LLM-based literature review methods, we create test sets from arXiv papers using a protocol designed for rolling use with newly released LLMs to avoid test set contamination in zero-shot evaluations. We release this evaluation protocol to promote additional research and development in this regard. Our empirical results suggest that LLMs show promising potential for writing literature reviews when the task is decomposed into smaller components of retrieval and planning. Particularly, we find that combining keyword-based and document-embedding-based search improves precision and recall during retrieval by 10% and 30%, respectively, compared to using either of the methods in isolation. Further, we demonstrate that our planning-based approach achieves higher-quality reviews by minimizing hallucinated references in the generated review by 18-26% compared to existing simpler LLM-based generation methods. Code at github.com.

1 Introduction

Writing a literature review—finding, citing, and contextualizing relevant prior work—is a fundamental requirement of scientific writing. It is a complex task and can be broken down into two broad sub-tasks: **1)** Finding relevant papers and **2)** Generating a related work section that situates the proposed research within the existing literature. This challenge is further amplified in the field of machine learning, with thousands of relevant papers appearing every month on ArXiv alone.[1] We explore the utility and potential of large language models (LLMs), in combination with retrieval mechanisms, to assist in generating comprehensive literature reviews for scientific papers.

Specifically, we investigate the use of LLMs to generate the related work section of a paper based on its abstract. We use the term abstract loosely, not necessarily to refer to the actual abstract of the paper, but rather to a textual passage that captures a concise summary of the paper's key contributions and scope. Using the abstract as input allows our system to target the central ideas of the paper without requiring the complete manuscript, which is often continuously evolving in the early stages of writing. While our experiments focus on using the abstract, our framework is designed to be flexible and can make use of the entire manuscript as it evolves, albeit at a larger computational cost and the need to use models that support

[1] Over 4,000 ML papers were submitted to ArXiv in October 2024: https://arxiv.org/list/cs.LG/2024-10

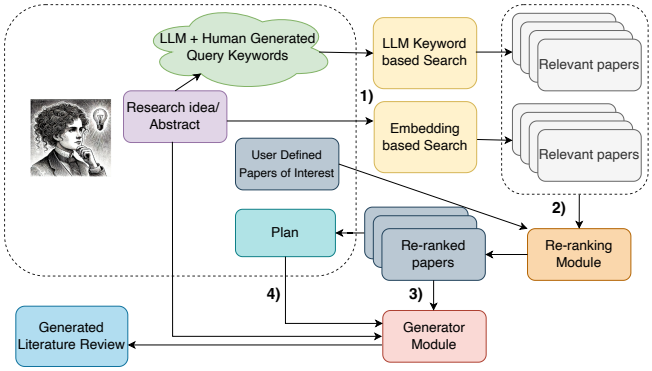

Figure 1: A schematic diagram of our framework, where: 1) Relevant prior work is retrieved using keyword and embedding-based search. 2) LLMs re-rank results to find the most relevant prior work. 3) Based on these papers and the user abstract or idea summary, an LLM generates a literature review, (4) optionally controlled by a sentence plan.

long context windows. This approach provides valuable early-stage insights for authors seeking preliminary references to shape their work, with the capacity to seamlessly incorporate additional information as the manuscript develops.

The architecture of our framework is illustrated in Figure 1. Correspondingly, in this work: **1)** We introduce an LLM-based approach to retrieve relevant papers, where we first extract the keywords from an abstract or research idea paragraph using an LLM and then feed these keywords to a keyword-based search tool – we experiment with Google search and Semantic Scholar. We optionally also transform the abstract or idea into an embedding and use an embedding-based search procedure. **2)** We then employ a prompting-based approach to rank the set of retrieved candidate papers based on their relevance to the query abstract, also requiring the LLM to attribute the relevance to specific excerpts in the candidate papers. We explore multiple re-ranking and aggregation strategies **3)** To generate the literature review, we select top-k papers from the ranked list and prompt the LLM to generate the related work section based on the query abstract and the abstracts of the selected papers. **4)** Additionally, we examine the effectiveness of providing a writing plan to the LLM that specifies which papers to cite at various points in the literature review. These plans can be generated entirely by the LLM, by the user, or a combination of the two. These plans serve as an intermediate representation giving the user more control over the organizational structure of the literature review.

Our most powerful model involves multiple innovations, where we use LLMs in multiple ways, namely for generating search queries, re-ranking search results, and attribution. We summarize the main contributions of our work as follows:

- To answer the key question that our paper poses, we present a data collection protocol and multiple instances of using it to collect arXiv papers. Critically, our protocol is based on using the most recent past month of arXiv papers in a rolling manner with the goal of avoiding test-set contamination when evaluating the most recent LLMs for literature review-related tasks. We then use this protocol to perform extensive retrieval and literature review generation experiments. We release both our datasets and our code to the community.

- We propose a novel LLM-based pipeline for the task of interactive literature review writing, which we decompose into two distinct components: retrieval and generation. This also facilitates more controlled studies investigating alternative LLM-based approaches for these sub-tasks. Our experiments focus on evaluating fully automated variants of these sub-tasks, but our framing of the problem and our proposed solutions are easily integrated into scenarios where human users interact with systems that assist them. To the best of our knowledge our decomposition of the problem into sub-tasks along with our proposed solutions to them and our framing of this assistive scenario is novel.

- We make multiple contributions that improve the retrieval phase of the two step process. Firstly, we propose and evaluate a novel strategy that first uses an LLM to extract meaningful keywords from

the abstract of a paper and then queries different types of external sources to retrieve potentially relevant papers. Second, we compare and combine the aforementioned LLM generated keyword search techniques, with document embedding based retrieval methods. Third, we propose and examine a wide variety of search re-ranking techniques. Among these we propose a novel prompting for attribution approach, which we find to empirically improve the relevance of retrieved literature, while also improving reliability, providing insights and improved transparency into the decision-making process of LLMs when used to rerank results. Going even further we examine debate prompted LLMs for aggregating and re-ranking keyword search and embedding search results. Our experiments show that combining these ideas improves precision and normalized recall by 10% and 30%, respectively, compared to standard retrieval methods.

- For text generation, we propose and examine a plan-based retrieval augmented approach to writing of literature reviews. By using a plan and conditioning on retrieved context we provide a user greater control over generated content and our experiments show that this approach can improve the quality of the generated literature reviews substantially. We evaluate the approach using both automated metrics and human assessments and show that our method generates higher-quality reviews as measured by ROUGE scores and as asessed by human evaluation. Our approach also reduces hallucinations by 18-26%.

2 Related Work

We decompose the task of literature review into two key sub-tasks: identifying relevant papers and generating the final related work section. This decomposition enhances the likelihood that the LLMs can effectively accomplish the task. We now discuss the relevant literature pertinent to both aspects of the process.

2.1 Ranking and Retrieval

Traditional methods for information retrieval rely on techniques like TF-IDF and BM25 to identify documents that are semantically similar to a given query. More recently, dense vector representations obtained through models like Sentence-BERT (Reimers & Gurevych, 2019) have been shown to improve retrieval accuracy by encoding both query and documents into an embedding space where semantic similarity can be readily computed. The initial retrieval stage often results in a large set of candidate documents, which then need to be re-ranked to obtain an ordered list based on relevance.

Recent efforts have explored the application of proprietary and open-source LLMs for ranking (Sun et al., 2023; Ma et al., 2023; Pradeep et al., 2023a;b), where the LLM is passed a combined list of passages directly as input and prompted to rank them based on a criteria. Notably, only top-k candidates are passed as input to the LLM for re-ranking (Zhang et al., 2023). In our work, we instruct an LLM to output an ordering of the different candidate papers (e.g. [3] > [8] > [6]) in descending order based on the relevance to the user-provided abstract. Although existing re-ranking methods improve the ordering of candidate papers, they do not provide explicit justification for the relative rankings assigned. To improve the reliability of the system and offer a clear explanation for the model's choices, our methodology also incorporates attribution capabilities, allowing us to identify specific textual elements contributing to relevance scores for different candidates. Among works exploring the attribution capabilities in LLMs, Yue et al. (2023) focuses on automatically evaluating whether generated statements are fully supported by cited references. Cohen-Wang et al. (2024) present ContextCite, a method for attributing model generation to context, which can be applied on top of any existing language model to help verify generated statements, improve response quality, and detect poisoning attacks. Gradient-based techniques, such as Integrated Gradients (Sundararajan et al., 2017) and Saliency Maps (Simonyan et al., 2014), measure the contribution of each input token by computing gradients of the output with respect to input features; advances like SmoothGrad (Smilkov et al., 2017) and DeepLIFT (Shrikumar et al., 2017) improve these methods by reducing noise and enhancing accuracy. Perturbation techniques involve modifying or occluding parts of the input and observing changes in the output to infer input significance (Li et al., 2016), utilizing methods like Meaningful Perturbations (Fong & Vedaldi, 2017) and LIME (Ribeiro et al., 2016). Despite advancements, challenges such as attribution leakage (Adebayo et al., 2018), unreliability of saliency methods (Kindermans et al., 2019), and complexities

in attributing outputs in large models (Ghorbani et al., 2019) persist. Surveys like Li et al. (2023) discuss current methodologies and inherent challenges, while research by Keeling & Street (2024) examines the theoretical basis for attributing confidence to LLMs, raising concerns about the reliability of experimental assessment techniques. In contrast to the discussed gradient-based attribution methods that are challenging to scale and perturbation-based approaches that need multiple passes through the model, we propose a straightforward prompting-based attribution approach that can be applied to any LLM agent, is readily scalable, and does not require multiple passes through the model.

2.2 Literature Review Generation

The concept of literature review generation using large language models (LLMs) is built upon the foundation laid by the Multi-XScience dataset proposed by Lu et al. (2020). This dataset paves the way for the challenging task of multi-document summarization, specifically focusing on generating the related work section of a scientific paper. As underlined by Lu et al. (2020), this approach favors abstractive models, which are well suited for the task. However, unlike the approach suggested by Lu et al. (2020), our work introduces the use of intermediate plans to improve the quality of generated literature reviews. The empirical evidence presented in our study shows that our novel strategy outperforms the vanilla zero-shot generation previously championed by the Multi-XScience dataset (Lu et al., 2020). (Note: This paragraph was entirely generated by GPT-4 following plan-based generation.[2])

Traditional methods for Natural Language Generation have typically employed a rule-based modular pipeline approach comprising of multiple stages of generation with intermediary steps of content planning (selecting content from input while also determining the structure of the output), sentence planning (planning the structure of sentences) and surface realization (surfacing the text in sentence) (Reiter & Dale, 1997; Stent et al., 2004; Walker et al., 2007). Our proposed plan-based prompting technique draws a parallel between the modern methods of end-to-end neural models for joint data-to-text generation with micro or content planning (Gehrmann et al., 2018; Puduppully et al., 2019; Puduppully & Lapata, 2021) where we use plans to define the sentence structure of the generated output. While some recent works have explored planning in terms of devising actions (Yang et al., 2022; Song et al., 2023; Wang et al., 2023), prompting LLMs based on sentence plans have not been explored, to the best of our knowledge. We show two strategies of using plans 1.) The model generates the sentence plan as an intermediary step and conditions on this generated plan to output the final summary autoregressively. 2.) Humans can provide a ground-truth plan which results in an iterative setting, inherently providing controllability to the generated text where LLMs are susceptible to generating additional content.

