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Faceted Classification Theory as a Conceptual Foundation for the Evolution of Knowledge Organization Systems in AI-Mediated Environments

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Abstract. *Artificial Intelligence (AI) has expanded the role of Knowledge Organization Systems (KOS), transforming them from traditional documentary tools into semantic infrastructures that support knowledge representation, interoperability, explainability, governance, and contextualization in AI-mediated environments. Although recent studies have explored the application of AI to KOS, limited attention has been given to how these transformations affect the conceptual foundations of KOS themselves. This study investigates how recent literature characterizes the challenges faced by KOS in AI-mediated environments and interprets them through the principles of Faceted Classification Theory (FCT). An integrative literature review, combined with a conceptual synthesis, identified recurring challenges, including semantic interoperability, integration of heterogeneous knowledge representations, explainability, knowledge governance, scalability, and continuous evolution. Based on this interpretation, a conceptual framework was developed to relate these challenges to core FCT principles, including conceptual decomposition, faceted synthesis, hospitality, terminological control, multidimensionality, explicit semantic relationships, and structural flexibility. Rather than proposing new theoretical principles, the study demonstrates that many challenges currently attributed to AI can be understood as conceptual organization problems for which FCT already provides relevant structural foundations, reaffirming its contemporary relevance for the evolution of KOS in AI-mediated environments.*

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1. Introduction

Knowledge Organization Systems (KOS) play a central role in information representation and retrieval by organizing entities, concepts, and semantic relationships. Traditionally used for terminological control and documentary organization, these systems now support semantic interoperability, inference, data integration, and intelligent information processing in digital environments.

This evolution reflects the convergence between Knowledge Organization (KO) and Knowledge Representation (KR). Qin (2020) argues that the historical separation between these traditions has progressively diminished through ontologies, Linked Data, Knowledge Graphs, and other formal representation models in Artificial Intelligence (AI)-based applications. In this context, KOS are understood not merely as tools for organizing documents but as essential components of semantic infrastructures that underpin intelligent systems.

The expansion of these technologies has broadened the scope of KOS. Recent studies have demonstrated their application in machine learning-supported automatic classification (Golub et al., 2018), competencies and services related to digital transformation (Paletta et al., 2021), semantic models for AI data governance (Aiyankovil et al., 2024), architectures integrating KO, ontologies, and intelligent services (Tan et al., 2024), bibliographic classification based on Large Language Models (LLMs) (Feng, 2025), and AI-assisted information visualization (Pinto et al., 2026). Together, these studies show that KOS are increasingly recognized as semantic infrastructures for intelligent applications.

Among the different approaches developed within KO, Faceted Classification Theory (FCT), originally proposed by Ranganathan and later advanced by the Classification Research Group (CRG), remains a conceptual framework for structuring knowledge domains. Hjørland (2013) identifies the analytic-synthetic paradigm as a contribution of the field, enabling the systematic decomposition and recombination of concepts based on their fundamental characteristics. Revisiting the historical development of the faceted approach, Broughton (2023) demonstrates that its principles extend beyond bibliographic classification and remain applicable to the modeling of semantic organizational structures. Similarly, Tennis (2011) demonstrates that adapting faceted theory for digital environments significantly enhances its representational capabilities. Consequently, this adaptation drives the continuous development of KOS by ensuring strict terminological control and robust semantic interoperability.

Despite the consolidation of these theoretical foundations and the increasing use of KOS in AI-based applications, limited attention has been paid to how these transformations reshape the role of KOS. Although the literature reports advances in ontologies, Knowledge Graphs, controlled vocabularies, and other semantic infrastructures, it still lacks a conceptual synthesis that connects the challenges faced by KOS to the classical principles of KO.

