Many-Shot Scaling of In-Context Learning with Self-Generated Demonstrations

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Abstract

The high cost of obtaining high-quality annotated data for in-context learning (ICL) has motivated the development of methods that use *self-generated annotations* in place of ground truth labels. While these approaches have shown promising results in few-shot settings, they generally do not scale to many-shot scenarios. In this work, we study ICL with self-generated examples using a framework analogous to traditional semi-supervised learning, consisting of annotation generation, demonstration selection, and in-context inference. Within this framework, we propose a simple baseline that outperforms ground truth ICL under zero-shot, few-shot, and many-shot settings. Notably, we observe consistent *scaling* behaviors with respect to the number of self-annotated demonstrations. To further extract performance from this many-shot capability, we introduce IterPSD, an iterative self-annotation approach that integrates iterative refinement and curriculum pseudo-labeling techniques from semi-supervised learning, yielding up to 6.8% additional gains on classification tasks. Motivated by our baseline and IterPSD results, we demonstrate that semi-supervised ICL offers a promising avenue for future ICL research. Code is available at `https://anonymous.4open.science/r/semi-supervised-icl-FB8B`.

1 Introduction

In-context learning (ICL) has emerged as a powerful paradigm in natural language processing, enabling large language models (LLMs) to learn, adapt, and generalize from examples presented within their input context. This approach eliminates the need for extensive retraining and parameter modifications, facilitating more flexible and efficient learning (Brown et al., 2020; Min et al., 2022; Agarwal et al., 2024; Fang et al., 2025). The high cost of obtaining high-quality annotated data for ICL has motivated the development of methods (Zhang et al., 2023; Li and Qiu, 2023; Mamooler et al., 2024; Li et al., 2024a; Chen et al., 2023) that use self-generated annotations in place of ground truth labels. However, previous research has not examined ICL performance with self-generated annotations in *many-shot settings*. Recently,

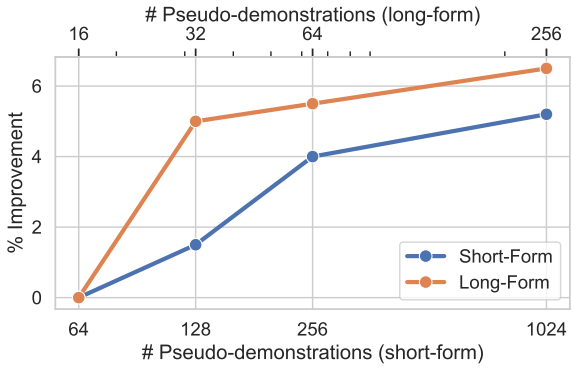

Figure 1: Average performance improvement in long-form (translation, reasoning) and short-form tasks (classification) with respect to number of pseudo-demonstrations used. Performance improvement on self-generated demonstrations scales beyond few-shot settings. Results obtained from GPT-4o.

(Agarwal et al., 2024) observed many-shot scaling with ground truth labels, showing that ICL performance improves with the number of demonstrations—up to thousands of examples. Inspired by this finding, we pose the following question:

Research Question:

Can we scale ICL performance using self-generated demonstrations up to thousands of examples as well?

We systematically investigate this question under a three-step framework: ① annotation generation, ② demonstration selection, and ③ semi-supervised inference, which we term *semi-supervised ICL*. We first introduce a simple baseline, Naive-SemiICL, which annotates unlabeled data in a single iteration, scoring each annotation using the LLM's verbalized confidence. Naive-SemiICL consistently outperforms ICL baselines under zero-shot, few-shot, and many-shot ground truth budgets. Additionally, we observe a consistent scaling behavior between ICL performance and number of self-annotated demonstrations across short-form and long-form generation tasks (Figure 1).

With potentially thousands of self-annotated examples in the prompt, each prompt can be viewed as a *dataset*, which motivates the following question:

Research Question:

In what ways can techniques from traditional semi-supervised learning be leveraged to improve ICL performance?

We address this question by proposing *IterPSD*, an iterative self-annotation approach that progressively refines pseudo-demonstration quality by incorporating self-generated annotations into the existing prompt. IterPSD further improves semi-supervised ICL performance on five classification tasks, achieving gains of up to 6.8%.

2 Method

In this section, we establish the framework of semi-supervised ICL, which consists of three phases: ① pseudo-demonstration generation, ② demonstration selection, and ③ semi-supervised inference. We then propose a simple baseline for semi-supervised ICL, Naive-SemiICL, which generates pseudo-demonstrations in a single iteration and filters out examples with low confidence scores. Building on Naive-SemiICL, we introduce an iterative method, IterPSD, that progressively improves the prompt by incorporating self-generated annotations during the demonstration generation process.

2.1 Semi-Supervised ICL

Confidence-Aware In-Context Learning extends traditional ICL by outputting an additional confidence score c for each input:

$$(y, c) = \text{LLM}(\rho, \mathcal{E}, x) \tag{1}$$

Like traditional ICL, the LLM is prompted with a prompt ρ associated with the task, a set of demonstrations $\mathcal{E}$, and an input x. The confidence score c provides a measure of certainty for its output y. We define the prediction y broadly in this setting. y could be a single predicted label in a classification task. Or it could could contain both a predicted answer and a rationale that leads to the answer (Wei et al., 2022)

$$y := (\hat{y}, r). \tag{2}$$

Pseudo-Demonstration Annotation. During step ①, Semi-supervised ICL annotates large set of *unannotated data* $\mathcal{X}_u = \{x_i\}^{k_u}$, using a small set of *ground truth data* $\mathcal{E}_g = \{(x_i, y_i)\}^{k_g}$ (or none) as demonstrations. We denote the resulting set of annotations as

$$\mathcal{D}_{\text{PSD}} = \{(x, y, c) | x \in \mathcal{X}_u\}, \tag{3}$$

where y and c are generated from Equation 1. We then sample pseudo-demonstrations from annotations whose confidence surpasses some threshold $c \geq \lambda$, which is assumed to be uniformly random unless otherwise stated.

$$\mathcal{E}_u = \text{Sampler}(\mathcal{D}_{\text{PSD}}, \lambda) \tag{4}$$

During inference, we prompt the LLM with both sampled pseudo-demonstrations and the ground truth data used to annotate them.

$$y = \text{LLM}(\rho, \mathcal{E}_u \cup \mathcal{E}_g, x) \tag{5}$$

Unlike ICL, where all used demonstrations are constructed from ground truth data, semi-supervised ICL uses both ground truth and self-annotated data, analogous to traditional semi-supervised learning. Departing from previous work on ICL that explores LLM's ability to self-annotated demonstrations (Li and Qiu, 2023; Zhang et al., 2023), semi-supervised ICL emphasizes how different budgets of ground truth data impacts model performances.

2.2 A Simple Baseline for Semi-Supervised ICL

We propose a simple method, Naive-SemiICL, that generates pseudo-demonstrations in a single iteration. Naive-SemiICL generates a prediction y and a confidence score c for each unlabeled instance by going through unannotated data exactly once. As a basic form of semi-supervised ICL, Naive-SemiICL's effectiveness relies on the successful filtering of low-quality annotations. We detail Naive-SemiICL in Algorithm 1.

