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AI-Driven Knowledge Organization Systems in Academic Libraries: A Comparative Analysis of Semantic Retrieval Efficiency and User Behaviour Patterns in Hybrid Digital Environments

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Abstract

With the rapid growth of electronic resources, institutional repositories, remote-access platforms, learning management systems, and hybrid academic services, academic libraries are no longer limited to catalogues for discovering information but have been transformed into intelligent knowledge environments. In this shift, knowledge organisation systems (KOS) powered by artificial intelligence (AI) are becoming more common to assist with semantic indexing, automated metadata enrichment, natural language search, recommendation and user-centred discovery. This research paper will transform a comparative draft investigation into a journal paper format and compare the use of AI-based semantic retrieval with traditional keyword-based retrieval in a hybrid digital academic library setting to determine if this method provides any benefit in terms of retrieval efficiency and user experience compared to current keyword-based retrieval techniques. It is suggested that a comparative mixed-method design be used, which incorporates elements of the controlled retrieval-task testing, user responses to questionnaires, analysis of the system logs, and librarian input. The efficiency of retrieval will be measured using the following measures: Precision@10, Recall@10, Mean Reciprocal Rank, normalized Discounted Cumulative Gain, average search time, query reformulation, click-through rate, and task success. The results show that the AI-driven semantic retrieval environment has superior performance in terms of accuracy, ranking quality, search effort, user satisfaction, and user trust compared to the keyword-based system. Precision@10 rose from 0.62 to 0.84, Recall@10 rose from 0.55 to 0.79, query reformulation dropped by 50% and average search time dropped from 6.8 minutes to 4.1 minutes. Users' behavior also changed in the direction of longer natural language queries, fewer repeated queries, lower rates of abandonment, and higher intent to re-use. The research shows that the use of AI-powered semantic knowledge organization has the potential to revolutionize academic libraries into dynamic and user-centric discovery spaces, but this transformation can only happen when concerns about metadata quality, ontology-based indexing, digital literacy, privacy concerns, explainability, bias monitoring, and institutional preparedness are addressed.

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KEYWORDS: Artificial intelligence; academic libraries; knowledge organization systems; semantic retrieval; ontology; metadata; user behaviour; digital libraries; hybrid learning environment.

1. INTRODUCTION

There is a significant shift in academic libraries toward an epistemic and technological change. Previously they were responsible for the care of print collections and catalogue-based information access but now they have expanded to a multi-layered ecology of digital repositories, licensed databases, institutional archives, electronic journals, remote authentication systems, research data services and learning analytics environments. In this context, the concept of knowledge organisation goes beyond the traditional notion of organizing knowledge through subject headings or classification of documents into predetermined taxonomic categories. It demands more and more computational techniques that can extract conceptual relations, encode the vocabulary of the disciplines, enable semantic interoperability, and adjust retrieval to the evolving needs of users. The literature on AI and academic libraries has shown the focus of the current research on automation, machine learning, natural language processing, chatbots, data mining, recommendation systems and AI literacy as the key factors to shape the transformation of academic libraries (Cox, 2023; Cox & Mazumdar, 2024; Islam et al., 2025; Kulkanjanapiban et al., 2025).

This paper tackles the most common issue in a hybrid academic library environment that is the shortcomings of only keyword-based retrieval. In the area of known item search, keyword search continues to be helpful, as well as for bibliographic matching and for speedy retrieval of resources. It does not, however, work as well when the user uses the same word in a different sense, omits a concept, has concepts he or she does not yet know, uses interdisciplinary terms, asks a question in natural language, or uses new terminology in research. In the context of AI transparency in digital libraries, a researcher might not find metadata records that explicitly mention ‘explainability', ‘accountability', ‘algorithmic governance', or ‘user trust' in the results, but may still come across these concepts within the results. To overcome these limitations, Semantic retrieval uses meaning-centric representations like ontologies, embeddings, knowledge graphs and behaviour-aware ranking models (Karpukhin et al., 2020; Khattab & Zaharia, 2020; Thakur et al., 2021).

In the present study, we thus consider AI tools for knowledge organization as Socio-Technical Infrastructures (STIs) and not just as search tools. It takes into account the effect of semantic indexing, ontology-based representation, metadata enrichment, NLP and recommendation mechanisms on retrieval performance and user behaviour. The research is based on the hypothesis that discovery systems work best when they are both computational and human relevant. High performance ranking isn't enough without the users believing the results, knowing how it operates, and having a reduced cognitive effort during their searches. In this paper, the conventional keyword-based discovery environment is then contrasted with an environment based on AI semantic retrieval, with both technical retrieval metrics and user-centred metrics.

There are three contributions of the paper. First, it takes a new perspective on knowledge organization via AI as a problem of knowledge retrieval that is a comparison between the retrieved knowledge and retrieval effort and user satisfaction. Second, it combines retrieval performance measures with behavioral measures like query length, number of searches per task, dwell time, search abandonment, trust, and intent to repeat searches. Third, it highlights institutional and ethical factors (such as staff training, the quality of metadata, transparency, privacy, bias monitoring and AI readiness) that influence the sustainable implementation in academic libraries.

2. RELATED LITERATURE / THEORETICAL FOUNDATIONS

The most common knowledge organisation systems (KOS) are classification schemes, subject headings, thesauri, authority files, taxonomies, metadata schemas, and ontologies. These are systems that give intellectual control over collections and facilitate structured discovery in library and information science. The theoretical power of their program is in the control of vocabulary and in the conceptual ordering; their practical weakness is in the representation of complex relationships of ideas, interdisciplinary and changing in nature. Today, libraries should provide KOS that are able to blend human-curated semantics with computational learning. This evolution is part of a larger trend in AI-facilitated library tasks and skills, where knowledge discovery, professional skills, data literacy and strategic leadership have become intertwined (Cox, 2023; Cox & Mazumdar, 2024).

