SEMAR: A Co-evolving Knowledge Architecture for Reflective Intelligence in Academic Ecosystems

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Abstract. Knowledge infrastructures in Indonesia face fragmentation, limiting visibility into how ideas connect and evolve. This study introduces SEMAR (Sistem Eksplorasi Mandiri Referensi), a dual-layer AI-based catalog designed to transform conventional repositories into reflective, semantically aware, and collaborative academic ecosystems. Using a design science approach, SEMAR integrates user-centered exploration (micro layer) with semantic interoperability (macro layer), enabling intelligent discovery, adaptive knowledge mapping, and collaborative information synthesis. Evaluation with five users demonstrated universal interest (100%), with 60% recommending adaptive display modes and machine learning refinement, and 40% requesting interactive query features. SEMAR addresses limitations of traditional catalogs—including bibliographic grouping, contextual keyword matching, and interface adaptability—demonstrating its relevance for collaboration technologies, organization design and engineering, and domain-specific academic discovery. As a co-evolving system within the academic ecosystem, SEMAR provides a scalable model for enabling reflective, interoperable, and collaborative knowledge infrastructures that support meaningful user-system interaction and academic knowledge growth.

Keywords: Knowledge Infrastructure, Semantic Interoperability, Reflective Exploration, Academic Ecosystem, Collaboration Technologies.

1 Introduction

Global academia faces a paradox: the more knowledge we produce, the harder it is to see how ideas interconnect. Digital repositories and citation indexes have multiplied, yet few capture meaning beyond data. In developing ecosystems like Indonesia's, this challenge is clear: platforms such as SINTA, Garuda, and Indonesia OneSearch have improved access but were established at different stages of digital maturity and policy evolution, resulting in heterogeneous metadata structures and domain vocabularies—reflecting a transitional scholarly infrastructure still converging toward semantic interoperability.

SEMAR (Sistem Eksplorasi Mandiri Referensi) proposes a new perspective, transforming static catalogues into reflective, collaborative, and semantically aware

environments. It does not replace existing systems but extends their cognitive capacity by learning from user exploration, linking ideas, and reconstructing conceptual relationships that might otherwise remain invisible.

At the micro level, SEMAR functions as an intelligent exploration companion, mapping user trajectories and recommending potential idea connections. At the macro level, it demonstrates how standardized and open metadata could connect personal exploration systems with institutional repositories into a unified scholarly network.

By aligning with Collaboration Technologies and Organization Design, SEMAR is more than a technical artifact: it is a design for collaborative intelligence between humans and knowledge systems, supporting not only information discovery but understanding its evolving meaning.

2 Conceptual Positioning: From Personal Reflection to Systemic Interoperability

Contemporary research on knowledge infrastructures has evolved along two converging trajectories.

The first emphasizes micro-level cognition, exploring how individuals construct and refine understanding through reflective and collaborative technologies. Recent studies on *collaborative knowledge systems* and *reflective sensemaking* demonstrate how digital tools can enhance human interpretation and foster shared understanding within academic environments [1–3].

However, these systems often remain confined within institutional silos, limiting their capacity to interact with external repositories or broader knowledge ecosystems.

The second trajectory addresses macro-level interoperability, advancing the design of open metadata frameworks, ontology-based integration, and collaborative data ecosystems [4–6].

While these initiatives enable structural connectivity, they frequently overlook the *cognitive dimension*—how meaning is produced, revised, and extended across interacting systems.