2.3 Iterative Pseudo-Demonstration Generation

Encouraged by the success of Naive-SemiICL, we explore whether pseudo-demonstrations can enhance the accuracy of subsequent pseudo-demonstration generation. We propose **IterPSD** (Algorithm 2), an iterative method for generating pseudo-demonstrations that:

1. recursively adds newly generated pseudo-demonstrations to its prompt until reaching the maximum number of allowed demonstrations (Line 13), and

2. re-samples the most confident pseudo-demonstrations according to a confidence threshold λ from all previously annotated instances once the demonstration size reaches its limit (Line 7).

In each iteration, IterPSD samples and annotates K unlabeled examples before applying a filtering step. The generated pseudo-demonstrations are recursively accumulated and fed back into the LLM to generate additional pseudo-demonstrations (Line 10). To mitigate performance degradation as more erroneous pseudo-demonstrations are incorporated, we impose an upper limit κ on the number of self-fed pseudo-demonstrations. Once this limit is reached, we resample the κ most confident pseudo-demonstrations from all existing pseudo-demonstrations, ensuring that only the highest quality examples are utilized for subsequent self-annotation.

Curriculum Learning. To further improve the accuracy of self-annotation, we sample both similar and diverse examples from the unannotated pool for each

Algorithm 1 Naive-SemiICL.

Input: prompt ρ, ground-truth demonstrations $\mathcal{E}_g$, unlabeled data $\mathcal{X}_u$;
Initialize $\mathcal{D}_{\text{PSD}} = \emptyset$;
for $x \in \mathcal{X}_u$ **do**
  $\hat{y}, \hat{c} = \text{LLM}(\rho_{\mathcal{T}}, \mathcal{E}_l, x)$;
  $\mathcal{D}_{\text{PSD}} = \mathcal{D}_{\text{PSD}} \cup \{(x, \hat{y}, \hat{c})\}$;
end for
Return $\mathcal{D}_{\text{PSD}}$;

iteration of self-annotation. At each iteration, a proportion $(1 - \epsilon)$ of examples is chosen to be the nearest previously annotated instances based on some similarity measure. This ensures that each selected example is similar to an existing annotation. The remaining examples are chosen from diverse clusters, similar to the strategy in (Zhang et al., 2023). By prioritizing similar examples, we create a structured progression from easy to hard cases, following a curriculum learning paradigm (Soviany et al., 2021). This schedule allows the model to first adapt to examples that closely resemble annotated data before being exposed to more challenging or atypical instances. As a result, the annotation process achieves lower error rates compared to uniform or random sampling strategies. We dub this family of samplers ϵ-Random Samplers. We present the detailed algorithm in Appendix D.

Mitigating Confirmation Bias. To maintain annotation quality, we find that at least half of the data ($\epsilon \geq 0.5$) should be sampled diversely. When $\epsilon = 0$, selections are exclusively based on similarity to previously annotated examples, and the pseudo-demonstrations become homogeneous, leading to bias in ICL predictions. This phenomenon closely parallels confirmation bias in semi-supervised learning (Arazo et al., 2019; Zou and Caragea, 2023).

2.4 Cost of Scaling

Semi-supervised ICL scales test-time performance by increasing the number of pseudo-annotations included in the prompt. Unlike generation-based test-time scaling methods such as CoT (Wei et al., 2022) and Self-Consistency (Wang et al., 2023), which improve performance through repeated sampling of model *outputs*, Semi-supervised ICL scales the *input* to the language model. (Agrawal et al., 2024) reported that output generation incurs at least 10 times higher latency than input processing. This gap is also reflected in per-token pricing differences between input and output across major inference service providers.[1] As a result, the large pricing gap between input and output tokens makes it economically feasible to scale Semi-supervised ICL to hundreds or even thousands of demonstrations.

[1]The input-to-output pricing ratios per token are 1/10 for GPT-5.1 models, 1/5 for Claude 4.5 models, and 1/8 for Gemini 2.5 models.

Algorithm 2 IterPSD

Input: prompt ρ, ground-truth demonstrations $\mathcal{E}_g$, chunk size K, ratio of random examples ϵ, maximum number of pseudo-demonstrations κ, sampler for pseudo-demonstrations $\text{Sampler}_{\text{PSD}}$;
Initialize $\mathcal{D}_{\text{PSD}} = \emptyset$; {*Set of all the annotated pseudo-demonstrations.*}
Initialize $\overline{\mathcal{D}}_{\text{PSD}} = \mathcal{X}_u$; {*Set of data yet to be annotated.*}
Initialize $\mathcal{E} = \mathcal{E}_g$; {*Demonstration for generating pseudo-demonstrations.*}
while $\overline{\mathcal{D}}_{\text{PSD}} \neq \emptyset$ **do**
  if $|\mathcal{E}| > \kappa$ **then**
    $\mathcal{E} =$ top-κ confident examples in $\mathcal{D}_{\text{PSD}}$;
    {*Cap the demonstration at a maximum size*}
  end if
  $S_u = \text{Sampler}_{\epsilon}(\mathcal{D}_{\text{PSD}}, \overline{\mathcal{D}}_{\text{PSD}}, K, \epsilon)$; {*Retrieves a sample of size K using ϵ-Random Sampler*}
  $S_{\text{PSD}} = \text{Naive-SemiICL}(S_u, \rho, \mathcal{E})$;
  {*Label S_u with one iteration of Naive-SemiICL.*}
  $S^{\lambda}_{\text{PSD}} = \text{Filter}(S_{\text{PSD}}, \lambda)$;
  $\mathcal{E} = \mathcal{E} \cup S^{\lambda}_{\text{PSD}}$;
  $\mathcal{D}_{\text{PSD}} = \mathcal{D}_{\text{PSD}} \cup S_{\text{PSD}}$;
  $\overline{\mathcal{D}}_{\text{PSD}} = \overline{\mathcal{D}}_{\text{PSD}} - S_{\text{PSD}}$;
end while
Return $\mathcal{D}_{\text{PSD}}$;

Compared to ground-truth ICL, Semi-supervised ICL only introduces an $O(1)$ annotation cost with respect to number of inference calls, as the cost of scaling demonstrations is the same as that of pseudo-demonstrations. Thus, this cost can be amortized over an arbitrarily large number of inference runs. We provide a cost estimate on representative datasets in Appendix B.2.

3 Experimental Setup

Tasks and Datasets. Our evaluation consists of 16 datasets spanning 9 tasks and 3 task types:

- **Classification.** We include BANKING77 (Casanueva et al., 2020), CLINC, CLINC(D) (Larson et al., 2019), FewEvent (Deng et al., 2020), and FP (Malo et al., 2013).
- **Translation.** We evaluate Naive-SemiICL's ability to translate English into low-resource languages using 6 datasets from FLORES200: Bemba, Fijian, Faroese, Tuvan, Venetian, and Sardinian (Costa-Jussà et al., 2022).
- **Reasoning.** We include 5 benchmarks spanning scientific, mathematical, and logical reasoning: GPQA (Rein et al., 2024), LiveBench Math (White et al., 2025), and three tasks from BigBenchHard (Suzgun et al., 2022): Logical7, Geometric Shapes, and Date.