Closely related to our work, Gao et al. (2023) generates answers for questions based on the citations from Wikipedia. Also related to our work, Pilault et al. (2020) examined LLM-based abstractive summarization of scientific papers in the Arxiv dataset of Cohan et al. (2018); however, their work was limited to creating the abstract of a single document. Perhaps the most similar prior prompting-based approach to our work is known as 0-shot chain-of-thought prompting (Kojima et al., 2022; Zhou et al., 2022) where a model is prompted with 'Let's think step-by-step' (and similar prompts).

Additionally, Galactica has been developed to store, combine, and reason about scientific knowledge (Taylor et al., 2022). It outperforms existing models on various scientific tasks and sets new state-of-the-art results on downstream tasks. These findings highlight the potential of language models as a new interface for scientific research. However, the Galactica model was not developed to specifically address the problem of literature review assistance and it was not instruction fine-tuned to follow writing plans, and as such it suffered from the effect of hallucinating non-existent citations and results associated with imaginary prior work.[3] Recent works (Rodriguez et al., 2024a;b; Awadalla et al., 2024) have focused on building datasets multimodal of documents and scientific contents. However, our study focuses on exploring the zero-shot abilities of LLMs for literature review generation and proposes a novel strategy that includes generating an intermediate plan before generating the actual text. Our empirical study shows that these intermediate plans improve the

[2]We use the plan: Please generate 5 sentences in 60 words. Cite @cite_1 at line 1, 3 and 5. We postprocess to replace delexicalized tokens with latex commands. Outputs from other models are compared later in Appendix (Tables 13 and 14).

[3]This sentence was inserted by the authors.

quality of generated literature reviews compared to vanilla zero-shot generation. Furthermore, we ensure the validity of our experiments by using a new test corpus consisting of recent arXiv papers to avoid test set contamination. (Note: GPT-3.5 generated this paragraph with the 4th sentence added by the authors).

3 Retrieval of Related Work

In this section, we discuss the creation of the corpus of arXiv papers to examine different retrieval strategies for finding related works for a given paper abstract using different academic and generic web search engines, including Semantic Scholar and Google Search.

3.1 Dataset Construction.

We create two datasets that contain papers posted on ArXiv in August and December 2023 respectively, starting with 1,000 papers from each month. We use ArXiv wrapper in Python[4] to create RollingEval datasets. We then filter out papers for which we were able to retrieve 100 relevant paper results using LLM summarized keywords. We query the Semantic Scholar API available through the Semantic Scholar Open Data Platform (Lo et al., 2020; Kinney et al., 2023) to search for the relevant papers. To get google search results, we use SERP API[5], specifically conditioned to leverage the "site:arxiv.org" parameter. This approach ensures the retrieval of search results are sourced solely from arXiv.org.

To combine results from multiple queries, we take the equal number of top results from each query to get a total of 100 papers. We took caution to avoid duplicate results from different queries. In case we are not able to retrieve sufficient number of results from a query, we then take the equal number from the rest of the queries. This way we ensure that we always retrieve a candidate pool of 100 possible related work for each query paper. We pass these papers as queries to our literature review generation pipeline. We now describe our two-step retrieval mechanism also demonstrated in Algorithm 1.

3.2 Retrieving Candidate Papers

Algorithm 1 Retrieval algorithm

Require: Input abstract a

keywords = LLMKeywords(a); // Generate keywords from the abstract using an LLM
candidate_papers = SearchEngine(keywords); // Query a search engine to retrieve candidates
reranked_papers = LLMRerank(candidate_papers, a); // LLM-based reranking of candidates
return reranked_papers

[4] https://pypi.org/project/arxiv/
[5] https://serpapi.com/

Search type	RollingEval-Aug (%)	RollingEval-Dec (%)
ArXiv API (Single query)	0.65	1.41
SERP API - Google Search (Single query)	1.23	4.34
Semantic Scholar API (Single query)	**3.93**	**4.76**
ArXiv API (Multiple queries)	2.75	1.92
SERP API - Google Search (Multiple queries)	**6.80**	5.04
Semantic Scholar API (Multiple queries)	6.07	**5.09**
SPECTER2	8.3%	6.8%
Semantic Scholar API (Multiple queries) + SPECTER2	**9.8%**	**8.2%**

Table 1: We created two datasets to measure the efficacy of search using LLM generated keywords - RollingEval-Aug and RollingEval-Dec. We evaluate the % of the ground truth references covered in the top 100 search list using LLM based keyword search and different academic search engines. We note that using multiple queries gives us an edge over using a single query; and we obtain a similar coverage for Semantic Scholar and the SERP API based Google Search.

To retrieve related work for a given paper abstract, **first,** for each query abstract in the dataset, we prompt an LLM to generate keywords that we use as queries for a search API (refer to Figure 14 in the Appendix for the detailed prompt used for this task). Importantly, we add a timestamp filter to the search API to retrieve papers published stricly before the publication date of the query paper. In addition to evaluating multiple search engines, we also experiment with generating multiple queries [6] from an LLM and various heuristics to combine the search results from each query (see Appendix D). We evaluate multiple general and academic search engines on the quality of the retrieved papers using coverage, which we define as the percentage of ground-truth papers retrieved by the search engine. Table 1 shows the coverage for different search engines and query heuristics. We note that using multiple queries achieves the highest coverage with comparable results for Semantic Scholar search and SERP API. However, at best, we retrieve just under 7% of the ground truth papers. The low retrieval percentage of just under 7% can be attributed to several factors. First, the task of finding related work for a given paper is inherently challenging due to the diverse styles and methods authors use in literature reviews. This stylistic variability means that a one-size-fits-all approach, such as generating search keywords and using a search engine, might not capture the nuanced criteria that a human expert would apply. Additionally, our retrieval process operates in a constrained setting, generating search keywords based solely on the abstract of the paper. In theory, including more of the paper—such as the introduction or methodology—could provide richer context and lead to higher retrieval rates. However, this would not align with our intended use case: supporting researchers in the early stages of drafting when only limited, unpolished material is available.

We also explore an embedding-based strategy for retrieval using SPECTER embeddings (Cohan et al., 2020). SPECTER uses a contrastive learning approach to train a SciBERT (Beltagy et al., 2019) model based on a triplet loss to discriminate between related versus unrelated papers. SciBERT is a BERT-like transformer model (Devlin et al., 2018) trained on scientific text. More recently, Singh et al. (2022) further extended the contrastive learning approach of SPECTER to better deal with multiple tasks of relevance to scientific papers, including citation prediction, leading to SPECTER2. Since SPECTER2 provides a large knowledge base of 150M document embeddings of scientific articles, we explore embedding-based retrieval of candidate papers, where we obtain the top-k papers based on the cosine similarity between the query abstract and the corpus of candidates papers in the SPECTER2 dataset.

3.3 Re-ranking Candidate Papers

Next, given a list of retrieved papers, we explore re-ranking the list using an LLM. The retrieved abstracts and the original query abstract are used as input to an LLM Re-ranker, which provides a listwise ranking of the candidate papers based on the relevance to the query abstract. We explore different strategies for reranking the candidates, detailed as follows: **a) Instructional permutation generation**: we use the approach by Sun et al. (2023), which prompts the model to directly generate a permutation of the different candidate papers, thus producing an ordered list of preferences against providing intermediate scores; **b) SPECTER2 embeddings**: We use SPECTER2 embeddings as an alternative to prompting-based strategies for reranking, where we rank the candidate papers based on their cosine distances to the SPECTER2 embedding of the query abstract (see Appendix D for more details on SPECTER2 implementation); and **c) Debate Ranking with Attribution (Ours)**: our prompting-based approach that builds on the work of Rahaman et al. (2024), where we pass each candidate paper's abstract along with the query abstract and instruct the LLM to (1) generate arguments for and against including the candidate paper and (2) output a final probability of including the candidate based on the arguments. Crucially, we add an attribution step to this ranking module, where we instruct the LLM to extract verbatim sentences from the candidate abstract that support the arguments, and we re-prompt the LLM if the extracted sentences are not present in the candidate abstract.

3.4 Retrieval and Re-ranking Experiments

We use an ensemble of search engines to retrieve candidates based on an abstract. We now describe the search engines used in our approach. Based on Table 1, we select the Semantic Scholar (S2) API as the search

[6] In our experiments, we generate three queries for each abstract.

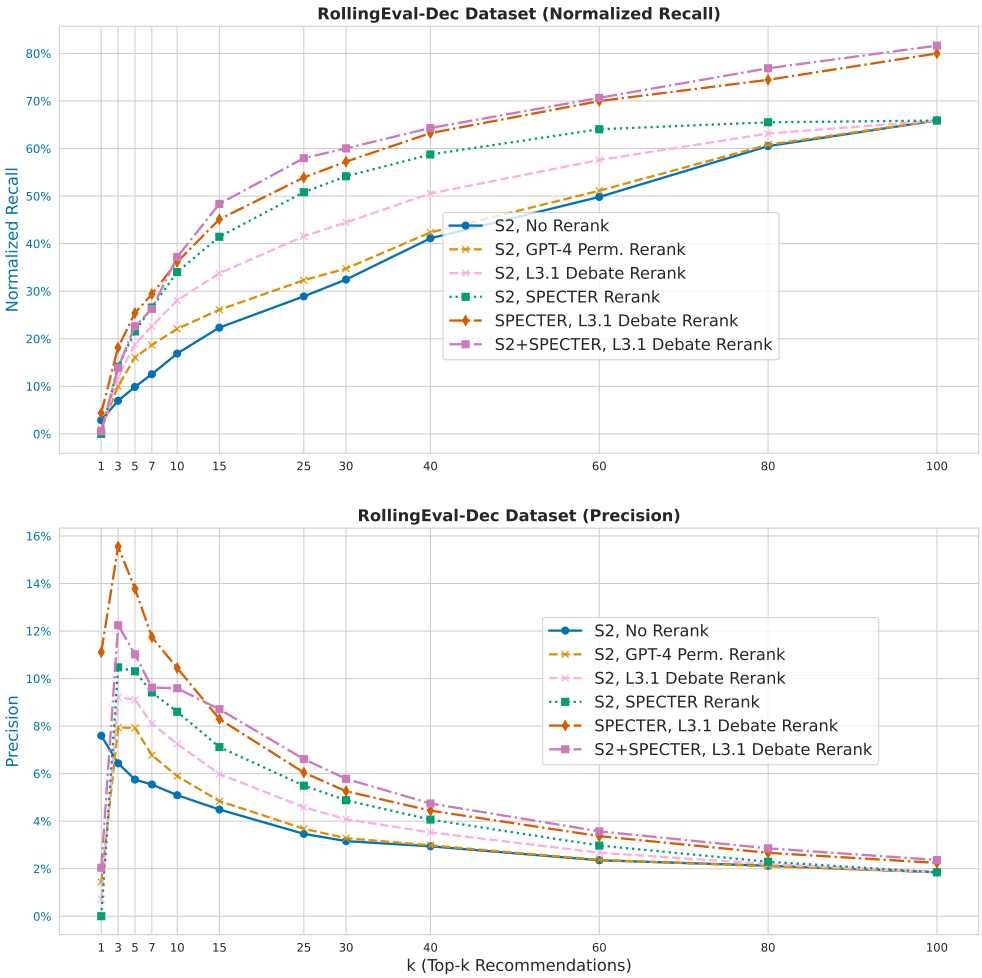

Figure 2: Effect of re-ranking strategies on the RollingEval-Dec dataset. We use the entire dataset (n = 500) and set k = 100 for these experiments. We evaluate the Precision and Normalized Recall of the re-ranked results with embedding-based ranker (SPECTER2) outperforming GPT-4 based re-ranking. We find a similar pattern for the RollingEval-Aug dataset, as shown in Appendix (Figure 7). **Note:** The first part in the legend denotes the search database for retrieval, and the second denotes the re-ranking mechanism.

engine to retrieve search results using LLM-generated keywords. As discussed in Section 3.2, we also explore SPECTER2 embeddings for retrieval and compare it with the different prompting-based strategies.