SEMAR (Sistem Eksplorasi Mandiri Referensi) bridges these trajectories by integrating *reflective cognition* with *semantic interoperability* in a unified conceptual framework. At the micro level, SEMAR acts as a *reflective exploration companion*, mapping users' conceptual journeys and visualizing how ideas evolve across contexts. As illustrated in Fig. 1, SEMAR integrates micro-level adaptive exploration with macro-level semantic interoperability

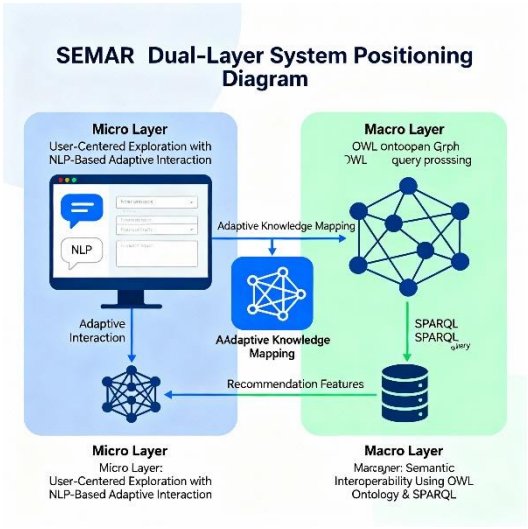

Fig. 1. SEMAR Dual-Layer System Positioning Diagram illustrating micro-level reflective exploration and macro-level semantic interoperability

At the macro level, it aligns with emerging principles of open and interoperable data ecosystems, allowing reflective systems to operate seamlessly across repositories and institutions.

This dual-layer architecture reframes digital libraries as *co-evolving epistemic infrastructures*—systems that not only exchange data but also adapt to how humans construct meaning.

By integrating reflection and interoperability, SEMAR contributes to *Collaboration Technologies and Organization Design* as a model for transforming fragmented repositories into adaptive, meaning-centered, and collaborative knowledge environments.

3 Research Design and Methodology

This study employs a design science methodology to construct and validate SEMAR as a conceptual and technological artifact addressing fragmentation in Indonesia's knowledge infrastructures.

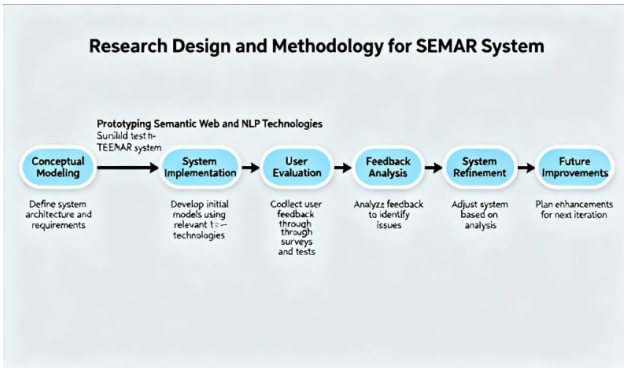

Fig. 2. Research Stages in SEMAR Development and Evaluation

The research unfolds through three iterative stages—conceptual modeling, prototype development, and evaluation—each integrating reflective cognition and semantic interoperability.

3.1 Conceptual Modeling

At this stage, SEMAR's dual-layer structure is defined.
The micro layer models user interaction as reflective exploration paths, capturing how researchers connect and reinterpret ideas through semantic traces (queries, references, and reading sequences).
The macro layer establishes interoperability through ontology alignment and adoption of open metadata standards such as Dublin Core, OpenAIRE, and Schema.org, enabling communication among repositories like Garuda, SINTA, and OneSearch.
Together, both layers form the foundation for SEMAR's reflective-interpretive framework.

3.2 Prototype Development

A proof-of-concept prototype is implemented using open-source semantic web technologies.
It includes modules for metadata crawling, ontology mapping, and reflective visualization that generate conceptual maps of related research.
This prototype demonstrates how reflective cognition (user meaning-making) and semantic interoperability (system-level linkage) can operate synchronously within academic exploration.

3.3 Evaluation

Evaluation combines expert validation, scenario-based testing, and reflective user feedback.
Experts assess conceptual and technical coherence; simulations test SEMAR's

performance in citation tracing and cross-domain discovery; and user reflection sessions capture changes in interpretive understanding.
Findings guide iterative refinement of SEMAR's ontology and visualization design, ensuring both usability and epistemic soundness.