We describe these datasets in detail in Appendix B.3 and explain how we split the training and testing data in

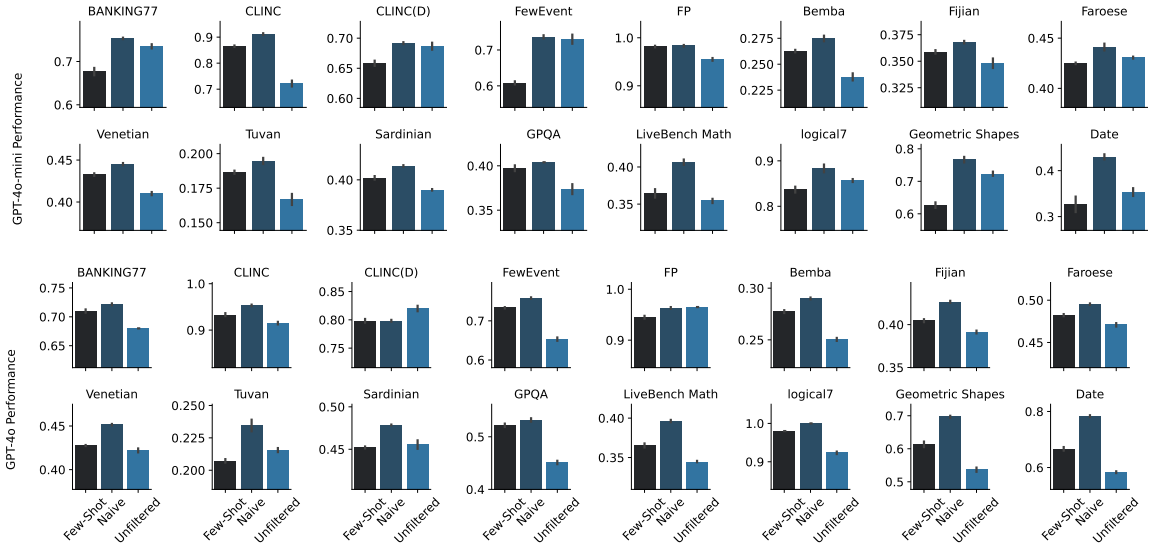

Figure 2: Comparison of GPT-4o-mini (top) and GPT-4o (bottom) performance across multiple datasets using three different methods: Few-Shot, Naive-SemiICL (Naive), and Naive-SemiICL without filtering (Unfiltered).

Appendix B.1.

Evaluation Metrics. For all classification and reasoning tasks, we report **accuracy** as the performance metric. We evaluate the equivalence of LaTeX-style mathematical outputs on LiveBench Math using the parser described in (Gao et al., 2024). For translation tasks, we report the **ChrF++** score (Popović, 2015) using its default configuration, as implemented in TorchMetrics (Detlefsen et al., 2022), following (Agarwal et al., 2024). We report the mean and standard error over three trials for baseline results(Section 4.1). The remaining results are based on a single trial.

Demonstration Budget. For fair comparison between ground-truth ICL and Semi-supervised ICL, we set the same ground-truth budget for both methods. This amounts to 16 ground truths for classification and translation tasks and 4 for reasoning tasks. We also experiment with no ground truths and many-shot ground truth budgets $k_g \geq 64$.

Baselines. We use the following methods as baselines.

- **k-Shot ICL.** The LLM is prompted with k ground truth annotated examples.
- **Unfiltered SemiICL.** To highlight the importance of confidence-based data selection, we include an unfiltered variant of Naive-SemiICL, which samples pseudo-annotations without applying the filtering step.
- **MoT.** (Li and Qiu, 2023) We include MoT as a domain-specific baseline for reasoning tasks. Unlike MoT, Naive-SemiICL uses a simple one-step filtering mechanism for demonstration selection, whereas MoT requires querying the LLM for each example.

	Task	Zero-shot	Naive	Improv.
Classification	Banking	61.50	**78.00**	26.80%
	FewEvent	56.00	**65.00**	16.07%
	CLINC	83.50	**88.50**	5.99%
	CLINCD	59.50	**61.00**	2.52%
	FP	91.00	**94.50**	3.85%
Translation	Bemba	0.2437	**0.2591**	12.37%
	Fijian	33.63	**35.16**	4.55%
	Faroese	42.45	**42.90**	1.06%
	Venetian	42.03	**42.82**	1.88%
	Tuvan	16.17	**18.40**	13.79%
	Sardinian	37.06	**38.46**	3.78%
Reasoning	GPQA	36.36	**38.38**	5.55%
	Math	35.48	**36.58**	3.10%
	Logical7	65.00	**72.00**	10.77%
	Shapes	56.00	**60.00**	7.14%
	Date	40.00	**65.00**	62.5%

Table 1: Performance comparison of Zero-shot ICL and Naive-SemiICL. All experiments are done on GPT-4o-mini with Verbalized Confidence.

- **Reinforced ICL.** (Agarwal et al., 2024) demonstrates that prompting the LLM with self-generated reasoning chains filtered by ground truth answers can significantly improve ICL performance. This method serves as an upper bound on semi-supervised ICL performance on the reasoning tasks when the filtering mechanism is assumed to be perfect.

Confidence Scores. We primarily evaluate three confidence metrics: Verbalized Confidence, which prompts the LLM to generate the confidence score, Entropy, and Self-Consistency. Self-Consistency measures the confi-

	Bemba	BANKING77	FewEvent
$k_g = 32$	27.08/**28.04**	-	-
$k_g = 64$	27.85/**27.92**	75.00/**83.00**	79.00/**79.50**
$k_g = 100$	28.01/**28.60**	77.00/**82.50**	80.50/**83.00**
$k_g = 500$	-	81.50/**89.50**	82.00/**83.50**

Table 2: Performance of Naive-SemiICL on three datasets, compared to ICL performance with a many-shot ground truth budget. Each cell follows the format (baseline / Naive-SemiICL).

Method	GPQA	Math	Logical7	Shapes	Date
Naive-SemiICL	42.42	**40.78**	**90.00**	**78.00**	**79.00**
MoT	**44.44**	25.86	88.00	64.00	58.00
Reinforced ICL	54.54	42.63	93.00	78.00	89.00

Table 3: Comparison of Naive-SemiICL (Naive) and MoT on reasoning datasets using GPT-4o-mini. Experiment conducted with $k_g = 3$. Reported performance reflects the optimal number of pseudo-demonstrations for each method.

dence as the frequency of the most frequent answer, and entropy is defined as

$$c_{\text{Ent}} = -\frac{1}{L}\sum_{i=s}^{L} \log P(w_i \mid w_{<i}). \quad (6)$$

We detail how we prompt the LLM for Verbalized Confidence in Appendix A, and how we apply the confidence measures in Appendix A and B.4.