We experiment with different combinations of search engine and the retriever method, and present our results in Figure 2. We present precision and normalized recall at different values of top-k recommendations, where we calculate normalized recall as the proportion of the number of ground truth papers retrieved (instead of all ground truth papers). Formally, normalized recall and precision follow the definitions:

$$\text{Normalized Recall} = \frac{|\text{Retrieved} \cap \text{Ground Truth}|}{|\text{Ground Truth}|}; \text{Precision@k} = \frac{|\text{Retrieved} \cap \text{Ground Truth}|}{k} \tag{1}$$

where k is the number of top-k recommendations, "Retrieved" denotes the set of top-k candidate papers, and "Ground Truth" denotes the set of Ground Truth (GT) cited papers (papers cited by the query paper).

From Figure 2, we note that debate ranking significantly outperforms permutation ranking, as denoted by the higher precision and normalized recall at smaller values of top-k recommendations; however, SPECTER

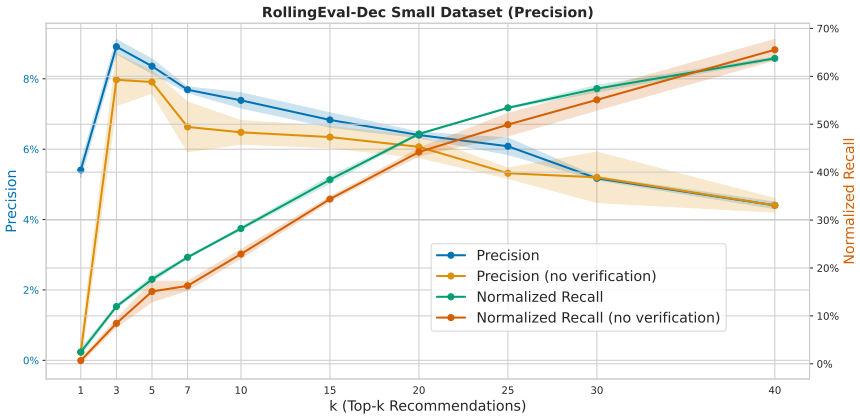

Figure 3: The effect of removing the referenced content verification step in our debate ranking strategy. We plot precision and normalized recall for two variants of the debate ranking strategy. For this ablation study, we select a smaller subset of $n = 100$ query abstracts, set $k = 40$, and repeat the experiment for three random seeds. We plot the mean and show the standard deviation as the shaded region. We find that the precision and normalized recall drop slightly upon removing the verification step. This different is significant (as determined by t-test,) indicating that the verification step is crucial for the success of the debate ranking strategy.

embeddings outperform both prompting-based strategies. Next, the higher precision and normalized recall values for SPECTER and S2+SPECTER settings suggest that SPECTER is also an excellent search engine.

In Table 2, we examine the behaviour of the GPT-4 reranking approach in more detail. Using GPT-4 as a reranker in the manner discussed above, produces an incomplete list 41% of the time. In 3% cases, GPT-4 produces a list which has repeated values with some rare cases with garbage values or numbers (e.g. 2020). We conclude that this strategy of using GPT-4 for reranking is brittle.

3.5 Positive Effect of Attribution Verification

We conduct an ablation study on the first 100 papers of the larger set of 500, and focus on the top $k = 40$ papers, which is representative of the typical number of papers cited in the Machine Learning community. In Figure 3 we show the result of removing the verification step in our debate re-ranking strategy, i.e. in this ablation we do not check if the sentences extracted by the LLM are indeed present in the candidate paper abstract. We find that removing this kind of attribution verification leads to a drop in the precision and normalized recalls, especially for lower k values. We perform a t-test to test the significance of the drop and find that for both precision and normalized recall, the drop is significant, with p-values of $4.7e-4$ and $1.9e-6$ for precision and normalized recall curves, respectively. This indicates that proper attribution also allows the LLM to provide more accurate ranking of candidates.

Ranker Predictions	RollingEval-Aug (%)	RollingEval-Dec (%)
Complete Ranked list	55.1	59.7
Incomplete list	41.5	40.2
Repeated Value	3.3	0.1

Table 2: Error modes of GPT-4 based ranking. When using GPT-4 to provide ranks, it suffers from multiple issues. While recent works like Sun et al. (2023) explore LLMs like GPT-4 for 0-shot rank predictions, we find a tendency of GPT-4 to produce an incomplete list or repeated values in the re-ranked order list with some rare cases of garbage values.

4 Literature Review Generation

4.1 Plan Based Generation Approach & Model Variants

We now focus on generating the related work section of a scientific document from a user-supplied list of papers. In a real-world scenario, this list might be obtained through traditional means, from the above-mentioned automated methods, or some combination. We evaluate several dimensions of writing quality in the generated text. Importantly, while modern LLMs can yield seemingly well-written text passages, "hallucinations" remain a problem and can be particularly egregious when LLMs are used in scientific writing (Athaluri et al., 2023). The hallucination of statements not entailed by the contents of cited papers and the hallucinations of imaginary papers that do not exist is a well-known issue of even the most powerful LLMs. We use ideas from retrieval augmented generation (RAG) techniques (Lewis et al., 2020) and instruction prompting to address the key problem of hallucinations.Our work also aims to increase the number of papers from the desired set that are indeed discussed (the coverage).

We present our general framework and problem setup in Figure 4. We use the abstract of a query paper — the one for which we generate a literature review, along with the abstracts of the set of papers to be cited (the retrieved abstracts of reference papers) to generate the related work section of the query paper. Our approach relies on prompting LLMs in different ways and measuring the similarity of the generated literature review text to ground truth literature reviews found within a corpus of recent scientific papers — i.e. ones not used in the training set of the underlying LLMs. We use both automated methods and human evaluations in our experiments below.

We propose to further decompose the writing task to increase passage quality, factual accuracy, and coverage. We examine different strategies for generating a *writing plan*, a line-by-line description including citations of the passage to write. These writing plans also give authors (users) control over the output passages. This is likely essential in practice to meet author preferences and possible publication constraints. These plans are defined and generated in such a way that the user can interact with and edit them if desired, or they can be used as an automatically generated intermediate (but human understandable) representation. We now we describe our proposed methods, elements of their use in practice and their evaluation in more detail.

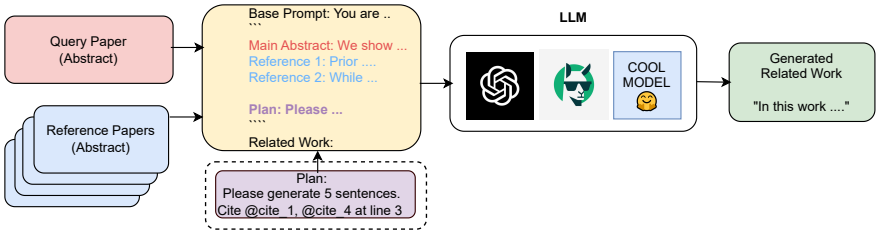

Figure 4: Pipeline of generation task where the model needs to generate the related work of the query paper conditioned on reference papers. Our method employs an optional plan — shown by the dotted purple box, either generated by the model or appended to the prompt.

In what we shall refer to as plan-based generation (**Plan**), a model is prompted with a known (user provided) plan to produce X sentences in Y words and cite references on specific lines. These plans are obtained from the ground truth data and serve as a proxy for a user who desires text to be written with specific constraints. This kind of Plan strongly guides generated text to what the user desires (as observed by the final ground truth text). During evaluation this might be thought of as a form of teacher-forcing at the structural level. An example of the format of these plans is provided below:

```
Please generate {num_sentences} sentences in {num_words} words.  Cite {cite_x} at line {line_x}.  Cite {cite_y} at line
{line_y}.
```

Prompted plan The previous method replicates the scenario of a detailed user provided plan. However, one can also generate such plans automatically from an LLM. The model is prompted to first generate a plan of

sentences and citations which it would then condition upon to generate the final related work text. When used as an interactive tool we envision the user might start with a suggested plan, see the corresponding generated full literature review text, and then iteratively edit the plan and regenerate the result. See our Appendix (Figures 9, 10 and 11) for the differences in the prompts used in our experiments. We also experiment with 2 other strategies in which researchers could prompt the model:

Per cite We first use a two-stage strategy to generate content relevant to each cited paper. In the first stage, the model is prompted to generate related works in 1-2 lines for each individual reference citation. All the outputs for different citations are combined together to form the generated related work. In the second stage, the LLM summarizes and paraphrases the output of the first stage.

Sentence by sentence Based on the Ground truth (GT) related work and the citation on each line, we prompt the model to generate one sentence conditioned on the abstract, the reference cited in that line, and the generated draft so far. In the absence of a citation or at the start, the model is prompted only with abstract and draft of the generated work till now.

5 Generation Experiments

For the following studies on generating related work, we introduce an additional corpus. We extend the Multi-XScience corpus (Lu et al., 2020) to include the full text of research papers. We also reuse the RollingEval-Aug introduced in Section 3. We use HuggingFace Transformers (Wolf et al., 2019) and PyTorch (Paszke et al., 2017) for our experiments[7] and calculate ROUGE scores (Lin, 2004) using the Huggingface evaluate library. Details on the dataset and the implementation are in Appendix B and D, respectively. Similar to Lu et al. (2020), we extract the ground truth cited references as the relevant papers and evaluate only the generated outputs from different systems. Since ROUGE score only measures token-level similarity and does not account for semantic meaning, we also report BERTScore and Llama-3-Eval in Table 4. We use BERTScore, an embedding-based evaluation metric, to account for the semantic meaning of two texts during evaluation as well. On the other hand, we use Llama-3-Eval, an open-source variant of the widely used G-Eval metric (Liu et al., 2023b), as G-Eval has been shown to have better correlation with human preferences.

5.1 Generation Baselines

Extractive baselines As in Lu et al. (2020), we report the performance of LexRank (Erkan & Radev, 2004) and TextRank (Mihalcea & Tarau, 2004). We also create a simple one-line extractive baseline which extracts the first line of the abstract and combines all the citations together to form the output.

Abstractive finetuned baselines We use the model outputs of Hiersum (Liu & Lapata, 2019) and Pointer-Generator (See et al., 2017) from Lu et al. (2020) for abstractive finetuned baselines. We also reproduce the finetuned PRIMER (Xiao et al., 2021) model (considered to be SOTA).

Abstractive zero-shot baselines We use the zero-shot single-document abstractive summarizers FlanT5 (Chung et al., 2022) and LongT5 (Guo et al., 2022) based on the T5 architecture (Raffel et al., 2020). Since Galactica (Taylor et al., 2022) is trained on documents from a similar domain, we include it along with Falcon-180B (Almazrouei et al., 2023).

Open and closed source models We use different chat versions (7B, 13B, 70B) of Llama 2-Chat[8] (Touvron et al., 2023) as zero-shot open-source LLM baselines. For closed-source models, we evaluate zero-shot both GPT-3.5-turbo (Brown et al., 2020) and GPT-4 (OpenAI, 2023). Since they perform best in our initial evaluations, we use the closed-source models in combination with the different generation strategies (Per-cite, Sentence by sentence, plan-based, and learned plan) from Section 4.1.