This study is based on the premise that many challenges currently attributed to KOS in AI-mediated environments—such as semantic interoperability, the integration of heterogeneous knowledge representations, explainability, knowledge governance, scalability, and continuous evolution—are not entirely new problems. Rather, they can be reinterpreted through the lens of FCT, which already provides structural principles relevant to addressing them. From this perspective, faceted structures are viewed not merely as classical models for information organization, but as conceptual foundations capable of guiding the evolution of KOS as semantic infrastructures for AI-mediated environments.

Considering this background, this study investigates the challenges faced by KOS in AI-mediated environments in relevant literature and interprets them through the lens of faceted structures, proposing a conceptual framework for the evolution of these systems. To achieve this objective, an integrative literature review was conducted, followed by a conceptual synthesis that relates contemporary evidence to the established foundations of KO. By reinterpreting AI-related challenges through the lens of FCT, this study seeks to connect current KOS challenges to classical KO principles and strengthen the dialogue between the KO tradition and the demands of contemporary semantic ecosystems.

The remainder of this paper is organized as follows: Section 2 presents the theoretical and conceptual background of the study; Section 3 describes the methodological approach; Section 4 presents the results of the review; Section 5 discusses the implications of these findings for the evolution of KOS. Finally, Section 6 summarizes the main conclusions, limitations, and directions for future research.

2. Theoretical and Conceptual Background

The theoretical background was developed to establish the conceptual basis for the interpretation presented in this study. Rather than providing a chronological review of the literature, it organizes the discussion around the evolution of faceted structures within KO, examining how different authors have extended, reinterpreted, and discussed their underlying principles over time.

The discussion is organized into three complementary perspectives. First, it examines FCT as a model for the conceptual organization of knowledge. Second, it analyzes the evolution of faceted structures within KO. Finally, it discusses how this evolution has contributed to their incorporation into digital environments and, consequently, to the contemporary requirements of KOS used in AI-mediated environments. This theoretical background provides the conceptual basis for interpreting the findings of the integrative literature review and for developing the conceptual framework proposed in this study.

2.1. Faceted Classification Theory as a Model for the Conceptual Organization of Knowledge

Among the approaches developed within KO, FCT proposes an analytic-synthetic model for representing knowledge domains by decomposing concepts into fundamental categories and subsequently recombining them. Unlike enumerative classifications, which seek to anticipate all possible combinations of subjects, the faceted approach identifies the constituent characteristics of concepts, supporting representations that can evolve as knowledge changes. From this perspective, classification is no longer understood merely as a mechanism for organizing documents, but as a process of conceptual organization that makes explicit the relationships among entities, properties, and phenomena.

This approach originated in the work of Shiyali Ramamrita Ranganathan, whose proposal departed from predominantly enumerative classification models by introducing faceted analysis as a structuring principle for KR. According to Ranganathan (1967), complex subjects can be understood by identifying their fundamental components, which can then be synthesized into new combinations that represent different contexts and information needs. Classification is therefore conceived as a dynamic system supported by principles such as analysis and synthesis, hospitality, continuous expansion, and the ability to accommodate new knowledge while preserving structural consistency.

Subsequent developments extended the scope of this approach. Binwal (1992) argues that Ranganathan's contribution extends beyond the construction of bibliographic classifications and provides a theory for conceptual organization. Similarly, Neelameghan (1997) shows that faceted analysis provides mechanisms for representing specialized and evolving knowledge domains by supporting the logical decomposition of concepts and their recombination at different levels of specificity. From this perspective, the flexibility of FCT derives less from predefined categories than from its capacity to structure emerging knowledge domains while maintaining semantic consistency and supporting expansion.

This interpretation shifts the focus of FCT from the construction of classification schemes to the conceptual modeling of knowledge. Facets are understood not only as components of bibliographic classifications but also as mechanisms for making conceptual structures explicit, organizing relationships among concepts, and supporting their recombination according to different representational requirements. Consequently, properties such as conceptual decomposition, synthesis, hospitality, and structural flexibility can be understood as general principles of KO, regardless of the type of KOS in which they are implemented.