Hyperparameters. We found setting the confidence threshold at 90% is generally performant across our benchmark, and thus refrained from further tuning. For IterPSD, we experimented with random sample proportion $\epsilon = 0.8$ and $K = 500$ as the annotation chunk size. We resample from annotated examples once the demonstration upper bound $\kappa = 1000$ is reached.

Models. We mainly experiment with GPT-4o-mini and GPT-4o. We also provide experimental results from Gemini 2.5 Flash and Qwen3. For the ϵ-random sampler, we compute similarity using vector embeddings generated by OpenAI's *text-embedding-3-large*. We discuss the computational cost associated with our experiments in Appendix B.2.

4 Empirical Analyses

4.1 Naive-SemiICL Consistently Beats Baselines

We first compare the performance of Naive-SemiICL with Verbalized Confidence to the few-shot baseline in Figure 2. In these settings, we use $k_g = 16$ ground truth demonstrations. We report the performance of Naive-SemiICL using 500 pseudo-demonstrations for classification tasks, 150 for translation tasks and 100

Method	BANKING	CLINC	CLINC(D)	FewEvent	FP
Naive-V	75.67	69.00	90.00	66.50	98.00
Naive-S	75.00	73.50	91.50	69.00	98.00
Iter-V	**78.00**	69.00	90.50	**73.50**	98.00
Iter-S	**78.00**	**78.50**	**94.50**	70.00	**98.50**
Improvement	3.10%	6.80%	3.28%	6.52%	0.50%

Table 4: Comparison of Naive-SemiICL (Naive) and IterPSD (Iter) methods on various datasets using GPT-4o-mini, evaluated using verbalized (-V) and self-consistency (-S) confidence scores.

for reasoning tasks. We can see in Figure 2 that Naive-SemiICL outperforms few-shot ICL on all tasks except CLINC(D), where it matches the baseline. Unfiltered SemiICL fails to match baseline performance in 20 out of 32 settings, highlighting the importance of the filtering step. We provide additional experimental results of Naive-SemiICL using different confidence scores in Appendix C.

We demonstrate the effectiveness of Naive-SemiICL in low-resource settings using a zero-shot experimental setup, with results shown in Table 1. The performance gap between Naive-SemiICL and the zero-shot baseline depends solely on the quality of the filtering mechanism. As shown in Table 1, Naive-SemiICL outperforms the zero-shot baseline on all tasks in the benchmark, attaining an average improvement of 11.36% under GPT-4o-mini. This exceeds the average improvement of 9.94% in the 16-shot setting (Figure 2), suggesting that Naive-SemiICL is more effective in resource-constrained conditions. Additionally, we found Naive-SemiICL to be effective in high-resource settings. Table 2 compares the performance of Naive-SemiICL and ICL across three tasks. Naive-SemiICL consistently outperforms the corresponding k-shot baselines. We observe diminishing returns in performance gains as the number of annotated demonstrations increases.

In addition to comparing Naive-SemiICL to the few-shot baseline, we also benchmark a previous semi-supervised ICL methods specifically tailored for reasoning tasks. The results are presented in Table 3. Following (Li and Qiu, 2023), we set a 4 ground-truth demonstration budget. Naive-SemiICL outperforms MoT on all reasoning tasks except GPQA. Surprisingly, the performance gap between the two methods is substantial on LiveBench Math, Shapes, and Date.

4.2 Semi-Supervised ICL Scaling

We observe consistent scaling trends for semi-supervised ICL, similar to the one reported in many-shot ICL (Agarwal et al., 2024). We illustrate this trend in Figure 3 using a ground truth demonstration budget of 16. Across all tasks, Naive-SemiICL performance improves with larger demonstration sizes, although the point of peak performance varies. Both GPT-4o and GPT-4o-mini scale effectively across most tasks, typically peaking between 500 and 1,000 examples for

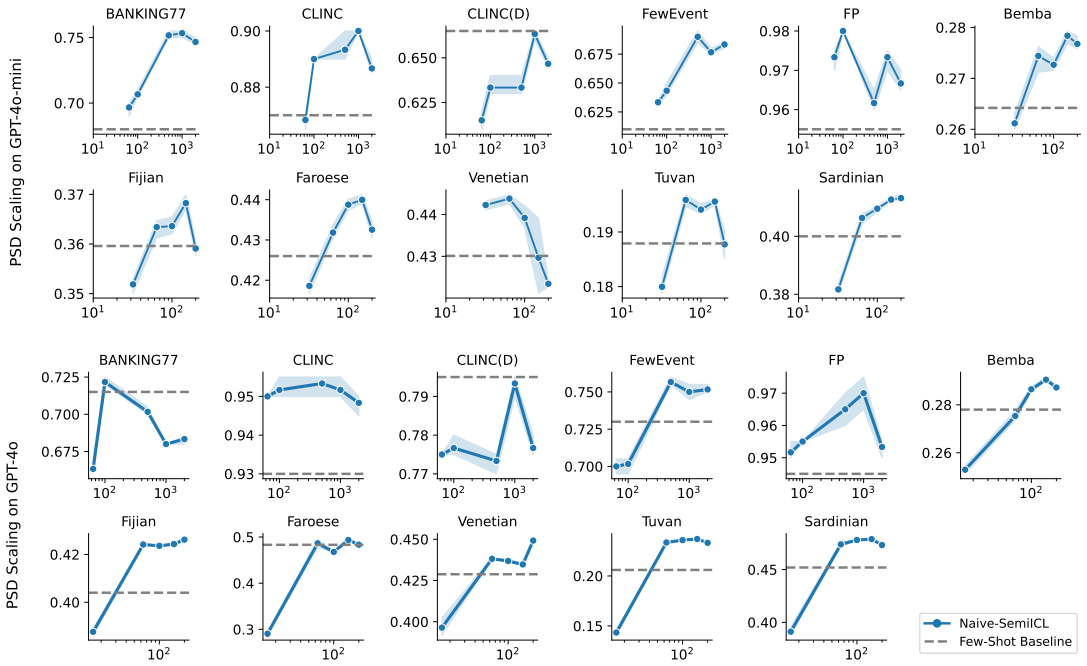

Figure 3: PSD (pseudo-demonstration) scaling trend of Naive-SemiICL on classification and translation tasks with GPT-4o and GPT-4o-mini. The dashed gray line represents the few-shot baseline.