[7]Code will be released at `github.com`

[8]We refer to Llama 2-Chat models as Llama 2 and GPT-3.5-turbo as GPT-3.5 for brevity.

Model Class	Model	ROUGE1 ↑	ROUGE2 ↑	ROUGEL ↑
Extractive	One line baseline	26.869	4.469	14.386
	LexRank	30.916	5.966	15.916
	TextRank	31.439	5.817	16.398
Abstractive Finetuned	Hiersum	29.861	5.029	16.429
	Pointer-Generator	33.947	6.754	18.203
	PRIMER	26.926	5.024	14.131
Abstractive 0-shot	Long T5	19.515	3.361	12.201
	Flan T5	21.959	3.992	12.778
	Galactica-1.3B	18.461	4.562	9.894
	Falcon-180B	22.876	2.818	12.087
Open-source 0-shot	Llama 2-Chat 7B (No plan)	24.636	5.189	13.133
	Llama 2-Chat 13B (No plan)	26.719	5.958	13.635
	Llama 2-Chat 70B (No plan)	28.866	6.919	14.407
	LLama-3.1-70B (No Plan)	33.289	8.050	15.898
Closed-source 2-stage	GPT-3.5-turbo (Per cite) 1st stage	26.483	6.311	13.718
	GPT-3.5-turbo (Per cite) 2nd stage	24.359	5.594	12.859
	GPT-3.5-turbo (Sentence by sentence)	31.654	6.442	15.577
Closed-source 0-shot	GPT-3.5-turbo (No plan)	29.696	7.325	14.562
	GPT-4 (No plan)	33.213	7.609	15.798
Plan	Llama 2-Chat 70B (Prompted plan)	30.389	7.221	14.911
	GPT-3.5-turbo (Prompted plan)	32.187	7.788	15.398
	GPT-4 (Prompted plan)	34.819	7.892	16.634
	Llama 2-Chat 70B (Plan)	34.654	8.371	17.089
	GPT-3.5-turbo (Plan)	35.042	8.423	17.136
	GPT-4 (Plan)	37.198	8.859	18.772
	LLama-3.1-70B (Plan)	35.575	9.406	18.772

Table 3: Zero-shot results for different models on the Multi-XScience dataset.

6 Results and Observations

From Table 3, we first note that unsupervised extractive models provide a strong baseline compared to abstractive 0-shot single document summarization baselines. Fine-tuning these abstractive models on Multi-XScience (released initially with the benchmark) improves performance at least to the level of extractive models. We reproduce the PRIMER model using their open-source code but find results lower than reported. As such, we consider the Pointer-Generator method to be the current state-of-the-art (SOTA).

Model	ROUGE1 ↑	ROUGE2 ↑	ROUGEL↑	BERTScore↑	Llama-3-Eval↑
CodeLlama 34B-Instruct	22.608	5.032	12.553	82.418	66.898
CodeLlama 34B-Instruct (Plan)	27.369	5.829	14.705	83.386	67.362
Llama 2-Chat 7B	23.276	5.104	12.583	82.841	68.689
Llama 2-Chat 13B	23.998	5.472	12.923	82.855	69.237
Llama 2-Chat 70B	23.769	5.619	12.745	82.943	70.980
GPT-3.5-turbo (0-shot)	25.112	6.118	13.171	83.352	72.434
GPT-4 (0-shot)	29.289	6.479	15.048	84.208	72.951
Llama 2-Chat 70B (Plan)	30.919	7.079	15.991	84.392	71.354
GPT-3.5-turbo (Plan)	30.192	7.028	15.551	84.203	72.729
GPT-4 (Plan)	33.044	7.352	17.624	85.151	75.240

Table 4: Zero-shot results on the proposed RollingEval-Aug dataset.

Single-document summarizers (LongT5, Flan T5) perform poorly in the zero-shot settings with limited ability to cite references. We are limited in the prompt we can provide (because of the training prompts) and resort to 'Summarize the text and cite sources.' Galactica's performance is encouraging compared to other models in the same group, but inspecting its output reveals that it generates the whole introduction of the paper instead of the related work. The model is very sensitive to the prompts used (mostly as suffixes) and struggles to follow instructions. Falcon 180-B, on the other hand, tends to hallucinate user turns and considers this task as multiple turns of user-system exchange, even though we prompted to generate relevant outputs.

All recent versions (7B,13B,70B) of zero-shot Llama 2 models underperform the supervised Pointer-Generator baseline (except for 70B on ROUGE2) and their GPT counterparts. All Llama 2 models tend to produce

Model	Multi-XScience			RollingEval-Aug		
	% ↑	Mean ↓	Max ↓	% ↑	Mean ↓	Max ↓
GPT-3.5-turbo (Plan)	4.73	3.65	17	3	4.7	16
Llama 2-Chat 70B (Plan)	19.04	2.66	22	17.4	2.72	18
GPT-4 (Plan)	60.7	-0.01	8	70.6	-0.16	5

Table 5: We show % of responses with the same number of lines as the plan for both datasets. Here we also show the mean and max difference in lines generated by the model vs. the original plan. -ive implies that a model generated fewer lines than the plan. We find GPT-4 to follow the plan more closely compared to Llama 2 and GPT-3.5.

output in bullet points and also provide references. We find that closed-sourced models like GPT-3.5-turbo and GPT-4 achieve SOTA in the zero-shot setting. However, the proposed sentence-by-sentence and per-citation strategies deteriorate the performance of GPT models which tends to cover all related concepts hierarchically.[9]

Our teacher-forced plan-based framework improves the scores over the 0-shot baseline for both closed-sourced (GPT-3.5 and GPT-4) and open-sourced LLMs, with Llama 2 70B achieving similar scores as GPT-3.5 on both the original Multi-XScience and the new RollingEval-Aug dataset (in Table 4). In Table 4, we also notice that BERTScore and Llama-3-Eval exhibit the same trends as ROUGE scores except in the case where GPT-3.5-turbo (Plan) obtains a higher Llama-3-Eval score than Llama 2-Chat 70B (Plan). These values also showcase the weaker discerning power of BERTScore compared to Llama-3-Eval as all the models achieve a high BERTScore between 82-85%. Llama 2 70B gets more uplift with the plan compared to GPT models where manual inspection reveals fewer hallucinations in the outputs (see qualitative results in Table 13 in Appendix using our abstract). In Table 5, we evaluate controllability of LLM based generation using sentence plans and find that GPT-4 tends to follow the plan more closely. It follows the exact plan 60% of the time, often producing fewer sentences than provided. Llama 2 70B comes in second place in following the plan instructions and GPT-3.5 struggles to follow the plan precisely. We also experiment with a learned plan strategy where the model first generates a plan and then autoregressively generates the output. Though it improves the results over 0-shot baseline, it does not outperform the teacher-forced plan generation in terms of automatic metrics. There is a considerable drop in performance on RollingEval-Aug dataset compared to the original Multi-XScience in terms of ROUGE1/2. It gives more credibility to the hypothesis that the Multi-XScience test set is in the training data of these LLMs and/or that there is a shift in the distribution of these more recent papers. Nevertheless, we find similar scores and ranking patterns between models as for Multi-XScience. We provide other experiments related to fine-tuning, longer context, and CodeLLM in the Appendix C, and we provide cost estimates for different methods in Appendix D.4.

Coverage and human evaluation: We evaluate coverage as the percentage of model outputs with the same number of citations as ground truth (identified using regex on the delexicalized citation in the generated related work). Table 6 shows the efficacy of plan-based approaches. All plan models provide more coverage than their counterparts, with GPT-4 achieving 98% in covering all the citations. The largest uplift is for (vanilla) 0-shot Llama 2 70B. Using a plan raises its coverage from 59% to 82%. Similar to results in Table 5, we find that the coverage of GPT-3.5 does not improve much.

Model	Coverage ↑	Avg. words
Llama 2-Chat 70B (0-shot)	59.31%	284.65
Llama 2-Chat 70B (Plan)	82.62%	191.45
GPT-3.5-turbo (0-shot)	63.11%	293.69
GPT-3.5-turbo (Plan)	68.03%	202.81
GPT-4 (0-shot)	91.34%	215.15
GPT-4 (Plan)	98.52%	125.10

Table 6: Coverage (in %) on the Multi-XScience dataset defines the number of citations covered in the generated response.

[9]We validated these strategies only on GPT-3.5 due to the high incurred cost with GPT-4 models.

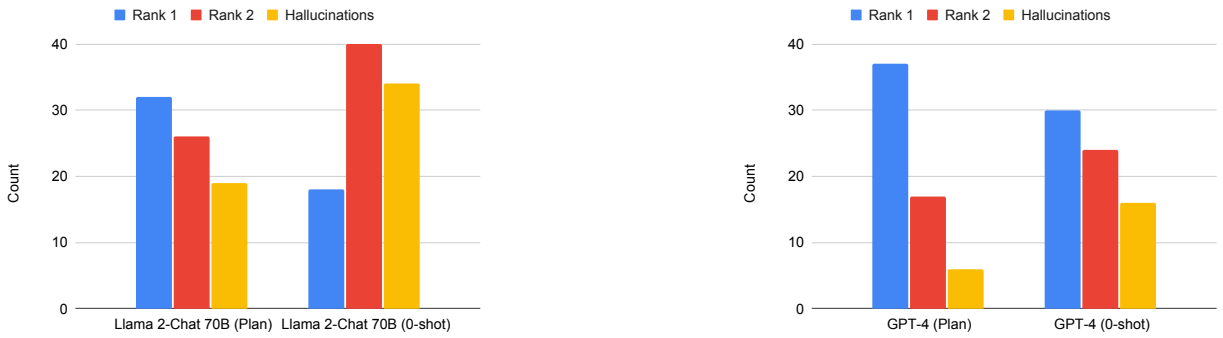

Figure 5: Human evaluation study where annotators ranked the generations of 0-shot models with their sentence-plan based counterparts. On the Y-axis, we show counts from an overall sample size of 58 annotations for Llama 2-Chat and 54 for GPT-4 (where ranking ties are allowed). We see a reduction of 58.6% cases of hallucinations to 32.7% for Llama 2-Chat and 29.6% to 11.6% for GPT-4 using plan-based prompting.

We also run a human evaluation study using 6 expert annotators. They rank model generated outputs for 160 papers with 3 citations[10] where we show the abstract of the query paper, cited references, and the model outputs of 0-shot vs plan counterparts side-by-side. We randomly selected 80 examples each for both GPT-4 and Llama 2-Chat comparison. Experts had the flexibility to choose rank 1 for one or both the models, otherwise they could select rank 2 for each of them. We also ask the annotators to identify hallucinations i.e. which model generated content not from the abstracts. The interface is described further and shown in the Appendix (Figure 8). Out of 160, we find agreement among the annotators for 112 examples (54 for GPT4 and 58 for Llama 2-Chat). The results in Figure 5 show that humans rank generated response to be significantly better[11] for Llama 2-Chat Plan based model where it was ranked at the top 32 times compared to 18 times for 0-shot. We can also observe a similar trend for GPT-4, where annotators rank GPT-4 Plan-based output 37 times at Rank 1 compared to 30 for GPT-4 0-shot. In terms of hallucinations, we find significant reductions in the hallucination for plan-based Llama 2-Chat models from 34 to 19 instances, where the 0-shot model often provided a made-up citation (XYZ et al.), possibly from background knowledge. Only 6 cases of hallucination were found for GPT-4 plan compared to 16 instances for 0-shot vanilla GPT-4 model.

