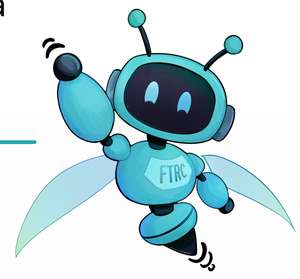
UNIVERSITAS KRISTEN MARANATHA

SMART TECHNOLOGY & ENGINEERING

Advancing Ethical and Sustainable Programming Education through AI-Driven Knowledge Reuse

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S-SPARC

Sustainable Smart Personal Assistant for Responsible Consumption

Green gateway chatbot designed to mitigate environmental costs of AI-driven code generation

Introduction

The Problem & Approach

A single LLM prompt emits ~4x more CO_2 than a search query, a cost that compounds with repetitive, unnecessary AI use in education.

S-SPARC addresses this by prioritizing validated knowledge reuse over new AI generation, reducing unnecessary LLM inference.

Research Objective

Does prioritizing knowledge reuse over new AI generation reduce environmental impact in programming education?

Experimental setup

- Pre-post quasi-experiment
- 55 informatics students
- Machine Intelligence course
- 7 lab sessions

Learning | Energy | Sustainability

Our Innovation

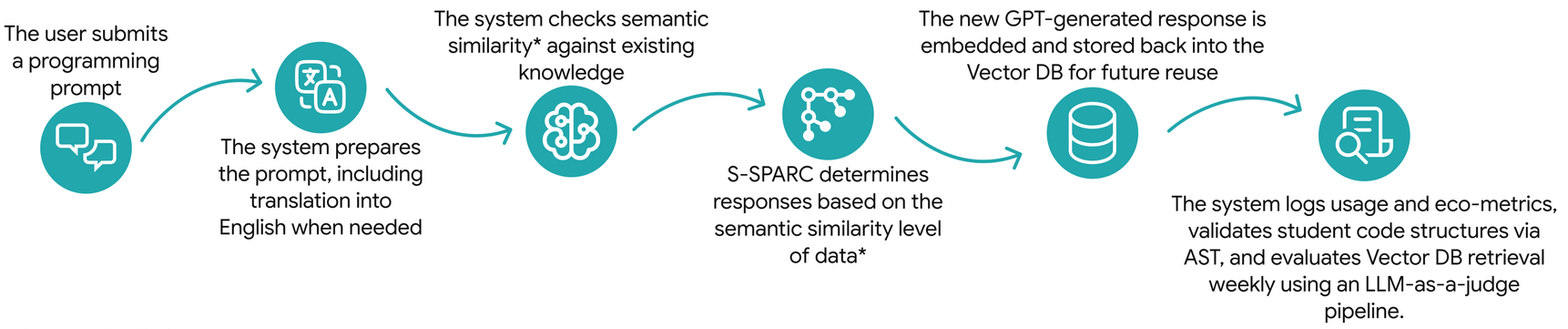
S-SPARC is a student-developed AI programming assistant designed to promote ethical and sustainable AI use through knowledge reuse, semantic retrieval, gamification, and environmental awareness.

Core components:

- Filters and prioritizes validated knowledge before querying AI
- Rewards token-efficient usage through dynamic engagement incentives
- Tracks and displays token-based energy metrics
- Encourages mindful, selective AI consumption

How S-SPARC Works

S-SPARC minimizes unnecessary LLM usage by prioritizing validated knowledge before generating new AI responses



Usage Policies

Minimum prompt lengths and a 1-minute rate limit to prevent “lazy prompting” and promote critical thinking.

Dynamic Threshold Gamification

Points are deducted proportionally for excessive usage

$$\text{Points}(u) = \begin{cases} 100, & u \le T \\ \max\left(0,\ 100 + 100 \cdot \dfrac{T-u}{T}\right), & u > T \end{cases}$$