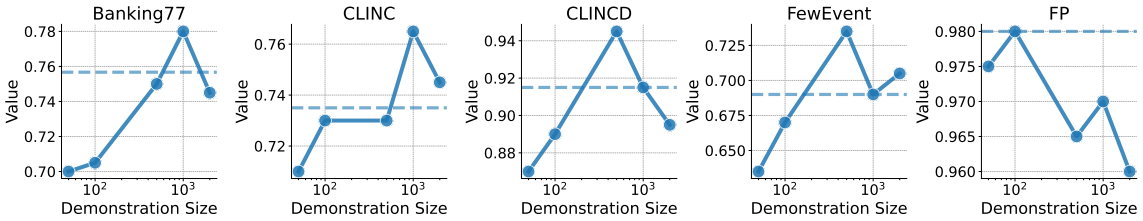

Figure 4: Performance scaling with respect to pseudo-demonstration size under IterPSD. Blue horizontal dashed line represents the best Naive-SemiICL performance on the same dataset. Results obtained from GPT-4o-mini.

classification tasks and between 100 and 200 examples for translation tasks. A similar scaling trend is observed with no ground truth demonstrations in Figure 6 across both classification and translation tasks. We observe that the scaling trend peaks at higher numbers of pseudo-demonstrations under the zero-shot setting, typically around 2000 pseudo-demonstrations compared to 500 in the 16-shot setting. This suggests semi-supervised ICL is more effective when the ground truth budget is stringent. We also observe scaling trends under high ground-truth budgets. Figure 8 demonstrates the scaling effect when $k = \{64, 100, 500\}$ ground truth demonstrations are used. In all, we demonstrate that self-annotated demonstrations can provide extra training signals even when ground truth data is abundant.

We hypothesize that Naive-SemiICL's decline in performance beyond a certain demonstration size stems from the accumulation of errors in pseudo-demonstrations. To isolate the negative impact of long contexts (Liu et al., 2023; Anil et al., 2022), we examine the scaling behavior when all demonstrations are ground truth data. Figure 7 shows that both GPT-4o-mini and GPT-4o continue to improve as the number of demonstrations increases, even beyond the optimal pseudo-demonstration size for Naive-SemiICL. This suggests that the performance could be primarily attributed to the accumulated errors in pseudo-demonstrations. This finding motivates the design of IterPSD, which addresses error accumulation in pseudo-annotations through curriculum learning and iterative refinement. Interestingly, we sample pseudo-demonstrations above a confidence threshold uniformly randomly in Naive-SemiICL, which implies that error is not introduced at a higher rate when more pseudo-demonstrations are incorporated. This indicates a previously uncharacterized phenomenon: the LLM becomes increasingly sensitive to noisy demonstrations as context length grows.

We examine whether the scaling behavior observed in Section 4.2 is generalizable to other frontier LLMs. Towards this, we evaluate Naive-SemiICL using Gemini-2.5-Flash and Qwen3 on three representative datasets, BANKING77, Bemba and GPQA, corresponding to

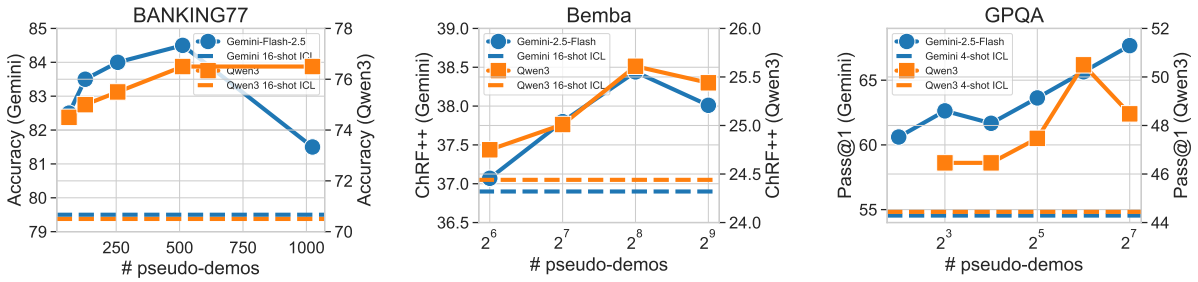

Figure 5: Scaling trend of Naive-SemiICL on three representative datasets using Gemini-2.5-Flash and Qwen3. The horizontal represents the few-shot baseline performance.

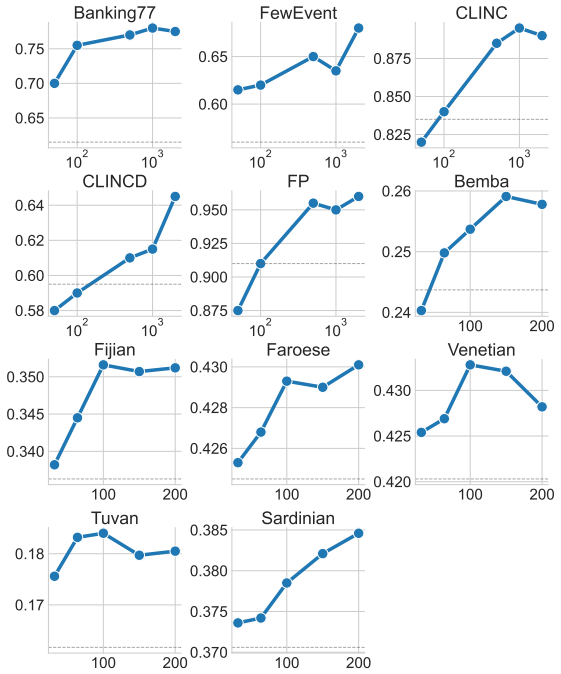

Figure 6: Scaling trend of Naive-SemiICL with no initial ground truth data. Grey dash line represents the prediction performance of zero-shot prompting. All results obtained from GPT-4o-mini.

classification, translation, and reasoning, respectively. The Scaling behavior is plotted in Figure 5. Like GPT-4o models, we observed scaling behavior on all three domains. Both Qwen3 and Gemini-2.5-Flash's performance peaks at 256 pseudo-demonstrations for translation tasks. Gemini- scales better on the reasoning task, showing no performance degradation within the maximum 128 psedo-demonstrations applied on GPQA, while Qwen3's performance drops sharply going beyond 64 pseudo-demonstrations.

4.3 IterPSD Improves Upon Naive-SemiICL

IterPSD outperforms Naive-SemiICL across five classification tasks, as shown in Table 4. We evaluate both methods using Verbalized Confidence and Self-Consistency using 16 ground truth demonstrations. Notably, IterPSD achieves significant gains on BANKING, CLINC, CLINC(D), and FewEvent (over 3.0% performance gain), but not on FP. Similar to Naive-SemiICL, we observe scaling behavior with respect to the number of pseudo-demonstrations used in IterPSD. We observe clear scaling trends in four out of five tasks, shown in Figure 4. The lack of scaling on FP may be attributed to the relative ease of the dataset, as Naive-SemiICL already achieved 98% accuracy on this task.

5 Related Work

Self-Generated Demonstrations. LLM's zero-shot predictions (Kojima et al., 2022; Zou et al., 2025a) have proven to be effective sources of demonstration for in-context learning. Auto-CoT (Zhang et al., 2023) prompts the LLM with self-generated rationales on diversely sampled inputs. Rationales consisting of more than five reasoning steps are excluded from the demonstration to maintain the simplicity and accuracy of the demonstration. Such a task-specific heuristic does not generalize to most recently published datasets, such as LiveBench Math, as most of the generated rationales contain more than five steps. (Li and Qiu, 2023) builds on top of Auto-CoT with extra an extra step of semantic filtering. At each example during inference, the LLM is prompted to choose the demonstration for itself after retrieving the semantically relevant demonstrations through an embedding model. Like Auto-CoT, Reinforced ICL (Agarwal et al., 2024) generates rationales for reasoning problems and filters out those leading to incorrect answers. While this method requires ground truths, our filtering method do so with self-generated confidence score.