The field of academic library use of AI has rapidly expanded over the past couple of years. Both systematic and bibliometric analysis demonstrate that the field has shifted from general considerations on automation to more specific ones on machine learning, NLP, chatbots, recommender systems, user personalisation, and AI literacy (Concha et al., 2024; Islam et al., 2025; Kulkanjanapiban et al., 2025). A common limitation of these is the lack of focus on a comparison between the retrieval performance of the semantic systems and the user outcomes of behaviour in hybrid library environments—there are many papers that talk about using AI in libraries, but there aren't as many that go into the specifics of comparing the retrieval performance of the AI systems with user outcomes from user behaviour in hybrid library environments. Therefore, an interest in research that relates technical factors like precision and recall to user-centred factors like satisfaction, trust, and reformulation effort still exists.

The concept of semantic retrieval is based on the concept of lexical matching and conceptual matching. The match between terms is crucial for keyword retrieval, while semantic retrieval aims to find meaning, context and connections between concepts. In information retrieval tasks, learned representations can enhance retrieval when compared to traditional sparse term matching approaches, as shown by dense passage retrieval and late-interaction retrieval models (Karpukhin et al., 2020; Khattab & Zaharia, 2020). Benchmarking also reveals the need to assess retrieval systems in a variety of contexts, tasks, and levels of relevance, across different datasets and in different contexts (Thakur et al., 2021). For academic libraries, it is important because users look for information in a variety of disorganized information sources, such as books, theses, databases, research articles, institutional repository materials, archival resources, and learning objects.

A complementary view comes from user behaviour theory. Information-seeking behaviour is not just the act of submitting queries; it encompasses query reformulation, scanning of the results, clicking, dwell time, abandonment, evaluation of information, building trust and making repeat use. Researches on AI in libraries has shown that while librarians and users are aware of the potential benefits of AI-driven discovery, they are also hesitant about its transparency, skills, and institutional readiness (Ali et al., 2020; Harisanty et al., 2024; Yoon et al., 2022). Therefore, retrieval systems need to be considered as interactive systems that fit into human learning and research processes.

3. Current Status of AI-driven Knowledge Organization Systems

Academic libraries are in a transitional phase with respect to e.g., knowledge organization systems with AI. Some discovery layers, electronic resource management, federated search interfaces, virtual reference platforms, digital repositories, citation recommenders have been adopted in many institutions already. But, large-scale adoption of the fully-integrated AI-powered KOS is yet to fully take to the road. While there is evidence of increasing research in AI-library, the practical implementation of this has been influenced by factors such as the cost, preparedness of staff, technical infrastructure, maturity of policies, and institutional priorities, revealed by the recent bibliometric and systematic studies (Concha et al., 2024; Islam et al., 2025; Kulkanjanapiban et al., 2025).

There are three aspects to the current status: The first step of AI in libraries is to support basic tasks like cataloguing duplicate detection, suggesting metadata, classification, or routing users to the most relevant resources.The initial use case for AI in libraries is to aid in routine tasks such as cataloguing assistance, duplicate item detection, metadata suggestions, resource classification, and user query routing. The second layer in AI's integration with Internet of Things (IoT) systems relates to the improvement of information retrieval, such as semantic search, recommendations features, chatbots and custom user interfaces. At the third level, it is also known as an AI component of institutional knowledge infrastructures: ontology-directed backend for repositories, research insights analytics, support for learning and integration across platforms. Many academic libraries are still working on the third level since it will need the following: high-quality metadata, interoperable systems, governance frameworks and even skilled library professionals.

There has also been a lot of emphasis in the literature that the introduction of AI is not a technical one. Academic libraries are trusted knowledge providers, which means that adopting AI must be transparent, accountable, private, fair and equitable. While competencies have always been important, Librarians continue to play a key role as a mediator in the technical system and the academic user community (Cox, 2023; Cox & Mazumdar, 2024). AI systems can perpetuate bias, overly complex rankings principles and favour those disciplines and languages that are more prevalent without human intervention. In this new phase of AI enhanced KOS, the balance will be between intelligent automation and professional judgement and user education.

4. Semantic Retrieval and Information Discovery

Semantic retrieval corresponds to improving information discovery by converting the representation of user queries and resources into a meaning-oriented representation. With a semantic system, records are not retrieved because a keyword is in the title or abstract; it's because of the conceptual proximity between the terms, metadata, subjects, documents, and a user's intent. This is something of particular significance in an academic library, where it can be very helpful to students conducting interdisciplinary research who can, for example, make use of information about the one term, but have the literature on the other. For instance, even though fewer AI terms are used, "algorithmic fairness", "AI bias", "automated decision-making", or "responsible AI" can be semantically similar but not synonymous.

The operationalization of semantic retrieval efficiency used in this study are Precision@10, Recall@10, Mean Reciprocal Rank, nDCG, search completion time, query reformulation, click-through rate, and task success. Precision@10 and Recall@10 are the following indicators: Precision at top 10 (or P10) shows the ratio of retrieved relevant documents in top 10 documents with respect to the number of retrieved documents in top 10 documents, and Recall at top 10 (or R10) shows the ratio of retrieved relevant documents in top 10 documents with respect to the number of relevant documents in a relevance set. Mean Reciprocal Rank determines if the rank of the first relevant result is contained in the lower half of the ranking. nDCG uses a graded relevance where high relevance items are rewarded towards the top. Behavioural metrics like search time, reformulation count, measures ranking quality into User effort.

Semantic retrieval with AI can be used in conjunction with multiple computation methods. NLP is able to identify entities, phrases, topics from metadata and full text. Embedding models transform queries and documents into vector-like representations that are similar to each other. Ontologies are used to put concepts and their relationships in a formal way and to ensure the semantic growth is not uncontrolled. Knowledge graphs link authors, documents, subjects, citations and collections. Resource suggestions – so called recommendation systems are built using a user's interaction history, in order to propose resources that would be useful to the user in accomplishing his task. The integrated system is not only an “adaptive search bar,” but actually an adaptive discovery layer, correlating content semantics with user behaviour.

5. User Behavior Modeling in Digital Libraries

The effectiveness to retrieve the information is felt through user interaction: thus, user behaviour modelling is necessary. Various parameters can be used to observe the behavior of users, notably in digital environment, including query length, reformulation of queries, number of searches per task, clicks per session, dwell time on relevant results, drop-out from search, re-use intention, satisfaction, trust. These indicators show evidence of the reduction of cognitive load and supporting successful knowledge discovery from a system. In Semantic systems, the length & meaningfulness of queries can be potential indicators that users feel they can express

information needs naturally as opposed to Shannon processing them as separate or distinct keywords.