This study adopts an expanded interpretation of FCT, according to which its contemporary contribution lies not in the development of specific classification systems but in the formulation of structural principles for organizing knowledge domains in an explicit, consistent, and evolving manner. From this perspective, faceted properties are understood as conceptual foundations applicable across different types of KOS, regardless of the technologies used to implement them. This interpretation provides the basis for the following sections, which examine how these principles have evolved within KO and how they relate to the challenges identified in recent AI literature.

2.2. The Evolution of Faceted Structures in KO

The continued use of faceted structures in KO does not result from preserving Ranganathan's original principles unchanged; rather, it reflects their adaptation to changes in knowledge representation and organization. The literature shows a process of conceptual development in which facets are no longer understood exclusively as components of classification systems, but as general principles for structuring different types of KOS.

Broughton (2006, 2011) argues that the faceted approach extends beyond bibliographic classification and provides the basis for taxonomies, thesauri, controlled vocabularies, and other KO mechanisms used in digital environments. According to the author, its main contribution lies in representing concepts through analytic-synthetic structures that support systems capable of accommodating different knowledge domains. This interpretation shifts the focus from classification to conceptual modeling while preserving Ranganathan's structural principles.

Gnoli (2007, 2011) also argues that the evolution of KO requires structures capable of representing increasingly complex, multidisciplinary, and dynamic knowledge domains. In this context, faceted synthesis provides a mechanism for combining different conceptual perspectives while preserving representational consistency. Facets are therefore understood not only as classificatory categories, but also as structural units that can be reused across different knowledge domains.

Hjørland (2013), however, argues that conceptual organization cannot be understood solely as a logical problem. Although recognizing the contribution of faceted analysis to KO, he emphasizes that KOS are historical, social, and epistemological constructions whose categories and relationships depend on the contexts in which they are produced and used. This perspective shifts the discussion from structural consistency alone to the epistemological foundations underlying KR.

This perspective is consistent with Tennis (2011), who emphasizes the evolutionary character of KOS. In discussing system maintenance, versioning, and interoperability, Tennis argues that the long-term stability of KOS depends on its ability to incorporate conceptual change while preserving semantic consistency. From this perspective, the evolution of faceted structures does not represent a departure from their original principles, but their adaptation to information environments characterized by continuous knowledge change.

This study considers these contributions as complementary stages in the evolution of faceted structures. Broughton (2006, 2011) emphasizes the expansion of their field of application; Gnoli (2007, 2011) highlights their capacity to represent complex knowledge domains; Hjørland (2013) incorporates the epistemological dimension of KO; and Tennis (2011) demonstrates the need for the continuous evolution of KOS. Together, these contributions indicate that the contemporary relevance of FCT lies not in preserving its principles unchanged, but in their continued reinterpretation in response to new representational requirements. From this perspective, faceted structures have evolved from instruments primarily associated with bibliographic classification into general principles of conceptual organization that can support different types of KOS and their incorporation into digital environments.

2.3. From Faceted Structures to Semantic Infrastructures for Digital and AI-Mediated Environments

The developments discussed in the previous section enabled the gradual incorporation of faceted structures into different forms of KO and representation in digital environments. As KOS became part of distributed ecosystems characterized by interoperability, data reuse, and computational representation, properties traditionally associated with FCT acquired new functions. Concepts such as conceptual decomposition, synthesis, explicit semantic relationships, hospitality, and structural flexibility no longer supported only bibliographic classifications but also semantic infrastructures designed to integrate heterogeneous information systems.

This development is reflected in recent studies. Golub et al. (2018) show that faceted principles remain applicable to information organization in digital environments by supporting information retrieval, navigation, and semantic representation. Similarly, Paletta et al. (2021) argue that faceted analysis continues to contribute to the organization of complex knowledge domains, particularly when combined with contemporary approaches to information organization. Together, these studies indicate that facets are understood not only as classificatory categories but also as mechanisms for conceptual organization compatible with different KR technologies.