PICLe (Mamooler et al., 2024) generates new demonstrations by annotating unlabeled examples and filtering out those with incorrect named entity types through self-verification prompting. Similarly, SAIL (Li et al., 2024a) employs an annotation strategy for the bilingual lexical induction task, discarding predictions that fail to translate back to the original input. Both methods rely on task-specific filtering and require additional LLM queries for self-verification or back-translation. In contrast, our Verbalized Confidence approach is task-agnostic and requires only a single prompt for pseudo-labeling, significantly reducing inference overhead. Z-

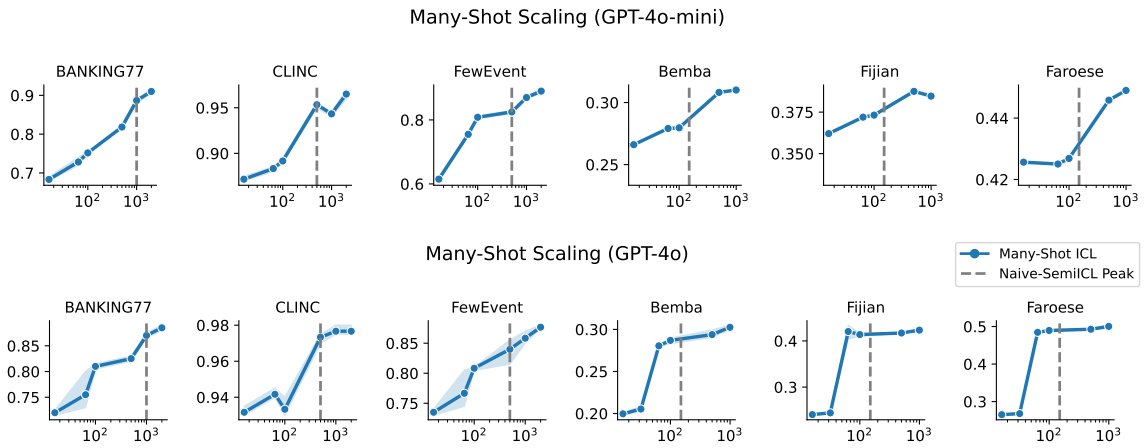

Figure 7: Many-shot scaling performance of GPT-4o-mini (top) and GPT-4o (bottom) across six selected datasets. The dashed vertical lines mark the peak performance of Naive-SemiICL.

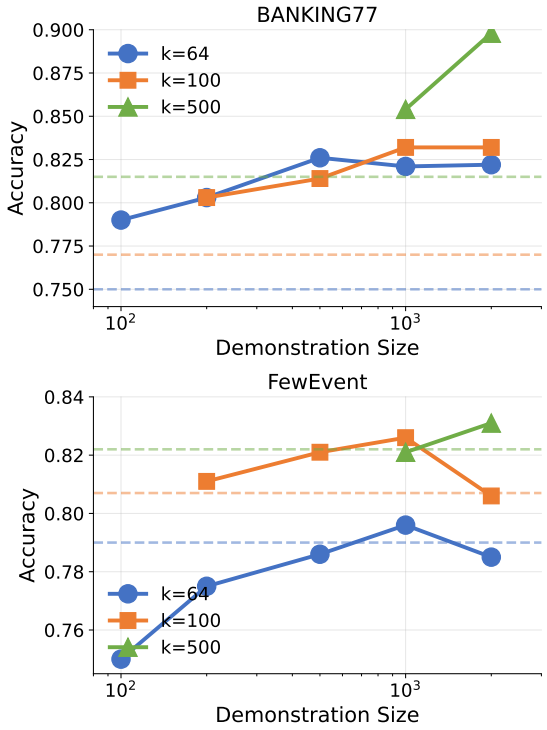

Figure 8: Naive-SemiICL across different ground truth budgets on BANKING77 & FewEvent.

ICL (Li et al., 2024b) leverages the zero-shot generative capability of large language models to synthesize demonstrations for subsequent in-context learning inference. In contrast, our approach assumes access to abundant unlabeled data and a small set of ground truth labels, using the LLM only for annotation rather than for input generation.

Many-Shot ICL. (Agarwal et al., 2024) observed a significant performance increase in a variety of generative and discriminative tasks, as well as scaling behavior between the number of examples in the demonstration and ICL performance. Our method hinges on this ability, as our proposed method, Naive-SemiICL, includes at least 64 examples in the prompt. We report similar scaling behavior for semi-supervised ICL in this work.

Traditional Semi-Supervised Learning. Semi-supervised learning seeks to reduce reliance on labeled data by leveraging abundant unlabeled data to enhance model performance (Lee et al., 2013; Sohn et al., 2020; Zou et al., 2025b). Self-training (McLachlan, 1975; Xie et al., 2020) iteratively refines the model by using its own predictions on unlabeled data for training. Pseudo-labeling (Lee et al., 2013; Sohn et al., 2020; Zou et al., 2023a,b) employs confidence-based filtering, retaining only high-confidence pseudo-labels to reduce error propagation and confirmation bias. JointMatch (Zou and Caragea, 2023) further alleviates error accumulation by using two independently initialized networks that teach each other through cross-labeling. Our work is the first to integrate confidence filtering and leverage both labeled and pseudo-labeled data in an in-context learning framework.

6 Conclusion

We introduced a semi-supervised ICL framework that scales in-context learning performance using self-generated annotations. By analyzing both Naive-SemiICL and IterPSD, we observe that performance continues to improve with thousands of pseudo-demonstrations, revealing a surprising scaling trend in semi-supervised ICL. Naive-SemiICL demonstrates consistent gains over standard k-shot ICL across a wide range of ground truth budgets, highlighting its robustness. We further incorporate curriculum learning into IterPSD, enabling iterative refinement of pseudo-demonstrations. This leads to substantial performance improvements over Naive-SemiICL on classification tasks, validating the benefit of curriculum learning in our framework.

7 Limitation

We observed limited scaling capability of semi-supervised ICL on reasoning and translation tasks. With the advent of long-context large language models such as the Gemini family (et al., 2025), we hope that future work could break this limitation by experimenting with models that scale better with long contexts. A direction for future work, motivated by semi-supervised learning, is re-annotation during the pseudo-demonstration annotation phase of our framework. Traditional semi-supervised learning can increase the annotation quality by re-annotating those with lower confidence, which we found not to be true under the ICL setting. Solving this hindrance could be valuable.

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A Prompts

The prompts are illustrated in Table 9. {CAPITAL LETTERS} enclosed in curly brackets are variables that are substituted during inference.

B Experimental Details

B.1 Train-Test Split

For classification tasks with more than 5,000 examples, we randomly sample 5,000 examples for demonstration and 200 for evaluation. For tasks with fewer than 5,000 examples, we randomly sample 200 for evaluation and use the rest for demonstration. Each FLORES dataset is comprised of a development set with 997 examples and a development test set with 1012 examples. We use all of 997 for demonstration and randomly sample 200 from the development test examples for evaluation. We use the diamond split (198 examples) of GPQA following (Agarwal et al., 2024), out of which 99 are used for evaluation and the other 99 are used for demonstration. Since LiveBench Math contains math problems from three sources, we evenly sample 150 questions from different sources for evaluation and use the rest for demonstration. Each BigBenchHard dataset contains 250 examples. We randomly sample 100 for evaluation and use the rest for prompting.