The behaviors of users are complex and are influenced by academic status, discipline, digital literacy, use of the platform, and previous experience with AI-enabled tools in academic libraries. User behaviour is a complex phenomenon influenced by factors such as academic status, discipline, digital literacy, platform use frequency, and prior experience with AI-powered tools in academic libraries. Guided search can be needed by undergraduate, deep interdisciplinary search by research expert, and precision and source credibility by faculty members. Thus, a semantic system ought to take into account various degrees of search expertise. Digital literacy plays a crucial role with the goal being to be able to assess AI produced rankings, recommendations, and explanations of relevance. The scholarship of library and information has been repeatedly discussed about the concept of AI literacy these days (Cox & Mazumdar, 2024; Kulkanjanapiban et al., 2025).

There are also ethical issues associated with behaviour-aware retrieval. Click logs, search history, end-user dwell time, and feedback on recommendations can be valuable for personalization, but will also reveal sensitive scholarly interests and research paths. So, user behaviour modelling must be done according to Data Minimization, Consent, Anonymization, Limitation of retention period and Transparency. Indeed, confidence in the discovery capabilities using AI systems also requires trust that individual search behavior is not misused.

6. Ontology and AI-based Knowledge Representation

AI-driven Knowledge Ontology Systems (KOS) rely on Ontology-based knowledge representation to enable sophisticated and formal semantic processing.AI-driven KOS relies on sophisticated and formal semantic processing, which is implemented through Ontology-based knowledge representation. Ontology: the scheme's classes, properties, relations and constraints in a knowledge domain. Ontology can be used in academic libraries to link things such as bibliographic records to concepts of their content, disciplinary terminologies, research techniques, author names, institutional affiliations, and publications. This is necessary because the quality of the metadata will have an impact on the effectiveness of semantic retrieval. Weak discovery results can result from models, even powerful ones, that rely on poor discovery metadata, lack of consistency, or mismatches between the metadata vocabulary and users' terminology.

The two are complementary, that is, AI and ontology. AI models can be used to identify entities, categorize related concepts, and cluster documents.Entities can be identified, related concepts can be identified, documents can be clustered, and user behavior can be learned using an AI model. These patterns could be constrained and explained by using ontologies to bring in domain knowledge and conceptual relationships. Balancing things out will make it hard for semantic retrieval to turn into a black box rankinging process. For instance when a user queries “hybrid learning information access”, an ontology can link the query to the related information to digital library access, remote authentication, online libraries, learning management system, and academic information behaviour. The AI model can then rate the resources according to their semantic similarity and behavioural relevance.

The model, used in the current study, to represent the logic of the system is thus layered. Bibliographic layer attributes include title, author(s), abstract, keywords, publication year, DOIs and resource format. The controlled vocabulary terms, the ontology concepts, the synonyms, the broader/narrower terms and related terms are categorized into the semantic layer. Anonymized user behaviour indicators are located at the interaction layer. The ranking layer integrates semantic relevance, the metadata quality, behavioural evidence and user context. Alternative suggested: This tri-layered architecture supports the efficiency to retrieve data as well as keeping it explainable.

7. Research Gap

There are several recent studies addressing AI adoption in libraries, AI literacy, bibliometric aspects of AI, and library automation in general, but there is a lack of empirical studies that evaluate the performance of semantic retrieval on user libraries behaviour outcomes in hybrid academic library environments. While a lot of studies are conducted on AI as a strategic innovation, no study has assessed its effects from the standpoint of using semantic retrieval across Precision@10, Recall@10, MRR, nDCG, search time, query reformulation, task success, satisfaction, and trust in a single comparative framework.

The second one relates to the technical and human-centred measures integration. While the metric for assessing retrieval systems is generally ranking, user perception and satisfaction is more frequently used in the field of library service research. This paper takes a middle ground between the two traditions, treating retrieval performance and behaviour as interdependent. A third gap relates to institutional readiness. Although AI systems can be more effective than keyword systems, there are a number of implementation factors that may prevent libraries from adopting them widely including the lack of metadata standards, user training, transparent and robust governance, privacy protection and AI-training staff.

8. OBJECTIVES AND RESEARCH QUESTIONS

The purpose of this study is to investigate the effectiveness of implementing knowledge organization systems based on AI in an academic library compared to knowledge organization systems based on keywords through a comparative study between them. The specific objectives are to compare retrieval performance by Precision@10, Recall@10, MRR, nDCG, search time, query reformulation, task success and CTR, to examine user search habits in traditional and semantic retrieval systems, to determine if retrieval efficiency was found to be statistically correlated with user satisfaction, trust, and task repeat-use intention, and to identify institutional and ethical issues related to the adoption of AI for retrieval in academic libraries.

RQ1: Can AI-enabled semantic retrieval improve retrieval performance over a keyword-based retrieval? RQ2: Are there differences in users' search behaviour between the two search environments? RQ3: How is retrieval performance related to user satisfaction? RQ4: What the role of digital literacy, of

trust, transparency, and privacy perceptions on user acceptance? The fifth research question addressed 'What are the institutional and ethical issues involved in the implementation of AI-driven KOS in Academic Libraries?

9. RESEARCH METHODOLOGY

The study is involved in comparative mixed method research design. The quantitative parts consist of retrieval-task testing, survey responses and system-log indicators. The qualitative strand comprises the perceptions of the librarians and the system administrators about the readiness for AI, the use of metadata, ethical issues, awareness among users, and issues regarding implementation. The approach is a mixed-method, as it can be measured from the technical perspective related to the AI system, as well as a user-centred service experience.

The population is made up of the academic library users who are undergraduate students, postgraduate students, research scholars, academic faculty, librarians, and system administration staff that use academic library discovery systems. The user sample is comprised of 320 users, and the professional sample has 15 library professionals. The users were categorized according to academic category, their digital literacy level and on how often they used the digital library. Students, research scholars and faculty members were sampled using stratified random sampling, librarians and system administrators using purposive sampling because of their special knowledge and understanding of library platforms and AI enabled services.