More recent studies further strengthen the relationship between faceted structures and computational representation. Aiyankovil et al. (2024), Tan et al. (2024), Feng (2025), and Pinto et al. (2026) show that properties such as modularity, interoperability, explicit conceptual relationships, structural flexibility, and multidimensional organization remain present in semantic representation, data governance, information retrieval, and intelligent services. Although these studies adopt different terminologies and technological approaches, many of the principles they employ correspond to properties traditionally associated with FCT.

This evolution also reflects a change in KOS's role. Initially designed to organize documents and support information retrieval, KOS have become key components of semantic infrastructures, supporting semantic interoperability across information systems (Soares 2025), cross-domain knowledge integration (Gregory et al. 2024). More recently, structured semantic resources such as ontologies and Knowledge Graphs have also been incorporated into Retrieval-Augmented Generation (RAG) architectures to improve information retrieval for Large Language Models (LLMs) (Gao et al., 2025; Sharma et al., 2025). This approach has also been shown to mitigate hallucinations and increase the accuracy of LLM-generated responses when grounded in ontology-based knowledge structures (Ali et al., 2026). The emphasis, therefore, shifts from documentary organization to formal conceptual representation that can be interpreted by both humans and machines, thereby expanding KOS's role within digital ecosystems.

This study assumes that this evolution provides the basis for the increasing convergence between KOS and AI. The argument is not that FCT was originally conceived to address AI-related challenges, but that the continued development of its principles has made them compatible with contemporary requirements for computational representation, semantic interoperability, explainability, and knowledge governance. This perspective provides the rationale for the integrative literature review presented in the following section, which examines how recent literature characterizes the challenges faced by KOS in AI-mediated environments and the extent to which these challenges can be reinterpreted through the properties of faceted structures.

3. Methodology

This study is a theoretical-conceptual investigation conducted through an integrative literature review followed by a conceptual synthesis. The integrative review was adopted because it enables the identification, analysis, and synthesis of theoretical and empirical studies addressing a given phenomenon, supporting the identification of research gaps, trends, and opportunities (Botelho et al., 2011; Dantas et al., 2022).

The review was conducted using the Scopus database, selected because it indexes journals in Information Science and Computer Science, enabling the retrieval of studies at the interface between KOS and AI. The search strategy was:

> TITLE-ABS-KEY ("knowledge organization systems") AND TITLE-ABS-KEY ("artificial intelligence")

The search included documents published between 2017 and 2026, a period that covers the expansion of research on AI applied to KOS, including machine learning approaches and, more recently, generative AI and Large Language Models (LLMs). Books, book chapters, notes, and documents published in Chinese were excluded, resulting in an initial corpus of 39 documents.

The 39 retrieved records were first screened by title, abstract, and keywords. This preliminary analysis showed that the co-occurrence of the terms knowledge organization systems and artificial intelligence did not necessarily indicate relevance to this study's objectives, as some publications used the term knowledge organization with meanings unrelated to KO in Information Science.

Based on this observation, an eligibility protocol was developed during the review process to distinguish studies in which KOS was the object of investigation from those in which it appeared only as an application, technological infrastructure, or tool designation.

The main inclusion criterion required that KOS be addressed as the object of analysis, a conceptual component, or a semantic infrastructure, with explicit discussion of their challenges, transformations, requirements, or implications in relation to AI.

Studies were excluded when the terms knowledge organization or knowledge systems referred to workflows, organizational ecosystems, knowledge management systems, cognitive processes, or software tools without addressing KOS from a KO perspective. Conference reviews and other documents without primary scientific contributions were also excluded.

After applying the eligibility criteria, the studies were classified into three categories:

- Included: studies that examine KOS or KO foundations as the central focus in relation to AI, addressing challenges, requirements, transformations, or opportunities for development.
- Background literature: studies that contribute to the understanding of technologies, applications, interoperability, ontologies, taxonomies, or application domains related to KOS, but do not directly address the analytical focus of this study.
- Excluded: studies outside the scope of the review, false positives, publications in which knowledge organization was used with a different meaning (e.g., cognition, knowledge management, or software tools), and documents without primary scientific contributions.