4 Results and Discussion

The evaluation involved five participants (three librarians, two students). Conventional catalogs were generally manageable, but lacked automated bibliographic grouping, spelling correction, and sometimes hindered item retrieval for less experienced users.
All participants (100%, 5/5) valued SEMAR. Key feedback:

1. Adaptive display modes (60%, 3/5)
2. Interactive query (Ask SEMAR) (40%, 2/5)
3. Keyword/ML refinement (60%, 3/5)

These results highlight SEMAR's practical advantages and potential for collaborative knowledge management. Its dual-layer framework integrates reflective user interactions with semantic interoperability, supporting interactive exploration and shared meaning-making in academic ecosystems.

5 Conclusion and Future Work

SEMAR is a dual-layer AI-based catalog system that enhances reflective exploration and semantic interoperability in academic libraries. Evaluations with librarians and students show that SEMAR addresses limitations of conventional catalogs, including automated bibliographic grouping, contextual keyword matching, and adaptive user interfaces. The system is intuitive, supports more accurate knowledge discovery, and integrates micro-level reflective interactions with macro-level semantic alignment, enabling coherent knowledge flows, interactive exploration, and meaningful user-system collaboration.

Future directions:

1. Refining machine learning models for contextual recommendations and search accuracy.
2. Expanding interoperability with additional repositories and metadata standards.
3. Conducting longitudinal studies to assess long-term user adaptation and knowledge synthesis.
4. Developing interactive features, such as *Ask SEMAR*, for personalized exploration for diverse academic users.

These efforts aim to further strengthen SEMAR as a co-evolving, semantically aware, and collaborative academic knowledge infrastructure.

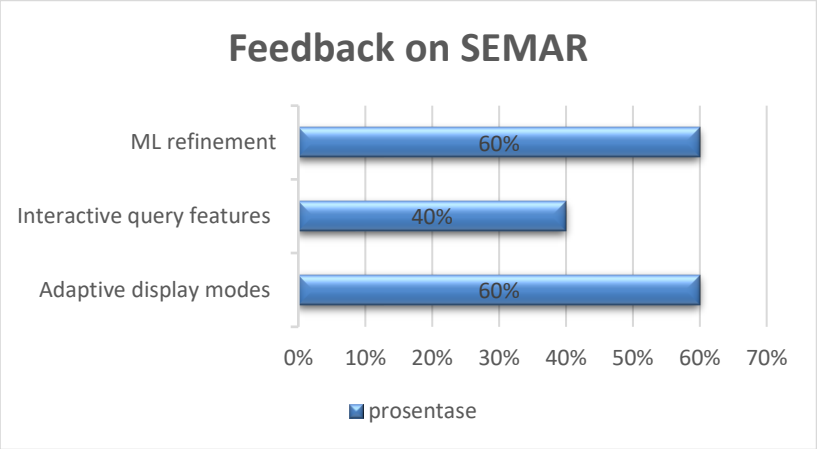

Fig. 3. Participant feedback on SEMAR features

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References

1. Ma, Z., & Zhang, Y. (2022). *Human–AI Collaboration for Knowledge Discovery: A Reflective Sensemaking Perspective.* Frontiers in Artificial Intelligence, 5, 872134**.**
2. Ehrlich, K., & Millen, D. R. (2023). *Collaborative Knowledge Systems: Rethinking Scholarly Communication in the Digital Age.* Proceedings of CSCW 2023**.**
3. Mayernik, M. S., & Borgman, C. L. (2023). *From Data Repositories to Knowledge Infrastructures: Designing for Interoperability and Reflection.* Data Science Journal, 22(1).
4. Fenner, M., & Smith, J. (2022). *Open Metadata: Interoperability, Sustainability, and Scalability of Research Information.* Data Science Journal, 21(1).
5. Curry, E., Ojo, A., & Zeleti, F. A. (2023). *Data Ecosystems for Knowledge Interoperability and Collaboration.* Journal of Web Semantics, 76, 100776.
6. Borgman, C. L. (2024). *Reframing Knowledge Infrastructures for the Age of Data Collaboration.* Information Processing & Management, 61(3), 103546.