B.2 Computational Budget

We ran all of our experiments on an Apple M3 chip, where embedding-based search constitutes less than 1% of the computation time during IterPSD. The embeddings can be precomputed during data processing for each dataset, as they only need to be computed once. It took about 400ms to retrieve each embedding from the OpenAI API. The cost of generating the embeddings is $0.13/million tokens.

As explained in Section 2, Semi-Supervised ICL methods incurs a constant overhead that can be amortized over inference calls. For completeness, we provide the cost of pseudo-annotation using Naive-SemiICL and IterPSD. We chose BANKING77, Bemba and GPQA for cost estimation under Naive-SemiICL for their representativeness of their respective domain. We choose BANKIN77, CLINC and FP for Iter PSD. For BANKING77 CLINC and FP, we pseudo-annotation 5000 examples. For Bemba, we pseudo-annotate 120 sentences. For GPQA, we pseudo-annotate 150 examples. The cost is presented in Table 6 and 7

B.3 Dataset Details

Classification Datasets.

- **BANKING77.** The BANKING77(Casanueva et al., 2020) dataset is a fine-grained intent classification benchmark in the banking domain, consisting of 13,083 customer queries labeled into 77 intent categories.
- **CLINC.** The CLINC150 (Larson et al., 2019) dataset is a benchmark for intent classification, containing 22,500 user queries across 150 intent categories grouped into 10 domains, along with an out-of-scope category. We refer to the intent classification task of CLINC150 as CLINC.
- **CLINC(D).** We refer to the domain classification annotation of CLINC150 as CLINC(D).
- **FewEvent.** The FewEvent(Deng et al., 2020) dataset contains 4,436 event mentions across 100 event types, with each event type having only a few annotated examples (typically 5 to 10 per type).
- **FP.** Financial Phrasebank(Malo et al., 2013) The Financial PhraseBank dataset consists of 4840 sentences from English language financial news categorised by sentiment.

Low-Resource Language Translation. FLORES-200 (Costa-Jussà et al., 2022) contains 200 languages translated from a common corpus. It is an extension of the original FLORES-101 (Goyal et al., 2022) dataset, which covered 101 languages. The dataset covers low-resource and high-resource languages, including many languages with little prior data on. It includes many African, South Asian, and Indigenous languages, making it one of the most diverse multilingual benchmarks.

Reasoning Datasets.

- **GPQA.** GPQA(Rein et al., 2024) is a multiple-choice question answering benchmark, with graduate-level questions that involve reasoning in biology, physics, and chemistry.
- **LiveBench Math.** LiveBenchMath contains 368 contamination-free mathematical problems, sampled from high school math competitions, proof-based fill-in-the-blank questions from Olympiad-level problems, and an enhanced version of the AMPS dataset.
- **BigBenchHard.** We include three tasks from BigBenchHard(Suzgun et al., 2022). **Logical7** evaluates a model's ability to deduce the order of a sequence of objects based on provided clues about their spatial relationships and placements. The **Geometric Shapes** task within the BigBenchHard evaluates a model's ability to interpret and identify geometric figures based on SVG path data. The **Date** task within the BigBenchHard benchmark evaluates a model's ability to comprehend and manipulate date-related information.

For MoT (Li and Qiu, 2023), we follow a recommended configuration of 5 clusters. For retrieval, we employ the same text embeddings, `text-embedding-3-large` as Naive-SemiICL, and the

Task Type	Task	GPT-4o-mini				GPT-4o			
		Verbalized	Self-Consistency	Entropy	Back-Translation	Verbalized	Self-Consistency	Entropy	Back-Translation
Classification	BANKING	$\mathbf{75.33 \pm 0.20}$	75.16 ± 0.20	-	-	72.17 ± 0.20	$\mathbf{72.30 \pm 0.20}$	-	-
	CLINC	89.16 ± 0.80	$\mathbf{91.17 \pm 0.40}$	-	-	95.50 ± 0.70	$\mathbf{95.80 \pm 0.90}$	-	-
	CLINCD	66.33 ± 0.50	$\mathbf{69.17 \pm 0.20}$	-	-	$\mathbf{79.33 \pm 0.20}$	77.80 ± 0.20	-	-
	FewEvent	69.33 ± 0.50	$\mathbf{73.33 \pm 0.20}$	-	-	76.17 ± 0.50	$\mathbf{77.17 \pm 0.20}$	-	-
	FP	97.50 ± 0.50	$\mathbf{97.83 \pm 0.20}$	-	-	96.50 ± 0	$\mathbf{97.83 \pm 0.20}$	-	-
	AVG	79.53	**81.33**	-	-	83.93	**84.18**	-	-
Translation	Bemba	$\mathbf{27.93 \pm 0.10}$	-	26.66 ± 0.20	27.42 ± 0.30	$\mathbf{29.16 \pm 0.20}$	-	27.65 ± 0.20	28.34 ± 0.20
	Fijian	$\mathbf{36.70 \pm 0.20}$	-	35.96 ± 0.10	36.14 ± 0.10	$\mathbf{42.67 \pm 0.40}$	-	41.42 ± 0.30	41.98 ± 0.40
	Faroese	$\mathbf{43.97 \pm 0.20}$	-	42.32 ± 0.20	43.95 ± 0.20	$\mathbf{49.69 \pm 0.40}$	-	48.01 ± 0.40	48.93 ± 0.30
	Venetian	$\mathbf{44.41 \pm 0.20}$	-	43.84 ± 0.10	43.26 ± 0.20	$\mathbf{45.05 \pm 0.30}$	-	44.53 ± 0.50	44.67 ± 0.40
	Tuvan	$\mathbf{19.61 \pm 0.30}$	-	19.53 ± 0.10	19.02 ± 0.20	$\mathbf{23.75 \pm 0.30}$	-	23.01 ± 0.30	22.57 ± 0.40
	Sardinian	$\mathbf{41.27 \pm 0.20}$	-	40.53 ± 0.10	40.63 ± 0.20	$\mathbf{47.94 \pm 0.20}$	-	46.82 ± 0.10	47.85 ± 0.30
	AVG	**35.65**	-	34.81	35.07	**39.71**	-	38.57	39.06
Reasoning	GPQA	40.40 ± 0.50	$\mathbf{42.42 \pm 0.50}$	41.41 ± 0.50	-	$\mathbf{52.52 \pm 0.50}$	47.47 ± 0.50	52.52 ± 0.50	-
	LB Math	$\mathbf{40.78 \pm 0.30}$	35.52 ± 0.50	35.48 ± 0.30	-	36.33 ± 0.80	$\mathbf{39.78 \pm 0.30}$	30.10 ± 0.30	-
	logical7	$\mathbf{90.00 \pm 0.50}$	84.00 ± 0	86.00 ± 0.50	-	98.00 ± 0.50	$\mathbf{100.00 \pm 0.50}$	100.00 ± 0.50	-
	Geometric	70.00 ± 0	66.00 ± 0	$\mathbf{78.00 \pm 0.50}$	-	61.00 ± 0	67.00 ± 0	$\mathbf{70.00 \pm 0.50}$	-
	Date	$\mathbf{42.00 \pm 0.80}$	32.00 ± 0	35.00 ± 0	-	$\mathbf{68.00 \pm 0.80}$	65.00 ± 0	67.00 ± 0.50	-
	AVG	**56.64**	51.99	55.18	-	63.17	63.85	**63.92**	-

Table 5: Comparison of GPT-4o-mini and GPT-4o performance using different confidence scores. Each task is evaluated using different inference strategies: Verbalized, Self-Consistency, Entropy, and Back-Translation (where applicable). Reported values on represent average accuracy and ChrF++ with standard deviations.