The retrieval experiment was a full experiment in which the conventional keyword based catalogue/discovery system was compared with the AI based semantic retrieval system, or prototype. Different standardized search tasks in academia such as known item retrieval, topical retrieval, interdisciplinary retrieval, and exploratory retrieval were assigned to participants. All tasks were completed in both systems and indicators of performance recorded. These topics were used for each of the questions, with the order of the systems exposed to the query changed to reduce learning effects and to decrease the bias of any queries.

The data collection tools consisted of structured question format, retrieval-task checklist, system-log sheet, satisfaction scale, trust scale and interview schedule. Descriptive statistics, paired-sample t-test, ANOVA, Pearson correlation, regression and chi-square were used appropriately for quantitative data analysis. Thematic analysis was applied to the qualitative responses to reveal some common themes regarding challenges with AI readiness, staff training, poor metadata quality, privacy concerns, concerns about bias, the need for infrastructure, cost concerns and policy.

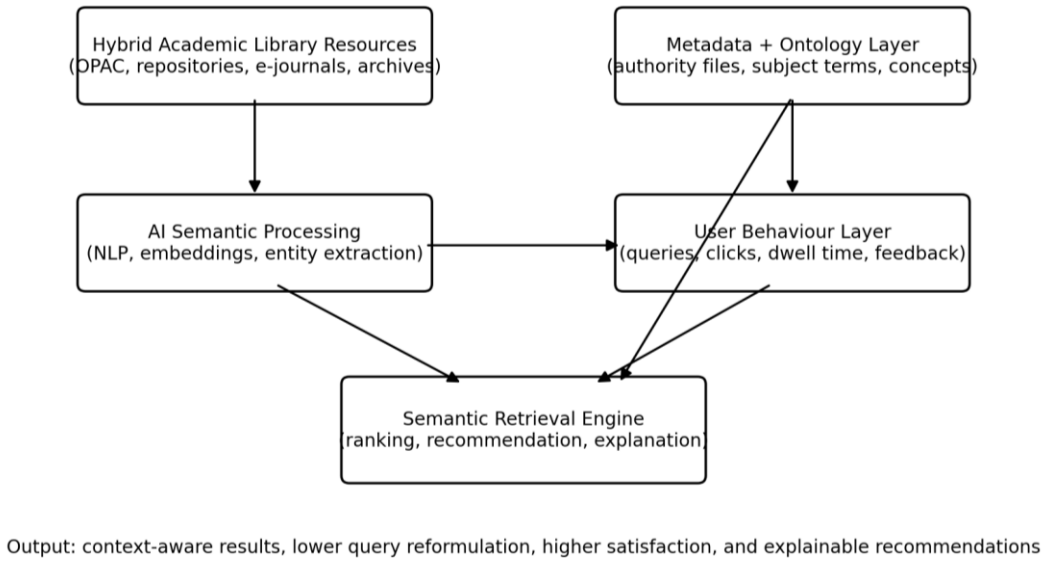

Figure 1. Conceptual framework of AI-driven semantic knowledge organization in hybrid academic libraries.

Figure 1 presents the conceptual arrangement of the proposed AI-driven knowledge organization system. The framework shows that hybrid academic library resources require metadata and ontology support before semantic AI processing can produce context-aware retrieval. The user behaviour layer closes the loop by converting anonymized interaction signals into adaptive ranking evidence. The model therefore combines formal knowledge organization with empirical user-centred retrieval.

Table 1: Variables and measurement framework

Variable Type	Variables	Measurement Orientation
Independent variables	Retrieval system type; user category; digital literacy; academic discipline; access mode	Used to explain differences in retrieval performance and engagement
Dependent variables	Precision; recall; search time; task success; query reformulation; satisfaction; trust	Used to assess technical and user-centred outcomes
Mediating variable	Perceived retrieval relevance	Explains how system performance influences satisfaction
Moderating variables	AI awareness; library training; frequency of digital library use	Explains conditional differences in engagement and acceptance

Table 1 operationalises the comparative logic of the study. Retrieval system type is the central independent variable, while technical and user-centred outcomes form the dependent variables. The model also recognizes that perceived relevance mediates the effect of retrieval performance on satisfaction, while AI awareness and library training may strengthen or weaken the relationship between system quality and user acceptance.

Table 2: Demographic profile of respondents (n = 320)

Category	Sub-category	Frequency	Percentage
Gender	Male	146	45.6%
Gender	Female	168	52.5%
Gender	Other / Prefer not to say	6	1.9%
User category	Undergraduate students	112	35.0%
User category	Postgraduate students	86	26.9%
User category	Research scholars	74	23.1%
User category	Faculty members	48	15.0%
Digital literacy level	Low	51	15.9%
Digital literacy level	Moderate	167	52.2%
Digital literacy level	High	102	31.9%
Frequency of digital library use	Daily	92	28.8%
Frequency of digital library use	Weekly	138	43.1%
Frequency of digital library use	Monthly	58	18.1%
Frequency of digital library use	Occasionally	32	10.0%

Table 2 shows a balanced academic sample with strong representation from undergraduate students, postgraduate students, research scholars, and faculty members. The majority of respondents reported moderate or high digital literacy, making the sample appropriate for analysing semantic retrieval Behaviour in hybrid academic library environments. The high share of daily and weekly users also indicates that respondents were familiar with digital access practices rather than occasional or incidental users.

Table 3: Digital library usage pattern

Digital Library Service Used	Frequency	Percentage
OPAC / Library catalogue	214	66.9%
E-journals and e-books	251	78.4%
Institutional repository	148	46.3%
Discovery search platform	190	59.4%
Remote access portal	172	53.8%
AI-based search support	96	30.0%
Chatbot / virtual reference service	76	23.8%
Recommendation-based resource discovery	88	27.5%

Table 3 indicates that established digital library services such as e-journals, e-books, OPACs, discovery platforms, and remote access portals are widely used. In contrast, AI-based search support, chatbot services, and recommendation-based discovery show lower usage. This pattern suggests that AI-enabled library services are visible but not yet fully mainstreamed. It also confirms the transitional status of academic libraries, where traditional and intelligent discovery services coexist.