This classification provided a transparent basis for distinguishing studies incorporated into the analytical corpus from those used only as theoretical background.

Of the 39 documents initially retrieved, 20 were examined in full. Thirteen of these composed the analytical corpus used for the results, discussion, and development of the conceptual framework. The remaining studies were either retained as theoretical background or excluded according to the eligibility criteria.

The included studies were analyzed using two analytical matrices developed for this research. The first recorded the following elements: study identification (author and year), type of KOS, function in AI, and main contribution. The second recorded: identified challenge, evidence extracted from the studies, potential contribution of faceted structures, and corresponding faceted properties.

The comparative analysis identified recurring challenges for KOS in AI-mediated environments, including semantic interoperability, explainability, scalability, semantic integration, knowledge governance, and continuous evolution.

In the final stage, these challenges were interpreted in light of the classical KO literature on faceted structures. This conceptual synthesis constituted an interpretative stage distinct from the integrative literature review, relating the empirically identified challenges to the structural properties described in the FCT literature. This articulation supported the development of a conceptual framework that interprets faceted structures as semantic infrastructures capable of addressing the main challenges KOS face in AI-mediated environments.

4. Results

The analysis focused on studies with full-text access, which constituted the review's analytical corpus. As described in the methodology, 39 documents were initially retrieved, of which 20 were examined in full after applying the eligibility criteria. Thirteen studies composed the analytical corpus of this research. The remaining studies were either retained as theoretical background or excluded according to the eligibility protocol.

Table 1 summarizes the main characteristics of the studies included in the analytical corpus, highlighting the diversity of KOS investigated, the functions assigned to these systems in AI-mediated environments, and each study's main contribution to understanding the interface between KO and A

Table 2. Characteristics of the studies included in the analytical corpus

Yea r	Author	KOS	Function in AI	Main contribution
2021	Urbieta et al.	Ontology	Semantic infrastructures	Integrates multiple taxonomies and improves interoperability for labeling and testing.
2020	Gomes & Barros	Ontology (FOAF)	Semantic mediation	Shows that bias is inherent to KOS and proposes the use of AI and machine learning to recognize multiple perspectives and support more contextualized information retrieval.
2019	Baracho et al.	Ontology	Semantic infrastructures	Proposes an ontology for smart cities, buildings, and living environments to integrate heterogeneous systems, support interoperability, and facilitate AI applications.
2026	Hjørland	Conceptual KOS	Semantic foundation for KR in AI	Reinterprets semantic primitives and compositionality as epistemological foundations for KOS used in AI.
2025	Gao et al.	Knowledge Graph	Structured knowledge base for Retrieval-Augmented Generation (RAG) agents	Integrates Knowledge Graphs and vector retrieval to produce more accurate, interpretable, and traceable responses in educational systems.
2024	Yuan et al.	ISO-based theoretical KOS model	Semantic foundation for ontologies, Knowledge Graphs, and AI	Integrates KO theories and international standards to model knowledge in an interoperable and computationally processable way.
2024	Bonacin et al.	Biomedical ontologies, international terminologies, and OpenEHR	Semantic infrastructures for interoperability and AI applications in Electronic Health Records (EHR)	Develops the BioFrame framework by integrating OpenEHR and international KOS to promote information model reuse, semantic standardization, and interoperability in Electronic Health Records.
2026	Jia et al.	Chinese Library Classification (CLC)	Classification structure for evaluating LLMs (DeepSeek-v3 and ChatGPT-4o)	Shows that LLMs perform well in general categories but present limitations in culturally specific and fine-grained classifications, highlighting the need for human–AI collaboration and further development of KOS.