7 Conclusions & Answering: Are We There Yet?

This work discusses, establishes and evaluates a pipeline to help people write literature reviews. To explore this problem setting we have proposed and implemented a rolling evaluation procedure and collected several recent datasets which we will make available to the community. We show that LLMs show significant potential for writing literature reviews when the task is decomposed into these smaller and simpler sub-tasks that are within the reach of LLMs, namely through the use of LLM generated keyword search and embedding based search for relevant prior work. Notably, our experiments indicate that attribution based on citing extracted content from source material improves LLM re-ranking results. The most powerful LLMs evaluated in our studies exhibit both extremely promising paper re-ranking abilities as well as promising literature review generation results. Importantly, LLM hallucinations can be substantially reduced using our proposed plan based prompting and retrieval augmented generation techniques. Our evaluation also reveals clear challenges: 1) retrieving all relevant papers consistent with a given human generated literature review will requires new querying strategies; 2) hallucinations can be significantly reduced using plan-based prompting, but our approach does not completely eliminate hallucinations. Moreover, based on the proposed retrieval and generation pipeline, we build a full working demo (see Figure 15 of our Appendix for a screenshot), which

[10]This was done to reduce cognitive load on annotators to read abstracts of 4+ papers and 2 model outputs. Annotators have research experience in machine learning at the Masters or Doctorate level.

[11]We used McNemar test (Lachenbruch, 2014) to measure statistical significance.

we will release to the community. We hope that authors can use this demo to better understand how these techniques and future alternatives can be most helpful for literature review generation assistance.

Limitations and Future Work Because of the low coverage for retrieval, we evaluate different components independently. During generation, this strategy assumes that we already have filtered relevant papers corresponding to the main paper. In the future, we would like to improve the search for relevant work using embedding-based models to get better coverage and, thus, the ability to evaluate the system end-to-end. Our retrieval component currently suffers from surface-level information about the papers, while in practice, authors frame search keywords based on information (such as underlying datasets) that might not be present in the abstract. Another issue stems from the retrieval evaluation setup based on coverage related to the ground truth papers, where the authors might have different biases. We also acknowledge that including more of the paper, like introduction and methodology, might help improve the set of initial candidate papers; however, using additional sections could inadvertently allow the model to detect explicit citations or references, essentially "cheating" by hinting at specific papers to retrieve. By focusing on the abstract alone, we maintain a more controlled setup that reflects a realistic, early-stage research scenario. It is important to highlight that while we operate in this abstract-only setup, our pipeline is designed to be flexible and interactive. As the paper matures and more content becomes available, researchers can provide additional context to the pipeline to improve retrieval accuracy. This adaptability ensures that our approach remains relevant and effective throughout different stages of the research process, allowing for incremental refinement of related work as drafts evolve over time.

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Appendix

A Ethics Statement

The potential for LLM and other NLP technology to help in scientific writing has led to the emergence of systems such as Explainpaper which helps researchers understand the contents of the paper and Writefull[12] for title and abstract generation. Scite[13] helps find appropriate resources and references while writing research papers. The usage of LLMs by researchers is so evident that some conferences (like ICLR) collect statistics from authors about their usage of these tools for retrieval (or discovery) or paraphrasing the related work section and provide LLM-specific guidelines to authors.[14] While writing assistant technology could have great promise as an aide to scientists, we think their use should be disclosed to the reader. As such assistants become more powerful they might be abused in certain contexts, for example where students are supposed to create a literature review as a part of their learning process. The use of such tools might also be problematic as authors of scientific work should read the articles that they cite and heavy reliance on such tools could lead to short term gains at the cost of a deeper understanding of a subject over the longer term. Any commercially deployed or systems actually used by authors should also contain appropriate mechanisms to detect if words have been copied exactly from the source material, and provide that content in a quoted style. Additionally, the rolling evaluations which we present here does not involved training LLMs on arXiv papers. This mitigates concerns regarding the copyright status of arXiv papers and their use for LLM training.

B New Datasets

While there are datasets available for different tasks in academic literature (see Table 7), we use the Multi-XScience dataset (Lu et al., 2020) for our experiments. Recent work (Chen et al., 2021b; Funkquist et al., 2022) also focuses on related work generation and provides a similar dataset. As part of this work, we release two corpora: 1. We extend the Multi-XScience corpus to include full-text of research papers and 2. We create a new test corpus RollingEval-Aug consisting of recent (August 2023) arXiv papers (with full content).

Dataset	**Task**
BigSurvey-MDS (Liu et al., 2023a)	Survey Introduction
HiCaD (Zhu et al., 2023)	Survey Catalogue
SciXGen (Chen et al., 2021a)	Context aware text generation
CORWA (Li et al., 2022)	Citation Span Generation
TLDR (Cachola et al., 2020)	TLDR generation
Multi-XScience Lu et al. (2020)	Related Work Generation

Table 7: Different tasks for academic literature

Multi-XScience full text We create these datasets based on the latest release (2023-09-12) of the S2ORC corpus[15] (Lo et al., 2020) available at the Semantic Scholar Open Data Platform (Kinney et al., 2023). The S2 Platform provides access to multiple datasets including papers metadata, authors, S2AG (Semantic Scholar Academic Graph), paper embeddings, etc. While the 'Papers' dataset consists of 200M+ metadata records, S2ORC consists of 11+M full-text publicly available records with annotations chunked into 30 files (~215G compressed json) where research documents are linked with arXiv and Microsoft Academic Graph (MAG) (Sinha et al., 2015) IDs, when available. This corpus provides full text of the research papers (parsed using a complex pipeline consisting of multiple LaTeX and PDF parsers such as GROBID (Lopez, 2023) and in-house parsers.[16]). The full text is also aligned with annotation spans (character level on the full

[12] https://www.explainpaper.com/, https://x.writefull.com/
[13] https://scite.ai/
[14] ICLR'24 Large Language Models guidelines https://iclr.cc/Conferences/2024/CallForPapers
[15] Dataset available at http://api.semanticscholar.org/datasets/v1/
[16] https://github.com/allenai/papermage

text), which identify sections, paragraphs, and other useful information. It also includes spans for citation mentions, and the matching semantic corpus-based ID for bibliographical entries making it easier to align with references compared to other academic datasets such as LoRaLay (Nguyen et al., 2023), UnarXive (Saier & Färber, 2020; Saier et al., 2023), etc. or relying on citation graphs like OpenAlex (Priem et al., 2022), next-generation PDF parsers (Blecher et al., 2023) or other HTML webpages.[17] For the Multi-XScience, we obtain the full text of papers for 85% of records from the S2ORC data using the span annotations from the corpus aligned with citation information.

RollingEval datasets Llama 2 was publicly released on 18th July 2023 and GPT-4 on 14 March 2023. Both provide limited information about their training corpus where academic texts in the Multi-XScience may or may not have been part of their training data. To avoid overlap with the training data of these LLMs, we process a new dataset using papers posted after their release date. To do so, we first filter the papers published in August 2023 from S2ORC that contain an arXiv ID resulting in ~15k papers. S2ORC does not provide the publication date of the papers directly, so we use regex '2308' on the arXiv ID to extract papers posted in 08'23. We then use section annotations to get the section names and match using synonyms ('Related Work, Literature Review, Background') to extract section spans. We take the rest of the text as conditioning context except the related work section which results in ~4.7k documents. Using the citation annotations, we extract the full text of cited papers from the S2ORC corpus again using corpus ID. Similar to Multi-XScience, we use paragraph annotations to create a dataset for the latest papers (~6.2k rows). We create a subset of 1,000 examples (RollingEval-Aug) where we have the content of all the cited papers. Average length of related work summary is 95 words while the average length of abstracts is 195. On an average, we have 2 citations per example which makes the dataset comparable to the original Multi-XScience dataset.

C Other Generation Experiments

Llama 2 fine-tuning In parallel, we also fine-tune Llama 2 models on the train set with the original shorter context, but they are very sensitive to hyperparameter configuration. When we instruct-finetune Llama 2 7B, it initially produces code. We find a slight improvement when fine-tuning the Llama 2 7B model for 30k steps with an LR of 5e-6 over 0-shot model (see Table 8), but it quickly overfits as we increase the LR or the number of steps. We leave hyperparameter optimization, the fine-tuning of larger models with RoPE scaling and plan-based generation for future work.

Model	ROUGE1 ↑	ROUGE2 ↑	ROUGEL ↑
Llama 2-Chat 7B - 0-shot	26.719	5.958	13.635
Llama 2-Chat 7B - 10k steps (LR 5e-6)	24.789	5.986	12.708
Llama 2-Chat 7B - 30k steps (LR 5e-6)	27.795	**6.601**	14.409
Llama 2-Chat 7B - 60k steps (LR 1e-5)	22.555	5.511	11.749

Table 8: Results after fine-tuning Llama 2-Chat 7B on Multi-XScience dataset

Longer context While Llama 2 can ingest 4096 tokens, recent studies have found that it uses 19% more tokens (Kadous, 2023) than GPT-3.5 or GPT-4 (2048 and 4096 tokens respectively), implying that the effective number of words in Llama 2 is considerably lower than GPT-4 and only a bit higher than GPT-3.5. We experiment with the popular RoPE scaling (Su et al., 2021) in 0-shot Llama models to increase the context length (4k–6k). This permits using the full text of the papers instead of just their abstracts. Results in Table 9 show that directly using RoPE scaling on 0-shot models produces gibberish results. Instead, one needs to fine-tune the model with the longer context. In fact, a plan-based-longer-context CodeLlama (initialized from Llama 2 and trained with a 16k token context through RoPE scaling) improves on ROUGE1/L, but achieves comparable results as a shorter-context plan-based CodeLlama on ROUGE2. For reporting results

[17] https://ar5iv.labs.arxiv.org/ and https://www.arxiv-vanity.com/

with longer context Llama 2 using RoPE scaling (Su et al., 2021), we use HuggingFace Text Generation Inference.[18]

Model	ROUGE1 ↑	ROUGE2 ↑	ROUGEL ↑
Llama 2-Chat 7B (4000 words)	17.844	1.835	10.149
Llama 2-Chat 7B (5000 words)	17.254	1.736	9.986
Llama 2-Chat 7B (6000 words)	17.179	1.647	9.897
Llama 2-Chat 13B (4000 words)	20.071	3.516	10.916
Llama 2-Chat 13B (5000 words)	20.722	3.714	11.13
Llama 2-Chat 13B (6000 words)	17.179	1.647	9.897
Llama 2-Chat 70 (4000 words)	19.916	2.741	10.456
Llama 2-Chat 70B (5000 words)	19.675	2.605	10.48
Llama 2-Chat 70B (6000 words)	20.437	2.976	10.756
CodeLlama 34B-Instruct (4000 words)	27.425	5.815	14.744

Table 9: Zero-shot results using RoPE scaling for larger context on RollingEval-Aug dataset. Here we report the max number of words used for truncation instead of the tokens.

Code LLMs We evaluate the performance of code-generating LLMs to write related-work section which requires more formal and structured language. Since Code LLMs are pre-trained on text they might offer the best of both worlds. However, we observe that for our task, the models produce bibtex and Python code with relevant comments as part of the generated outputs. As shown in Table 10, CodeLlama (34B Instruct) is good at following instructions and at generating natural language (ROUGE2 of 5.8 and 5.02 on Multi-XScience and RollingEval-Aug dataset). With a plan, CodeLlama even surpasses vanilla 0-shot Llama 2 70B (Table 4).