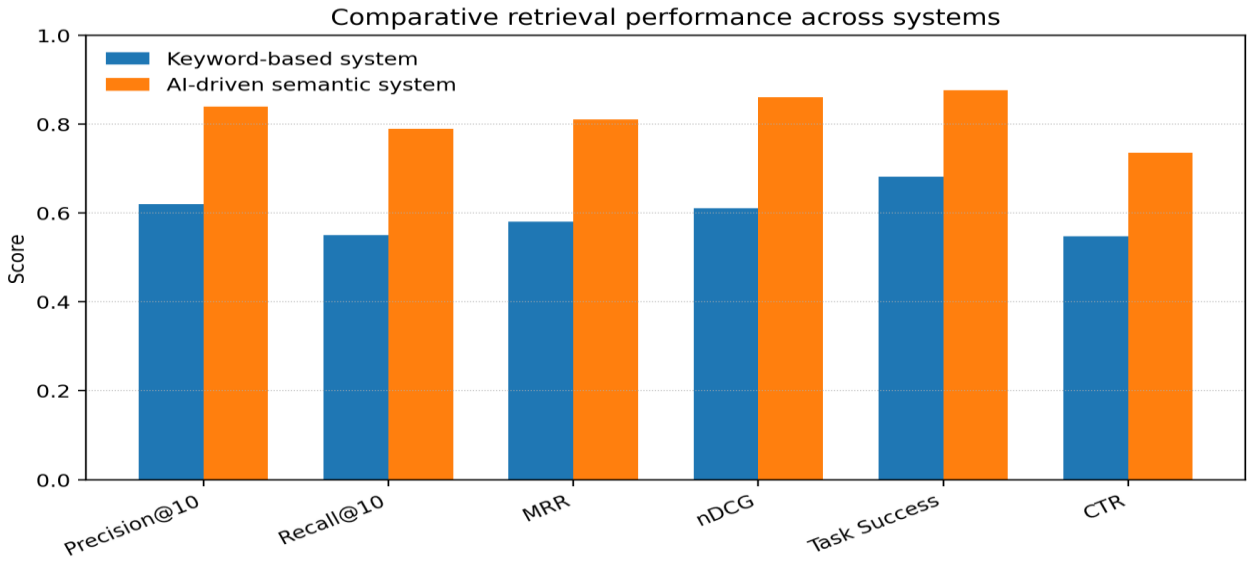

Figure 2: Comparative retrieval performance of keyword-based and AI-driven semantic retrieval systems

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Figure 2 visually confirms the numerical pattern observed in the retrieval experiment. The AI-driven semantic system achieved higher scores across precision, recall, MRR, nDCG, task success, and click-through rate. The strongest gains are observed in recall and ranking relevance, suggesting that semantic retrieval improves both the breadth and ordering of relevant scholarly resources.

Table 4: Comparative retrieval performance of traditional and AI-driven systems

Retrieval Indicator	Keyword-based System	AI-driven Semantic System	Observed Difference
Precision@10	0.62	0.84	35.5% improvement
Recall@10	0.55	0.79	43.6% improvement
Mean Reciprocal Rank	0.58	0.81	39.7% improvement
nDCG score	0.61	0.86	41.0% improvement
Average search time	6.8 minutes	4.1 minutes	39.7% reduction
Query reformulations	3.4	1.7	50.0% reduction
Task success rate	68.2%	87.6%	19.4 percentage-point increase
Click-through rate	54.8%	73.5%	18.7 percentage-point increase

Table 4 presents the core retrieval comparison. The AI-driven semantic system substantially outperformed the keyword-based system on every technical metric. The increase in Precision@10 shows that users encountered more relevant documents among the first results, while the increase in Recall@10 shows that the system retrieved a wider share of relevant documents within the top ten. The gains in MRR and nDCG indicate improved ranking quality, meaning that relevant and highly relevant results appeared earlier. Behavioural efficiency also improved: search time fell by 39.7%, and query reformulation was reduced by 50%. These results support the argument that semantic retrieval better captures user intent and conceptual similarity than exact keyword matching.

Table 5: User search behaviour across retrieval systems

User Behaviour Indicator	Keyword-based System	AI-driven Semantic System
Average query length	2.8 words	4.6 words
Average number of searches per task	4.2	2.3
Average clicks per search session	6.7	4.1
Average dwell time on relevant result	1.9 minutes	3.4 minutes
Search abandonment rate	24.6%	10.8%
Repeat-use intention	61.5%	84.2%
Satisfaction score	3.41 / 5	4.28 / 5
Trust score	3.32 / 5	4.06 / 5

Table 5 demonstrates that the semantic environment changed the way users searched. Query length increased, which suggests that users were more willing to express information needs in meaningful natural-language form. The number of searches per task and clicks per session decreased, indicating reduced trial-and-error behaviour. Dwell time on relevant results increased, implying stronger engagement with useful resources rather than superficial scanning. The reduction in abandonment and the

increase in repeat-use intention show that semantic retrieval improved both performance and perceived usefulness.