2022	Rogushina & Grishanova	Ontologies, SKOS, taxonomies, Semantic MediaWiki	Semantic infrastructures for knowledge-based intelligent systems	Examines how KOS support knowledge representation, semantic retrieval, and the scalability of knowledge-based intelligent systems.
2025	Thellefsen & Friedman	Domain analysis, ontologies, taxonomies, controlled vocabularies	Epistemological foundation for knowledge-based AI	Proposes a sociotechnical framework based on Domain Analysis to support AI systems that are more contextualized, interpretable, and epistemically responsible.
2026	Azeroual	Knowledge Graphs, knowledge categories, semantic interoperability	Contextual knowledge representation and negotiation during user interaction	Proposes Dialogic Artificial Intelligence (DAI), a model that uses semantic structures to adapt KR dynamically according to context and users' epistemological preferences.
2025	Maculan & Aganette	Interoperable faceted taxonomy (TAFNAVEGA), SKOS, OWL, CERIF	Interoperable controlled vocabulary for integration with Knowledge Graphs, the Semantic Web, and AI applications	Proposes the reformulation of a faceted taxonomy into an interoperable semantic vocabulary aligned with KO, Semantic Web standards, and AI infrastructures.
2024	Moura	Thesaurus (COEXISTENCE – Thesaurus of Intersectionality and Decolonial Issues)	Mitigating informational bias and supporting intelligent systems through a KOS grounded in intersectional and decolonial perspectives	Proposes an experimental thesaurus construction model that incorporates intersectionality, decoloniality, and epistemological pluralism as structuring principles of KOS.

The studies show a progressive diversification of KOS types employed in AI-mediated environments. Publications between 2019 and 2021 focus primarily on ontologies used as semantic infrastructures for interoperability, system integration, and conceptual standardization (Baracho et al., 2019; Gomes & Barros, 2020; Urbieta et al., 2021). From 2022 onwards, a broader range of semantic structures is observed, including Knowledge Graphs, models based on international standards, interoperable taxonomies, thesauri, and other forms of KR designed to support intelligent systems, Retrieval-Augmented Generation (RAG), Large Language Models (LLMs), and generative AI applications.

This diversification is also reflected in the functions assigned to KOS. Earlier studies emphasize their use for semantic representation and integration, particularly through ontologies supporting interoperability across information systems (Baracho et al., 2019; Urbieta et al., 2021). More recent studies describe KOS as infrastructures that support contextualized information retrieval (Gao et al., 2025), conceptual modeling for AI applications (Yuan et al., 2024), explainability and epistemic responsibility (Thellefsen & Friedman, 2025), knowledge governance and dynamic knowledge adaptation (Azeroual, 2026), and the mitigation of bias through the incorporation of ethical guarantees into KR (Moura, 2024). Together, these studies indicate that KOS are no longer viewed solely as mechanisms for semantic representation and integration but also as structural components of AI ecosystems.

Taken together, the studies reveal not only a diversification of the types of KOS employed in AI-mediated environments but also a change in the functions attributed to these systems. This development makes it possible to identify recurring challenges, summarized in Table 2. It should be noted that the relationships established between these challenges and the properties of faceted structures were not extracted directly from the studies included in the review. Rather, they were developed by the authors through a conceptual synthesis grounded in the classical KO literature.

Table 2. Challenges identified for KOS in AI-mediated environments and their interpretation through the properties of faceted structures