Model	ROUGE1 ↑	ROUGE2 ↑	ROUGEL ↑
StarCoder	12.485	1.104	6.532
Lemur-70B	15.172	2.136	7.411
CodeLlama 34B-Instruct	25.482	5.814	13.573

Table 10: 0-shot results using code-based models on Multi-XScience dataset. CodeLlama performs reasonably well in generating natural language compared to the other code based counterparts.

D More implementation details

D.1 Generation Implementation

We use HuggingFace Transformers and PyTorch (Paszke et al., 2017) for our experiments.[19] We calculate ROUGE scores (Lin, 2004) using the Huggingface (Wolf et al., 2019) evaluate library[20]. To split sentences, we use 'en_core_web_sm' model from SpaCy[21]. Additionally, we use Anyscale endpoints[22] to generate 0-shot Llama 2 results and OpenAI API[23] to generate results for GPT-3.5-turbo and GPT-4.

[18] https://github.com/huggingface/text-generation-inference

[19] Code will be released at github.com

[20] https://huggingface.co/spaces/evaluate-metric/rouge Since it is a known issue in the NLG community of different implementations producing different results, we stick to evaluate==0.4.0 for reporting all the results, reproducing the ROUGE scores for baselines from Multi-XScience model outputs.

[21] https://spacy.io/usage/linguistic-features

[22] https://app.endpoints.anyscale.com/

[23] https://platform.openai.com/docs/guides/gpt

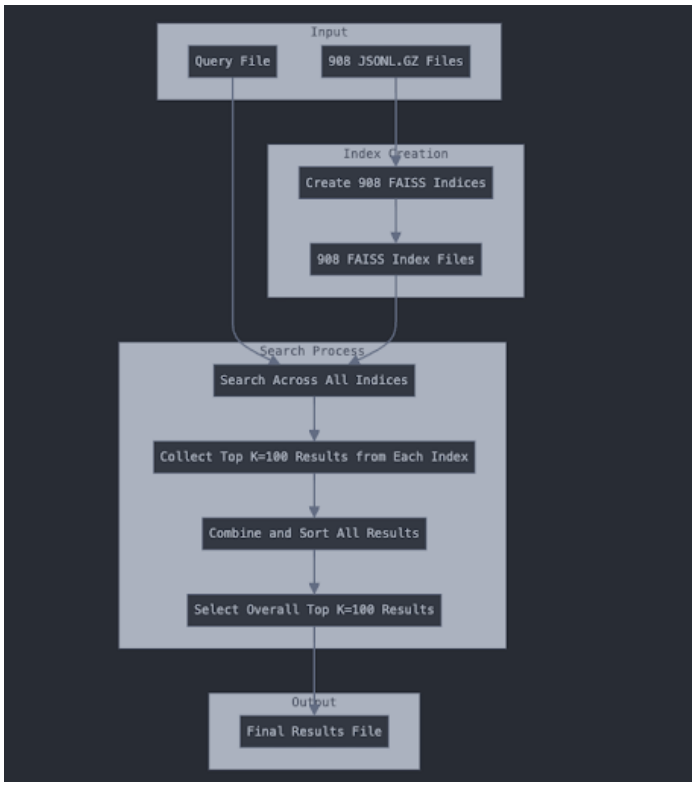

Figure 6: Pipeline for creating FAISS indexes for 150M SPECTER2 embeddings.

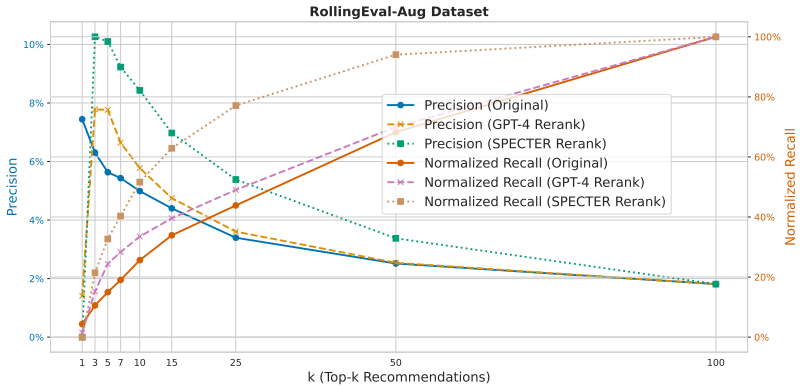

Figure 7: Effect of re-ranking strategies on the RollingEval-Aug dataset. We evaluate the Precision and Normalized Recall of the re-ranked results contrasting LLM-based based re-ranking with embedding-based ranker. We find a similar pattern as the RollingEval-Aug dataset.

D.2 Demo implementation

We build our system using Gradio (Abid et al., 2019), which provides a nice interface to quickly and efficiently build system demos. Our user interface is also available at HuggingFace Space[24].

We query the Semantic Scholar API available to search for the relevant papers. Specifically, we use the Academic Graph[25] and Recommendations[26] API endpoint. We use OpenAI API to generate results for LLM using GPT-3.5-turbo and GPT-4 models. At the same time, our modular pipeline allows using any LLM (proprietary or open-sourced) for different components. We also allow the end-user to sort the retrieved papers by relevance (default S2 results), citation count, or year. More details about the demo system can be found in our system paper.

D.3 SPECTER Implementation

We build an index of 150M SPECTER2 embeddings that we can use as an alternative to both a search engine and a prompting-based ranking module. Figure 6 shows our pipeline for creating the index. Specifically, the SPECTER2 database comes with 908 json.gz files containing compressed embeddings. For each json.gz file, we construct a FAISS index that we can query for the nearest neighbors of a given query embedding. We perform index construction in a multi-threaded manner to speed up the process. Upon constructing a FAISS index for all the json.gz files, we iterate over each query paper, search for top 100 relevant papers using the SPECTER embeddings in *each* FAISS index, and then finally merge the results to get the top 1000 papers for each query paper.

D.4 Comparative analysis of the computational costs

We compare costs of different LLMs for both the stages in Table 11.

Ranking: We explore two types of LLM-based reranking mechanisms: permutation and debate ranking. If we have n query papers (=500 for our RollingEval datasets) and choose top-k candidates from S2 (=100 in our experiments), we need to make n API calls for permutation ranking and $n * k$ requests for debate ranking.

Generation: There was only one request per query abstract in the RollingEval dataset, so 500 requests in total for each experiment (as n = 500 in RollingEval). The table below summarizes the API analysis for the two stages of the pipeline for the RollingEval experiments.

Experiment	Method	Requests	Tokens	Cost
Ranking	GPT-4 Permutation Reranking	500	~20M input + ~0.25M output tokens	$50
	Llama-3.1 Debate Ranking (w/o attribution)	500 x 100	~33M input + ~0.25M output tokens	$0
	Llama-3.1 Debate Ranking (w/ attribution)	500 x 100	~33M input + ~15M output tokens	$0
Generation	Llama 2 70B (using Anyscale Endpoint)	500	~0.75M input + ~0.15M output tokens	$3.84
	GPT-3.5-turbo	500	~0.75M input + ~0.15M output tokens	$4.2
	GPT-4	500	~0.75M input + ~0.15M output tokens	$22
	GPT-4 (Plan)	500	~0.75M input + ~0.15M output tokens	$25

Table 11: Computational costs for different experiments on the RollingEval dataset. Costs for generation experiments on the Multi-XScience are approximately 10 times than the RollingEval dataset.

[24] https://huggingface.co/spaces/
[25] https://api.semanticscholar.org/api-docs/graph
[26] https://api.semanticscholar.org/api-docs/recommendations

Abstract of Multi-XScience paper (Lu et al., 2020)
Reference @cite_1: Multi-document summarization is a challenging task for which there exists little large-scale datasets. We propose Multi-XScience, a large-scale multi-document summarization dataset created from scientific articles. MultiXScience introduces a challenging multi-document summarization task: writing the related-work section of a paper based on its abstract and the articles it references. Our work is inspired by extreme summarization, a dataset construction protocol that favours abstractive modeling approaches. Descriptive statistics and empirical results—using several state-of-the-art models trained on the MultiXScience dataset—reveal that Multi-XScience is well suited for abstractive models.
Abstract of Extractive and Abstractive Summarization paper (Pilault et al., 2020)
Reference @cite_2: We present a method to produce abstractive summaries of long documents that exceed several thousand words via neural abstractive summarization. We perform a simple extractive step before generating a summary, which is then used to condition the transformer language model on relevant information before being tasked with generating a summary. We show that this extractive step significantly improves summarization results. We also show that this approach produces more abstractive summaries compared to prior work that employs a copy mechanism while still achieving higher rouge scores. Note: The abstract above was not written by the authors, it was generated by one of the models presented in this paper.
Abstract of Galactica paper (Taylor et al., 2022)
Reference @cite_3: Information overload is a major obstacle to scientific progress. The explosive growth in scientific literature and data has made it ever harder to discover useful insights in a large mass of information. Today scientific knowledge is accessed through search engines, but they are unable to organize scientific knowledge alone. In this paper we introduce Galactica: a large language model that can store, combine and reason about scientific knowledge. We train on a large scientific corpus of papers, reference material, knowledge bases and many other sources. We outperform existing models on a range of scientific tasks. On technical knowledge probes such as LaTeX equations, Galactica outperforms the latest GPT-3 by 68.2% versus 49.0%. Galactica also performs well on reasoning, outperforming Chinchilla on mathematical MMLU by 41.3% to 35.7%, and PaLM 540B on MATH with a score of 20.4% versus 8.8%. It also sets a new state-of-the-art on downstream tasks such as PubMedQA and MedMCQA dev of 77.6% and 52.9%. And despite not being trained on a general corpus, Galactica outperforms BLOOM and OPT-175B on BIG-bench. We believe these results demonstrate the potential for language models as a new interface for science. We open source the model for the benefit of the scientific community.
Plan for Table 13
Please generate 5 sentences in 120 words. Cite @cite_1 at line 1, 3 and 5.
Plan for Table 13
Please generate 5 sentences in 120 words. Cite @cite_1 at line 1 and 3. Cite @cite_2 at line 2 and 5. Cite @cite_3 at line 4 and 5.

Table 12: Abstracts of papers which are reference citations in Tables 13 and 14.