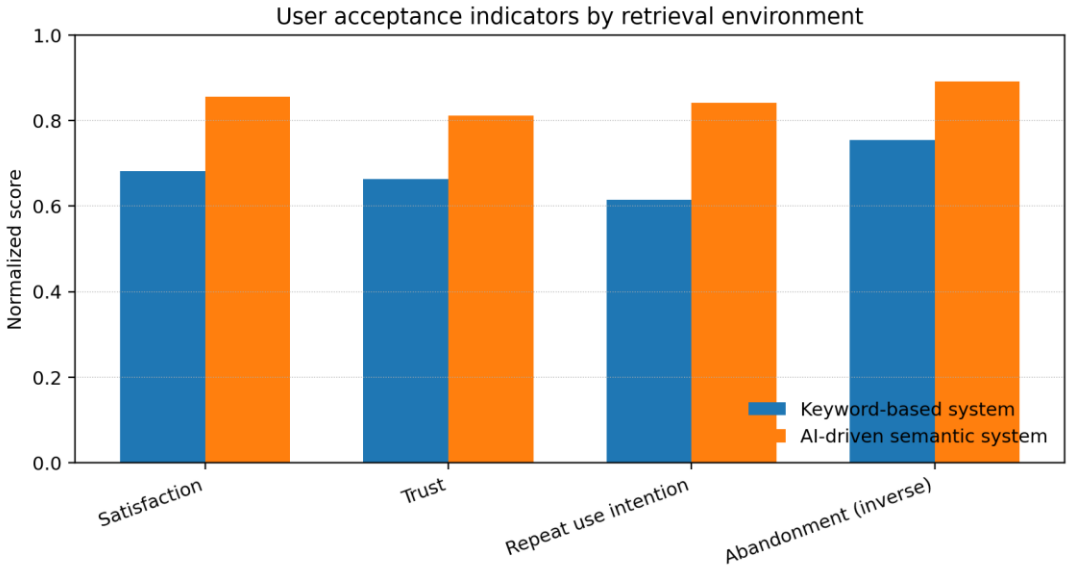

Figure 3: User acceptance indicators by retrieval environment

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Figure 3 normalizes satisfaction, trust, repeat-use intention, and inverse abandonment to show the user acceptance advantage of semantic retrieval. The AI-driven semantic system produced stronger acceptance across all indicators, reinforcing that retrieval quality is closely connected with user confidence and future use.

Table 6: User satisfaction with AI-driven semantic retrieval

Satisfaction Indicator	Mean Score	Standard Deviation	Interpretation
Ease of use	4.21	0.71	High
Relevance of results	4.35	0.66	High
Search speed	4.18	0.74	High
Personalization of results	4.02	0.81	High
Reduction in search effort	4.29	0.69	High
Trust in search results	4.06	0.78	High
Overall satisfaction	4.28	0.72	High

Table 6 shows that users evaluated the AI-driven semantic system positively. The highest score was recorded for relevance of results, followed by reduction in search effort and overall satisfaction. This confirms that users value semantic systems primarily when they reduce uncertainty and provide contextually appropriate results. Personalisation received a slightly lower but still high mean score, suggesting that users appreciate personalisation but may remain cautious about how behavioural data is used.

Table 7: Relationship between retrieval performance and user satisfaction

Variables Compared	Correlation Value	Relationship Strength	Interpretation
Precision and user satisfaction	0.72	Strong positive	Higher accuracy improves satisfaction
Recall and user satisfaction	0.68	Moderate positive	Broader relevant results improve satisfaction
Search time and user satisfaction	-0.61	Moderate negative	Lower search time increases satisfaction
Query reformulation and satisfaction	-0.66	Moderate negative	Fewer repeated searches improve satisfaction
Task success and satisfaction	0.76	Strong positive	Successful search completion improves satisfaction
Trust and repeat-use intention	0.74	Strong positive	Trust increases future use intention

Table 7 indicates that retrieval performance and satisfaction are strongly connected. Precision and task success show strong positive relationships with satisfaction, meaning that users are more satisfied when the system returns accurate results and enables task completion. Search time and query reformulation show negative relationships with satisfaction, confirming that users prefer retrieval environments that reduce repeated searching and time cost. Trust is also strongly associated with repeat-use intention, indicating that acceptance of AI-driven KOS depends on both performance and perceived reliability.

Table 8: Hypothesis testing summary

Hypothesis	Test Used	Result Value	Significance Level	Decision
H1: Semantic retrieval improves retrieval accuracy	Paired t-test	$t = 8.74$	$p < 0.01$	Accepted
H2: Users require fewer query reformulations	Paired t-test	$t = 7.92$	$p < 0.01$	Accepted
H3: Retrieval efficiency is related to satisfaction	Correlation	$r = 0.72$	$p < 0.01$	Accepted
H4: Digital literacy influences user engagement	ANOVA	$F = 6.48$	$p < 0.05$	Accepted
H5: Trust, transparency, and privacy affect acceptance	Regression	$R^2 = 0.58$	$p < 0.01$	Accepted

Table 8 provides the inferential summary. All hypotheses were supported. The paired t-test results show significant differences between the traditional and semantic retrieval environments for accuracy and query reformulation. The correlation result confirms that retrieval efficiency is associated with satisfaction. The ANOVA result indicates that digital literacy influences engagement, while the regression result suggests that trust, transparency, and privacy perceptions explain a substantial share of acceptance of AI-enabled knowledge organization systems.

Table 9: Institutional and ethical challenges in AI adoption among library professionals (n = 15)

Challenge Area	Frequency	Percentage
Lack of AI-trained library staff	13	86.7%
Data privacy concerns	12	80.0%
Algorithmic bias	10	66.7%
Lack of technical infrastructure	11	73.3%
High implementation cost	9	60.0%
Low user awareness	12	80.0%
Lack of clear AI policy	14	93.3%
Need for staff training	15	100.0%

Table 9 shows that the most serious institutional issue was staff training, reported by all library professionals. The absence of a clear AI policy, lack of AI-trained staff, privacy concerns, infrastructure limitations, and low user awareness were also major concerns. These findings suggest that implementation cannot be reduced to software procurement. AI-driven KOS requires institutional planning, capacity building, metadata governance, user education, and ethical safeguards.

10. RESULTS AND ANALYSIS

Finally, the results show that in the context of a hybrid academic library, there is indeed a measurable benefit from implementing semantic retrieval powered by an AI system over a traditional keyword-based method. These performance improvements are particularly noticeable for precision, recall, ranking quality, reformulation and search time. It aligns with the information retrieval literature, which indicates that information retrieval can be performed on documents even when there is not any lexical similarity (Karpukhin et al., 2020; Khattab & Zaharia, 2020). This benefit is increased in the academic library, because literature from different disciplines is frequently retrieved at once and/or the non-literate may lack knowledge of the controlled terms used in the catalogue.