T = dynamic threshold $= 1.10 \times u$

u = weekly token usage of a learner

Environmental Impact Estimation

Measures environmental impact through token-based energy metrics

$$E_{kWh} = \frac{t \cdot e(t)}{1000}, \quad CO_2e_{kg} = E_{kWh} \cdot CIF$$

t = total tokens produced

$CIF = 0.384\ \text{kgCO}_2e/kWh$

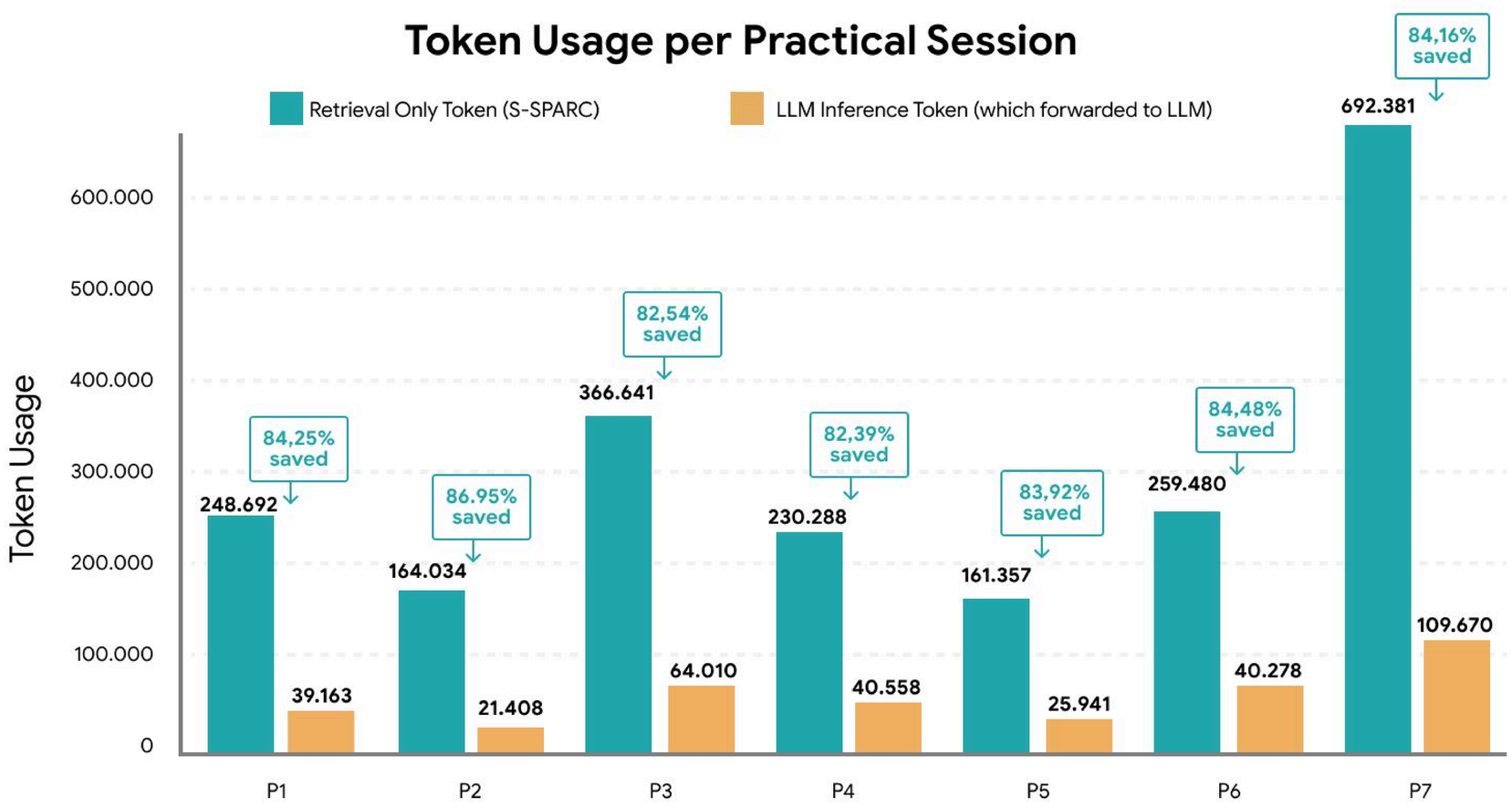
$e(t) = \begin{cases} 2.1775 \times 10^{-3}\ \text{Wh/token}, & t \le 400 \\ 1.5805 \times 10^{-3}\ \text{Wh/token}, & 400 < t \le 2000 \\ 4.2026 \times 10^{-4}\ \text{Wh/token}, & t > 2000 \end{cases}$

$\text{H}_2\text{O}_{\text{liters}} = 0.19\ \text{L / execution}$

*

- Threshold >= 0.90 (Direct Retrieval)
- Threshold 0.80 - <0.90 (Suggested Retrieval)
- Threshold < 0.80 (AI Generation)

Results



Significant Reduction in LLM Inference
83.94% fewer tokens processed by external LLM, only 16.06% of workload required generation.

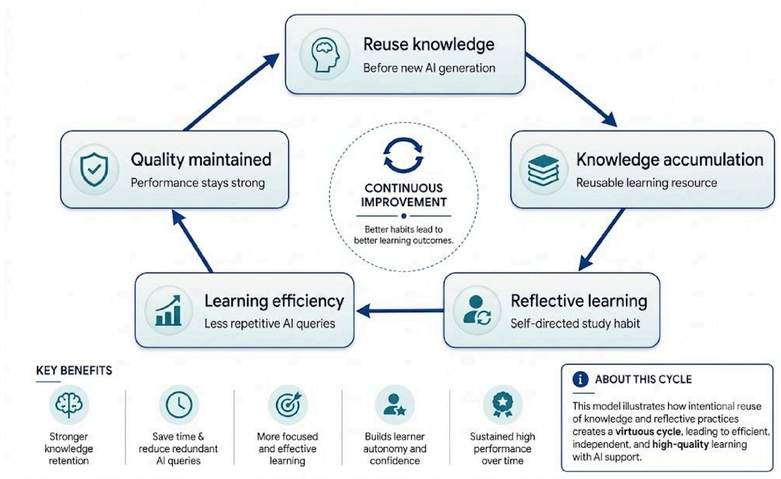
Improved Retrieval Over Time
Retrieval usage grew steadily each session, peaking at 582,711 tokens in P7, less dependence on cloud AI.

Comparable Code Quality
87.72% (baseline) vs 88.13% (S-SPARC) average code-quality score across both workflows.

High Retrieval Precision
100% precision, 96% recall at operational threshold, evaluated on 200 human-labeled prompts.

Growing Knowledge Base
Retrieval token share rose from 84.25% (P1) to 84.16% (P7), peaking at 84.48% in P6, sign of a maturing, self-sustaining knowledge base.

Educational Sustainability



Responsible AI

- Think before asking
- Reuse Before Generate
- Learn Before Copy
- Transparent AI Usage

Conclusion

S-SPARC demonstrates that sustainable AI in education is achieved not by limiting AI adoption, but by enabling smarter and more responsible AI usage. Through knowledge reuse, semantic retrieval, and environmental awareness, S-SPARC reduces unnecessary computation and demonstrates a scalable path toward sustainable AI use in education, while learning-outcome effects remain a direction for future research.

Reference

References and full technical documentation are available at:
https://github.com/06202003/s-sparc