GPT-4 0-shot
The field of multi-document summarization has been a challenging one due to the lack of large-scale datasets (@cite_1). One significant attempt to address this gap is the Multi-XScience dataset, a large-scale collection of scientific articles designed to simulate the task of writing the related-work section of a research paper (@cite_1). This approach was inspired by extreme summarization, a methodology that promotes abstractive modeling approaches. However, the current study offers a novel strategy for literature review generation using large language models (LLMs), which goes beyond the scope of the Multi-XScience dataset. The proposed method involves the creation of an intermediate plan, which is then used to generate the actual text. Empirical evidence suggests that this approach improves the quality of the generated literature reviews compared to the conventional zero-shot generation. Additionally, this work expands the Multi-XScience corpus to include the full text of research papers, further enhancing the depth and breadth of information available for literature review generation. This study also ensures the validity of zero-shot experiments by creating a new test corpus from recent arXiv papers, thus avoiding test set contamination. This reflects a more comprehensive and rigorous approach to the generation of literature reviews using LLMs.
GPT-3.5 Plan
The task of generating literature reviews using large language models (LLMs) has gained attention recently. One approach is to condition the LLM on the abstracts of the papers to be cited and generate the literature review directly. However, the authors propose a novel strategy where they first generate a plan for the review and then use it to generate the actual text. This intermediate planning step is found to improve the quality of the generated literature reviews compared to vanilla zero-shot generation. The authors extend the Multi-XScience corpus, previously containing only abstracts, to include the full text of research papers. Additionally, they create a new test corpus consisting of recent arXiv papers, ensuring that their zero-shot experiments are not affected by contamination from the test set. The Multi-XScience dataset, used in their work, is particularly suitable for abstractive models due to its challenging multi-document summarization task (@cite_1). The empirical results from several state-of-the-art models trained on this dataset demonstrate its effectiveness for abstractive modeling approaches.
GPT-3.5 0-shot
Prior work in the field of generating literature reviews has primarily focused on the use of large language models (LLMs) and multi-document summarization. Multi-document summarization is a challenging task due to the lack of large-scale datasets (@cite_1). The Multi-XScience dataset was proposed as a solution to this problem, specifically designed for generating the related-work section of a paper based on its abstract and the articles it references. This dataset introduced a challenging multidocument summarization task that favors abstractive modeling approaches (@cite_1). Our work builds upon these prior efforts by exploring the zero-shot abilities of recent LLMs for the task of generating literature reviews. We propose a novel strategy that involves generating an intermediate plan for the review, which is then used to generate the actual text. While modern LLMs can generate literature reviews without such intermediate plans, our empirical study shows that the use of these plans improves the quality of the generated reviews compared to vanilla zero-shot generation. In addition to extending the Multi-XScience corpus to include the full text of research papers, we also create a new test corpus consisting of recent arXiv papers. This allows us to ensure that our zero-shot experiments are not affected by test set contamination. The prior work on multi-document summarization and the Multi-XScience dataset provides a valuable foundation for our study. However, they do not specifically address the use of intermediate plans for literature review generation, which is a key contribution of our work. By incorporating these intermediate plans, we aim to enhance the quality and coherence of the generated literature reviews.
Llama 2 Plan
The task of generating literature reviews for scientific research papers has gained significant attention in recent years, with a focus on using large language models (LLMs) for zero-shot generation. Inspired by extreme summarization, Multi-XScience was introduced as a large-scale dataset for multi-document summarization, including the challenging task of writing related-work sections based on abstracts and referenced articles. Our work builds upon this foundation by exploring the effectiveness of intermediate plans for literature review generation. Our empirical study shows that these plans improve the quality of generated literature reviews, and we contribute to the extension of the Multi-XScience corpus to include full-text papers. Additionally, we create a new test corpus to ensure zero-shot experiments are free from test set contamination. (@cite_1)
Llama 2 0-shot
In recent years, there has been growing interest in using large language models (LLMs) for zero-shot literature review generation. However, most studies have relied on training or prompting LLMs to condition on all abstracts of papers to be cited, which can be limiting in terms of quality and efficiency. In contrast, our proposed approach involves generating a plan for the literature review and then using it to generate the actual text. We evaluate the effectiveness of this approach using a novel extended version of the Multi-XScience corpus, which now includes the full text of research papers. Our results show that intermediate plans improve the quality of generated literature reviews over vanilla zero-shot generation. One of the key challenges in multi-document summarization is the lack of large-scale datasets. To address this, we have created a new test corpus consisting of recent arXiv papers with full content, ensuring that our zero-shot experiments are not contaminated by the release of the LLMs used in our study. Our work builds on the concept of extreme summarization, which favors abstractive modeling approaches. We have employed several state-of-the-art models trained on the Multi-XScience dataset to evaluate the effectiveness of our approach. The results show that our dataset is well-suited for abstractive models, providing a valuable resource for researchers working in this area. In summary, our contribution includes a novel approach to literature review generation using LLMs, an extended version of the Multi-XScience corpus, and a new test corpus. Our results demonstrate the effectiveness of our approach and highlight the potential of using LLMs for zero-shot literature review generation. References: * @cite_1: Multi-XScience: A Large-Scale Multi-Document Summarization Dataset. * @cite_2: Extreme Summarization: A Dataset Construction Protocol for Abstractive Modeling.

Table 13: We show outputs of different models corresponding to the same plan and prompt as paragraph of our related work (by GPT-4 Plan). Llama 2 70B 0-shot has the tendency to hallucinate citation (in red) which is remedied in plan based generation. Abstract of reference paper shown in Table 12 while the main abstract is a slight modified version of our current abstract. We also find that the 0-shot results are more verbose, copying the exact text verbatim, while the generated literature review using plans are more representative of the way humans write literature review.

GPT-4 Plan
The concept of generating the related-work section from abstracts and referenced articles is not entirely new, as evidenced by the Multi-XScience dataset proposed by @cite_1. The approach of extending abstractive summarization to lengthy documents via an extractive step for conditioning, as described by @cite_2, aligns with the proposed methodology here. However, the strategy introduced in this study differentiates itself by creating an iterative plan prior to the generation of the review, a step not present in the work of @cite_1. The LLM used in this study also builds upon the capabilities of models like Galactica @cite_3, which have demonstrated exceptional performance on scientific tasks. The results of @cite_2 and @cite_3 support the potential of large language models in scientific literature review generation, while the proposed approach aims to further enhance the quality of these outputs through structured planning.
GPT-4 0-shot
The literature review generation task, a form of multi-document summarization, has been tackled through different strategies. @cite_1 proposed a dataset, MultiXScience, to foster abstractive approaches, while @cite_2 used an extractive step to enhance neural summarization. Our work complements these by introducing intermediate plans to improve generation quality. Meanwhile, @cite_3's Galactica demonstrated potential for language models in scientific tasks, a direction we explore with zero-shot experiments.
GPT-3.5 Plan
The task of generating a literature review using large language models (LLMs) has gained attention recently. One approach is to condition the LLM on the abstract and content of related papers to generate the review (@cite_1). However, it has been observed that generating an intermediate plan for the review improves its quality compared to vanilla zero-shot generation. This motivated the proposal and examination of a novel strategy where a plan is first generated and then used to generate the actual text (@cite_1). Another method to improve abstractive summarization is by performing an extractive step before generating the summary. This step conditions the transformer language model on relevant information, leading to better summarization results compared to prior work that employs a copy mechanism (@cite_2). Additionally, the use of large language models like Galactica has shown promising results in organizing and reasoning about scientific knowledge (@cite_3). Galactica outperforms existing models on technical knowledge probes and downstream tasks, demonstrating the potential for language models as a new interface for science (@cite_3).
GPT-3.5 0-shot
Prior work has explored the use of large language models (LLMs) for various natural language processing tasks. Multi-document summarization is one such task, and the Multi-XScience dataset (@cite_1) has been created specifically for this purpose. This dataset focuses on writing the related-work section of a scientific paper based on its abstract and the articles it references. The dataset construction protocol favors abstractive modeling approaches, making it suitable for LLMs. Another approach to abstractive summarization is presented in a paper (@cite_2), where the authors propose a method to generate summaries of long documents. They employ an extractive step to gather relevant information before conditioning the transformer language model for summary generation. This approach yields more abstractive summaries compared to prior work, while still achieving higher rouge scores. Furthermore, the concept of using LLMs for scientific knowledge organization and reasoning is introduced in the Galactica model (@cite_3). This model is trained on a large scientific corpus and outperforms existing models on various scientific tasks. It demonstrates superior performance on technical knowledge probes and reasoning tasks, surpassing GPT-3 and other models. Galactica also achieves state-of-the-art results on downstream tasks such as PubMedQA and MedMCQA, showcasing the potential of LLMs as a new interface for science. Based on these prior works, we propose a novel strategy for literature review generation using LLMs. We first generate a plan for the review and then use it to generate the actual text. While modern LLMs can generate literature reviews without intermediate plans, our empirical study indicates that these plans improve the quality of generated reviews. Additionally, we create a new test corpus consisting of recent arXiv papers, ensuring that our zero-shot experiments are not affected by test set contamination.
Llama 2 Plan
In recent years, there has been a growing interest in using large language models (LLMs) for scientific literature review generation (@cite_1). One approach is to use a novel strategy that involves generating a plan for the review and then using it to generate the actual text (@cite_1). This approach has been shown to improve the quality of generated literature reviews over vanilla zero-shot generation (@cite_1). Another approach is to use a simple extractive step before generating a summary, which is then used to condition the transformer language model on relevant information (@cite_2). This approach has been shown to produce more abstractive summaries compared to prior work that employs a copy mechanism while still achieving higher ROUGE scores (@cite_2). Additionally, there have been efforts to train LLMs on large scientific corpora to improve their ability to store, combine, and reason about scientific knowledge (@cite_3). For example, Galactica, a large language model, has been trained on a range of scientific tasks and has outperformed existing models on technical knowledge probes, reasoning, and downstream tasks (@cite_3). These advancements in LLMs have the potential to revolutionize the way we interact with scientific literature and accelerate scientific progress.
Llama 2 0-shot
In this section, we discuss the related work in the field of scientific literature review generation using large language models (LLMs). Recent works have explored the use of LLMs for multi-document summarization tasks, such as generating the related work section of a paper based on its abstract and the articles it references (@cite_1). These works have shown that LLMs can produce high-quality summaries, but may suffer from the lack of relevant information and context (@cite_2). To address this issue, we propose a novel strategy for literature review generation that involves generating a plan for the review before generating the actual text. This approach has been shown to improve the quality of generated literature reviews over vanilla zero-shot generation (@cite_3). Additionally, we create a new test corpus consisting of recent arXiv papers to ensure that our zero-shot experiments do not suffer from test set contamination. Our work builds upon the recent advances in LLMs and their ability to store, combine, and reason about scientific knowledge (@cite_3). We believe that our approach has the potential to revolutionize the way scientific literature is reviewed and organized, and we open source our model for the benefit of the scientific community. In summary, our related work demonstrates the potential of LLMs for scientific literature review generation, and highlights the importance of context and information in producing high-quality summaries. Our proposed approach aims to address these limitations and provide a more effective way of generating literature reviews using LLMs.

Table 14: We show outputs of different models corresponding to the reference cited abstracts and plan mentioned in Table 12 while the main abstract is a slight modified version of our current abstract. In this example, though, we have all the citations covered by all the models, we can see GPT-4 (Plan) output to be concise and closely following the plan. Moreover, GPT-3.5 and Llama 0-shot outputs are are excessively elaborate, making them unsuitable for inclusion in the literature review. Our findings indicate that while LLMs can help in certain aspects, the final output still heavily relies on inputs from a human researcher.