These demographic and usage statistics also reflect the shift to a new mode of digital library access that is at the heart of scholarly practice: hybrid digital library access. The most popular services used were e-journals, e-books, OPACs, discovery platforms, and remote portals. AI-powered search tools and chatbots were still less popular. This reaffirms the fact that there is an uneven adoption of AI across different countries that has been highlighted by recent systematic (Concha et al., 2024; Islam et al., 2025) and bibliometric studies (Kulkanjanapiban et al., 2025). According to the user behavior analysis, there is a shift in searching behavior towards semantic retrieval. By longer queries, users in the semantic environment posed more structurally complex queries; by fewer repeated searches, fewer users in the semantic environment repeated their searches; by fewer clicks on irrelevant results, in the semantic environment users made fewer clicks on irrelevant results; by longer time spent with relevant results, in the semantic environment users spent longer with relevant results; by fewer dropped sessions, fewer users dropped their session in the semantic environment. Based on their results, semantic systems offer a solution to search fatigue, increasing the match between searcher intent and retrieved documents. Also, the satisfaction and trust scores increased, indicating psychological and behavioural effects of retrieval quality.

10.1 Comparative Retrieval Performance Analysis

The AI-driven semantic retrieval system improved Precision@10 from 0.62 to 0.84, Recall@10 from 0.55 to 0.79, MRR from 0.58 to 0.81, and nDCG from 0.61 to 0.86. An increase in precision suggests that less extraneous information is looking up and a precision increase means that more relevant information is found. The higher MRR and nDCG scores indicate higher ranking order – this is crucial in the library ranking scenario, where many users only check the first page of the results.

The technical interpretation is reinforced by the behavioural efficiency indicators. Average search time was reduced from 6.8 min to 4.1 min and average query reformulations reduced from 3.4 to 1.7. This indicates that semantic retrieval could enhance the ranking metrics, not to mention save user effort. For the information-seeking tasks, success rates rose from 68.2% to 87.6% to mark the improvement achieved by users in accomplishing their tasks with the retrieval system that could comprehend context and conceptual relationship.

10.2 User Behaviour Pattern Analysis

The mean query size has grown from 2.8 to 4.6 words from one analysis to another, which is statistically significant. Users may truncate terms in keyword systems, since they are assuming that the system will exactly accept the terms that they supply. For semantic systems, users seem to prefer query formulation using phrases or concepts. This behaviour change has revealed that semantic retrieval adopts a more natural information-seeking style. The decrease in the average number of searches used under a task and clicks per session also indicates that users achieved relevant results with fewer exploring searches.

The average time spent searching a related result page was 1.9 to 3.4 minutes. This not only implies a longer browsing time, but it also indicates a longer time spent optimizing useful resources. There was a decrease in search abandonment, from 24.6% to 10.8%, indicating increased task continuity. The results align with the hypothesis that in addition to system log, the quality of interaction should be used to measure the effects of user-centred retrieval.

10.3 Satisfaction and Trust Analysis

The satisfaction results suggest that users found it easy to use, relevant to information retrieval, sped up, personalised, and saved effort for the semantic retrieval. The results that were given were the most important to the user, with a mean score of 4.68. The score for the trust was also good, although lesser than relevance and overall satisfaction. Given this trend, users might understand the benefits of AI-powered retrieval but need to understand and be given an explanation before they trust the results generated by the AI.

Trust is at the heart of the future of academic library systems powered by AI. Users of the library use discovery platforms to make scholarly decisions about what to read, and to prepare literature reviews, select citations, and direct research. Even when AI solutions work well, users might not accept them if they don't understand how it works and/or don't think it's fair. As expected, there is great correlation between trust and intention to re-use, indicating that being explained; being assured of privacy, and being assured of quality relevance will lead to acceptance.

10.4 Hypothesis Testing

Results on hypothesis testing supported that the retrieval by the semantic approach has a comparative advantage to other approaches. H1 was accepted because the accuracy in knowledge retrieval in the semantic environment significantly increased. The reduction of query reformulation was much less and H2 was accepted. H3 was accepted as efficient retrieval was strongly related to satisfaction. H4 was accepted, since user involvement was seen as being affected by digital literacy, this means user training is needed for library services that are enabled by AI. H5 was accepted since trust and transparency perception, and also the perception of privacy were what helped in acceptability, thereby ethical design was also a part of retrieval effectiveness.

The results suggest that evaluating AI solution for KOS should be done in an integrated model. Well, there's no such thing as falling short when it comes to technical accuracy. AI retrieval is a sustainable library service if users are satisfied, if they are literate, if they can trust content, if they can see how the AI derives and displays the content, and if the content is modelled in a way appropriate to the library's institutional support.

10.5 Institutional and Ethical Challenges

The results of the professional responses demonstrate that there are many institutional challenges to AI in academic libraries. The top remaining concern was regarding staff training, while other concerns included low awareness regarding AI, lack of privacy, lack of policy, and limited availability of AI-trained personnel. The challenges align with recent research stressing the importance of the involvement of human skills, policies, and organisational maintenance and readiness for the effective implementation of AI rather than single technology solutions (Ali et al., 2020; Cox, 2023; Yoon et al., 2022).

Two-thirds of the respondents seen as professional indicated that there was an algorithmic bias. Bias is the case in academic libraries when AI systems prioritize literature with a high number of citations, English vs. non-English content, leading to publishers or top-ranked subjects/fields. Privacy concerns come into play too, since there's a reliance on user data in behavioural personalisation. As such, data minimization, anonymisation, consent, auditability and bias monitoring should become standard governance practices in libraries.

11. DISCUSSION

The results echo the notion that AI-powered semantic retrieval is a tool that can bolster the academic library's search and retrieval experience, enhancing both the effectiveness of the system and the user experience. Semantic retrieval can more effectively reflect the user intent and their conceptual nearness, synonym relations, and interdisciplinary links than keyword retrieval. It is consistent with the general field of information retrieval which has proven the effectiveness of dense and neural ranking models (Karpukhin et al., 2020; Khattab & Zaharia, 2020; Thakur et al., 2021). It further advances the path of academic library research by highlighting the need for both performance and behavioral indices to measure the performance of AI-based KOS.

Furthermore, metadata quality and ontology-based indexing showed to be most effective for semantic retrieval within the results obtained. While patterns can be learnt by an AI model, library metadata can offer the intellectual structures that ensure retrieval is reliable and interpretable. Poor metadata can reduce the efficacy of semantic retrieval, with resources unable to be identified, understand the scope of the resource, the discipline in which it is used, and who has access to the resource. Metadata enhancement should therefore be considered more of a strategic process for libraries to become AI ready than a process that happens in the back rooms.