Dataset	BANKING77	Bemba	GPQA
Naive-SemiICL	\$3.24	\$2.67	\$ 13.78

Table 6: Pseudo-annotation cost for Naive-Semi-ICL using GPT-4o-mini.

Dataset	BANKING77	CLINC	FP
IterPSD	\$40.24	\$26.12	\$ 14.67

Table 7: Pseudo-annotation cost for Naive-Semi-ICL using GPT-4o-mini.

same confidence threshold set at the 90th percentile. Since MoT needs to query the LLM k times to select the most relevant examples, it is not suitable for classification and translation tasks that might utilize many examples, we only compare MoT to Naive-SemiICL on reasoning tasks.

B.4 Applying Confidence Scores

On all tasks, we sample from the LLMs 10 times to compute the Self-Consistency score. Self-consistency is unsuitable for translation tasks due to the computational challenges of assessing equivalence between translations. Instead, we introduce Back-Translation, which evaluates translation quality by translating the output back to the original language. The confidence score is then derived using the cosine similarity (on embeddings) between the back-translation and the original input. A detailed description of Back-Translation is provided in Appendix B.5.

B.5 Back-Translation

Suppose an LLM has translated a source language input s into a target language output t. We then use the same LLM to translate t back to the original language

$$\hat{s} = \mathrm{LM}(t, \rho_b),$$

where ρ_b is a prompt that induces the back-translation. Then, the Back-Translation Confidence is the cosine similarity between the original input s and the back-translation $\hat{s}$

$$c = \mathrm{sim}_{\cos}(\phi(\hat{s}), \phi(s)),$$

where ϕ is an embedding function.

C Effects of Different Confidence Methods

In this section, we examine the performance of Naive-SemiICL paired with different confidence methods, which we compile as Table 5. We observe that classification and translation tasks each have a dominant confidence measure. For classification tasks, Self-Consistency emerges as the most effective confidence method. It surpasses the Verbalized Confidence method on 4 out of 5 datasets across both models. Verbalized Confidence is the leading measure for translation tasks, consistently achieving the highest performance across all languages. For reasoning tasks, no single method clearly dominates. Under GPT-4o-mini, Verbalized Confidence yields the best average performance, while under GPT-4o, Entropy slightly outperforms Self-Consistency, securing the top position by a narrow margin.

Overall, Self-Consistency improves classification and reasoning tasks, but its effect varies across translation tasks and is not applicable to all tasks. Entropy is sometimes useful in reasoning tasks, but falls short on translation tasks. Verbalized inference remains a strong and economical baseline across all tasks, but is generally outperformed by Self-Consistency on classification tasks.

Model	Bemba	Fijian	Faroese	Venetian	Tuvan	Sardinian	Banking	FewEvent	CLINC	CLINCD	FP
4o-mini	100	150	150	100	64	64	1000	2000	2000	2000	500
4o	100	150	100	200	100	100	1000	500	500	1000	100

Table 8: Optimal demonstration counts for Naive-SemiICL per dataset under 4o-mini and 4o models.

Algorithm 3 ϵ-Random Sampler

1: **Input:** annotated demonstration $\mathcal{D}_l$, un-annotated demonstration $\overline{\mathcal{D}}_l$, chunk size K, random ratio ϵ, prompt ρ, embedder ϕ.
2: Initialize $S = \emptyset$;
3: $K_{\text{random}} = \epsilon K, K_{\text{sim}} = (1-\epsilon)K$;
4: Compute $d_{ij} = \text{sim}_{\cos}(\phi(x_i), \phi(x_j))$ for all $x_i \in \mathcal{D}_l, x_j \in \overline{\mathcal{D}}_l$;
5: Compute $d_j = \min_i d_{ij}$ for all $x_j \in \overline{\mathcal{D}}_l$;
{*Compute distance to the nearest annotated example.*}
6: $S_{\text{sim}} = \{x_j | d_j \in \text{Smallest}_{K_{\text{sim}}}\{d_j\}\}$;
{*select the K_{sim} examples with the smallest distance to its nearest annotated demonstrations*}
7: Compute S_{random}, a random sample of size K_{random} from $\overline{\mathcal{D}}_l - S_{\text{sim}}$);
8: $S = S_{\text{sim}} \cup S_{\text{random}}$;
9: **Return** S;

D Sampler for IterPSD

In our IterPSD experiments, we implement Algorithm 3 for the ϵ-random sampling strategy in Section 2.3. In Line 4 and 5, the algorithm computes the similarity between every pair of annotated and unannotated pairs. Then the closest K_{sim} unannotated examples are chosen (Line 6). The remaining K_{random} examples are sampled randomly from those not chosen. Lastly, the similar and random samples are combined and returned.

A way of sampling diverse random samples is the clustering strategy in (Zhang et al., 2023). In this method, samples are divided into clusters according to some clustering algorithm. Then k_{random} most representative samples are from each cluster. Representativeness is computed by computing the shortest sum of euclidean distance to other examples in the cluster.

Table 9: The prompt template we use for classification, translation, and reasoning tasks, respectively.

Types	Prompts
Classification	You are a helpful assistant who is capable of performing a classification task (mapping an Input to a Label) with the following possible labels: {A LIST OF POSSIBLE LABELS} ___ Here are zero or more Input and Label pairs sampled from the classification task. {DEMONSTRATIONS} ___ Now, Label the following Input among the following Input: {INPUT}
Translation	You are an expert translator. I am going to give you zero or more example pairs of text snippets where the first is in the source language and the second is a translation of the first snippet into the target language. The sentences will be written in the following format: <source language>: <first sentence> <target language>: <translated first sentence> ___ {DEMONSTRATIONS} ___ Now, Translate the following $source text into $target. Also give the Confidence of your given Answer in the following format: **Confidence**: <a confidence score between 0 and 1>: English: {INPUT SENTENCE} {TARGET LANGUAGE}:
Reasoning	First, I am going to give you a series of Questions that are like the one you will be solving. ___ {DEMONSTRATIONS} ___ Now, Answer the following Question. Think step by step. Question: {QUESTION} Also give the Confidence of your given Answer in the following format: **Confidence**: <a confidence score between 0 and 1>