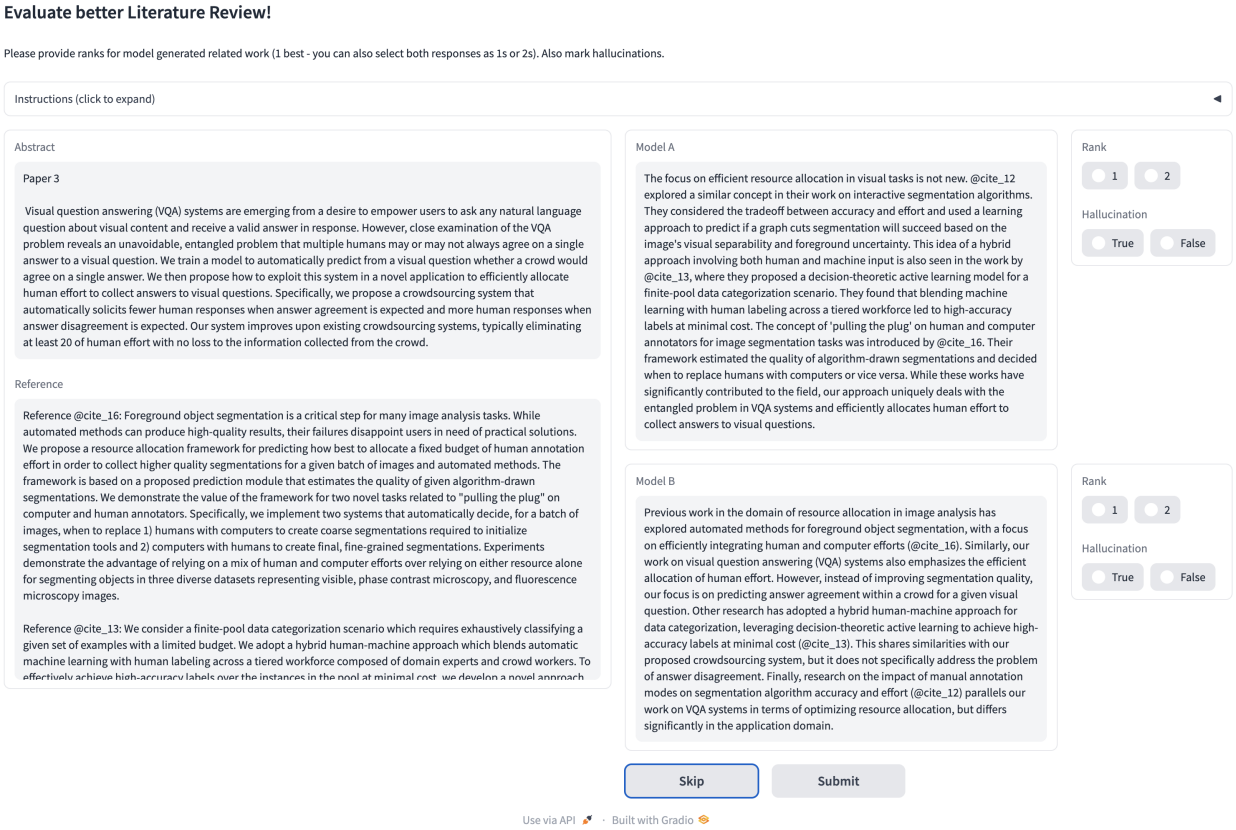

Figure 8: Interface of our human evaluation setup.

Vanilla 0-shot prompt

You will be provided with an abstract of a scientific document and other references papers in triple quotes. Your task is to write the related work section of the document using only the provided abstracts and other references papers. Please write the related work section creating a cohesive storyline by doing a critical analysis of prior work comparing the strengths and weaknesses while also motivating the proposed approach. You should cite the other related documents as (@cite_#) whenever it is referred in the related work. Do not cite abstract. Do not include any extra notes or newline characters at the end. Do not copy the abstracts of reference papers directly but compare and contrast to the main work concisely. Do not provide the output in bullet points. Do not provide references at the end. Provide the output in max 200 words.

Suffix - “Related Work: \n”

Figure 9: Prompt used for Vanilla 0-shot generation.

Plan based prompt

You will be provided with an abstract of a scientific document and other references papers in triple quotes. Your task is to write the related work section of the document using only the provided abstracts and other references papers. Please write the related work section creating a cohesive storyline by doing a critical analysis of prior work comparing the strengths and weaknesses while also motivating the proposed approach. *You are also provided a plan mentioning the total number of lines and the citations to refer in different lines. You should cite the other related documents as (@cite_#) whenever it is referred in the related work.* Do not cite abstract. Do not include any extra notes or newline characters at the end. Do not copy the abstracts of reference papers directly but compare and contrast to the main work concisely. Do not provide the output in bullet points. Do not provide references at the end. Please follow the plan when generating sentences, especially the number of lines to generate. Provide the output in max 200 words.

Suffix - “Related Work: \n”

Figure 10: Prompt used for Plan based generation. Underlined text shows the variation compared to the vanilla 0-shot prompting, where the user provides a structure of the expected paragraph.

Learned plan prompt

You will be provided with an abstract of a scientific document and other reference papers in triple quotes. Your task is to write the related work section of the document using only the provided abstracts and other reference papers. Please generate the related work creating a cohesive storyline by doing a critical analysis of prior work comparing the strengths and weaknesses while also motivating the new work. You should cite the other related documents as (@cite_#) whenever it is referred to in the related work. Do not cite abstract. Do not include any extra notes or newline characters at the end. Do not copy the abstracts of reference papers directly but compare and contrast to the main work concisely. Do not provide the output in bullet points. Do not provide references at the end. Provide the output in max 200 words. *You should first generate a plan, mentioning the total number of lines, words and the citations to refer to in different lines. You should follow this plan when generating sentences. \n Example: \n\n Plan: Generate the related work in [number] lines using max [number] words. Cite @cite_# on line [number]. Cite @cite_# on line [number].*\n

Suffix - “Related Work: \n”

Figure 11: Prompt used when plan is learned during generation. The model first generates a plan of sentences and citations which it would then condition upon to generate the final related work text, which can be considered as an extension of CoT style thinking step by step.

Sentence by sentence prompt

You are assisting a researcher to write a related work section of a paper sentence by sentence. *You will be provided with an abstract of the scientific document and raw draft of generated related work till now in triple quotes.* *Additionally, you will be provided with a reference paper if it has to be cited in the sentence. Your task is to write another 1 sentence for the related work section of the document or paraphrase the draft using only the abstract and other reference papers if provided. Initially, the raw draft would be empty.* Please complete the related work creating a cohesive storyline by doing a critical analysis of prior work comparing the strengths and weaknesses while also motivating the proposed approach. You should cite the other related documents as (@cite_#) only whenever it is referred to in the related work. Do not cite abstract. Do not include any extra notes or newline characters at the end. Do not copy the abstracts of reference papers directly but compare and contrast to the main work concisely. Do not provide the output in bullet points. Do not provide references at the end. Provide the output in max 200 words. *Provide the complete related work including the new sentence.*

Suffix - “Related Work: \n”

Figure 12: Prompt used for Sentence by sentence generation. In this scenario, we prompt the model to generate one sentence for each of the citation individually.

Per cite prompt

You will be provided with an abstract of a scientific document and other references paper in triple quotes. Your task is to write the related work section of the document using only the provided abstracts and other references papers. Please generate the related work creating a cohesive storyline by doing a critical analysis of prior work comparing the strengths and weaknesses while also motivating the new work. You should cite the other related documents as (@cite_#) whenever it is referred in the related work, comparing with the main paper. Do not cite abstract. Do not provide references at the end. Provide the output in 1-2 sentence.

Suffix - “Related Work: \n”

Figure 13: Prompt used for generating output per citation.

Keyword summarization prompt

You are a helpful research assistant who is helping with literature review of a research idea. You will be provided with an abstract of a scientific document. Your task is to summarize the abstract in max 5 keywords to search for related papers using API of academic search engine.
```Abstract: {abstract}```

Figure 14: Prompt used to summarize the research idea by LLM to search an academic engine
```

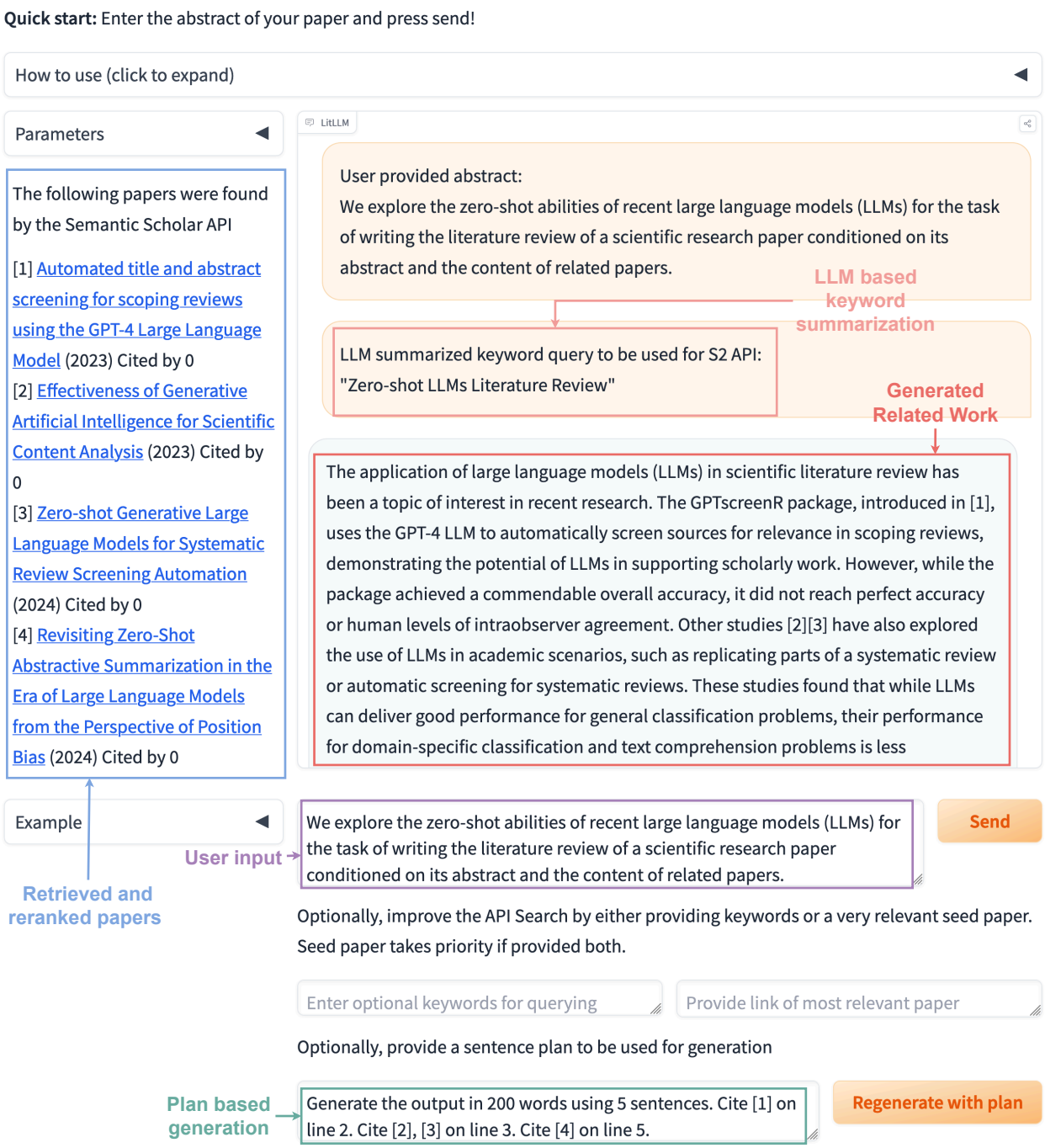

Figure 15: Anonymized system interface on Huggingface Space. Our system works on the Retrieval Augmented Generation (RAG) principle to generate the literature review grounded in retrieved relevant papers. User needs to provide the abstract in the textbox (in purple) and press send to get the generated related work (in red). First, the abstract is summarized into keywords, which are used to query a search engine. Retrieved results are re-ranked (in blue) using an LLM, which is then used as context to generate the related work. Users could also provide a sentence plan (in green) according to their preference to generate a concise, readily usable literature review.