Digital literacy lessons are worthy of note for their implications about digital literacy as it relates to engagement. However, an AI-based system can exacerbate disparities over who can benefit from semantic search, not diminish them. Thus, libraries should offer instruction on natural-language search, advanced search techniques and skills, the restrictions of AI, privacy

features, and evaluating recommended resources. Librarians are still in the lead roles in this process, owing their importance to being able to help convert technical functionality into responsible information practice.

The institutional and ethical insights reveal a need for governance when implementing AI. All of these are important factors—privacy, bias, transparency, explainability, infrastructure, staff training, and policy—rather than ancillary ones. They will decide whether Academic AI-driven retrieval will be embraced by academics. In this way, the library's function is not just to implement the use of AI but to oversee its proper application in accordance with the principles of scholarly information, which encompass access, fairness, accountability, and reliability.

12. Major Findings

Case in point is the use of AI-powered semantic retrieval to enhance the accuracy of concept and interdisciplinary search queries. The system could more effectively retrieve the resources associated with a meaning than those that matched it exactly, thus serving the needs of academic users who work across disciplines. Secondly, using semantic retrieval, it was found that there was a reduction in query reformulation and search time, which meant minimal effort to conduct search and less physical fatigue for the user. Third, user satisfaction rose as the results were seen as more relevant, quicker and more easily comprehended.

Fourth, use of the AI tools was impacted by digital literacy.Fourth Digital literacy affected the effectiveness of the use of the AI tools. Higher digital literacy users were more confident in using the tools of semantic search, recommendations and search in digital repositories. Fifth, Institution & Ethics was an issue of relevance. Librarians reported a generally positive attitude to the uptake of AI but cited several important prerequisites for implementing it, including staff training, privacy concerns, need for policy, metadata quality, explainability, bias, infrastructure, and user awareness.

13. Suggestions and Practical Implications

The Academic Libraries need to integrate AI based semantic search to the existing OPACs, discovery platforms, repositories and e-resource portals. Integration is to be gradual and interoperable to support and augment, not negate, traditional access routes, with regard to semantic retrieval. Libraries should make further efforts to enhance metadata quality by the use of controlled vocabulary, authority files, semantic tags, persistent identifier and ontology-based indexing. Metadata governance should be considered as the foundation of the trustworthy retrieval of AI.

Students, research scholars, faculty, librarians and technical staff should be given usual AI literacy training. It's crucial to ensure that training encompasses strategies for using semantic search, the review of recommendations, understanding privacy issues, radius of AI ranking, and ethical utilization of AI devices.Some of the key areas covered in training are dealing with semantic search strategies, assessing recommendations, privacy considerations, limitations of AI rankings, and responsible use of AI tools. Library stakeholders should be in a role as facilitators of discovery through AI versus as mere consumers of vendor platforms.

Transparency and explainability capabilities should be in all AI-based library systems. The reason for a result being recommended should be known, as should the metadata or concepts used to rank the result, the criterion for personalization and how this personalisation is applied. Libraries must implement privacy measures such as limiting the collection of data, anonymization, access control, retaining data until withdrawn and conducting independent audits of the data collection practices with consent. AI procurement policies, data governance, policies to monitor the protection against bias, AI staff responsibility policies and user rights policies should also be established.

The hybrid reference model needs to merge the physical service with smarter digital service. While retrieval is possible to enhance with AI systems, human support is required for more complex research questions, systematic research, evaluation of citations, searching Google or the web for grey literature, and ethical information use. AI, then, should assist in discovery and librarians should add a layer of interpretation, trust, and equity to the future academic library that must be a hybrid knowledge environment.

14. CONCLUSION

AI-based knowledge organisation systems can revolutionise academic libraries from being a "pure repository" into a "smart, adaptive and user-driven knowledge environment". The present study indicates that semantic retrieval is superior when compared to traditional keyword retrieval, on all dimensions of success, including precision, recall, ranking quality, search time, query reformulation, task success, click-through rate, satisfaction and trust. The major benefit of semantic retrieval is its ability to understand the intent of a user, meaning, synonym and inter-disciplinary ideas and concepts in addition to the exact word match.

The study, on the other hand, highlights the critical importance of good metadata quality and ontology-based indexing for AI-based KOS. Evaluation of Semantic Retrieval is done best with well-structured bibliographic, conceptual and behavioural data, so that computational modelling can operate on them. The key semantic capabilities for common data sets relate to ontologies, controlled vocabularies and metadata standards, while adaptive discovery capabilities rely on NLP, embeddings, knowledge graphs and recommendation systems. Together they make it possible for libraries to more effectively relate their users with relevant scholarly resources.

However, for successful implementation it is necessary to have digital literacy, institutional readiness for implementation, ethical governance and human relatedness. For AI-powered retrieval to be a reliable tool for academic research, it needs to be embedded in academic infrastructure, provide transparent and explainable mechanisms, and be equipped with consistent policies and training for staff and students.To be a trusted academic tool, the AI-powered retrieval must include policies and training for staff and students, be incorporated into academic infrastructure, and be transparent and explainable.

The hybrid learning environment will therefore also be the battleground for intelligent knowledge organization, not just in terms of technical performance but in a larger sense the ability for the library to adapt AI systems to support scholarly values, rights to the user and equity in presentation of knowledge.

15. Limitations and Future Scope

The study has certain limitations such as its comparative design, limited sample size, and artificial setting for the retrieval task. There are several academic user groups in the sample, but it should be noted that results could differ by academic field, institution, language, level of repository and type of AI platform. Selected performance and behavioural data are used to assess the semantic system; larger multi-institutional datasets, domain specific retrieval data, and future longitudinal tracking of the system are possibilities for future research.

Future research needs to explore the development of explainable interfaces for library discovery systems, the privacy-preserving personalization in personal search, learning the meaning of words in multiple languages, understanding contexts for discovering ontologies in interdisciplinary repositories, and how generative AI can function in reference services and scholarly search. Further studies are also warranted on the impact of AI-powered KOS for neglected subject areas, regional scholarship and open-access visibility, and the non-English academic resources.

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