Challenge identified in the corpus	Evidence from the studies	Potential contribution of faceted structures	Faceted properties
Semantic interoperability	The studies converge on the need to integrate data, metadata, ontologies, Knowledge Graphs, and heterogeneous systems to support information reuse and semantic exchange.	Support the articulation of concepts across different domains through explicit semantic structures that enable interoperability.	Explicit semantic relationships; faceted synthesis; semantic interoperability
Explainability	The increasing use of LLMs and AI systems highlights the need to represent concepts, relationships, and classification criteria explicitly, making decision processes interpretable and auditable.	Make the conceptual structure underlying KO explicit, supporting transparency and traceability.	Explicit conceptual structure; hierarchical relationships; associative relationships
Scalability	The studies identify the need to accommodate new concepts, knowledge domains, and increasing volumes of information while preserving semantic consistency.	Support the progressive expansion of KOS while preserving structural consistency.	Hospitality; modularity
Semantic integration	The studies emphasize the integration of multiple information sources, conceptual models, vocabularies, and knowledge representations in intelligent environments.	Support the articulation of multiple conceptual perspectives and different levels of representation.	Multidimensionality; associative relationships
Knowledge governance	Several studies emphasize data quality, terminological standardization, conceptual control, bias mitigation, and responsibility in KOS development.	Support conceptual control, terminological consistency, and the governance of KR.	Terminological control; conceptual warrant; semantic governance
Continuous evolution	The evolution of knowledge domains, AI technologies, and users' needs requires continuous	Support the incorporation of new concepts and the reorganization of	Structural flexibility; hospitality

	mechanisms for reviewing, expanding, and adapting KOS.	conceptual structures while preserving system stability.	

Table 2 synthesizes the main challenges identified in the recent literature concerning KOS in AI-mediated environments and their interpretation through the properties of faceted structures. The analysis shows that, in addition to requirements traditionally associated with KOS, such as semantic interoperability, system integration, and scalability, recent studies increasingly emphasize explainability, the governance of KR, the continuous evolution of vocabularies, and the mitigation of conceptual and cultural bias.

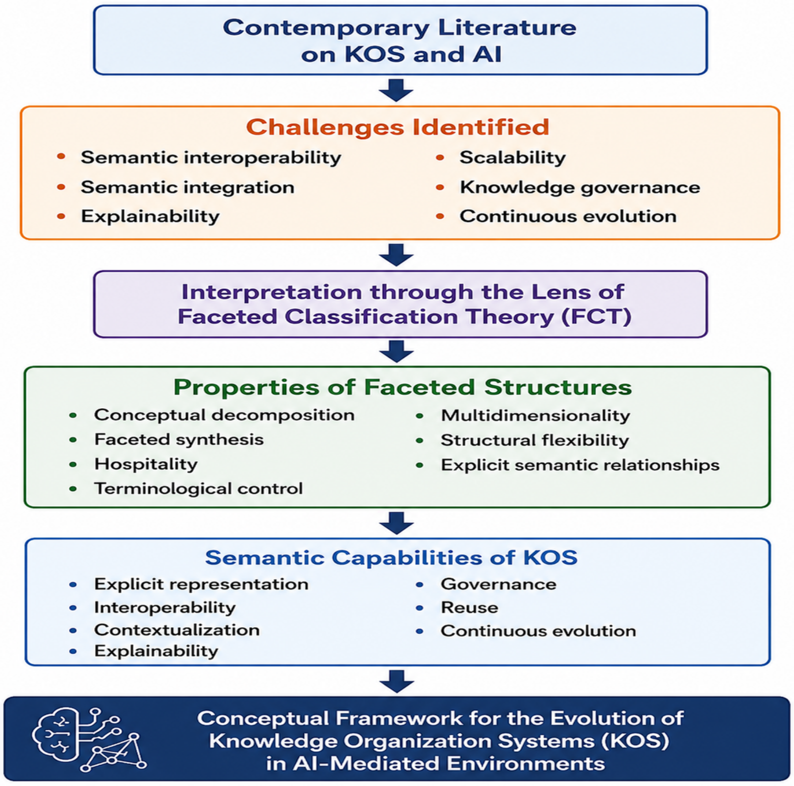
The synthesis also indicates that these challenges can be interpreted in terms of structural properties established by FCT. Explicit semantic relationships, faceted synthesis, hospitality, multidimensionality, terminological control, and structural flexibility provide analytical categories that relate the challenges identified in the contemporary literature to the classical foundations of KO. It should be emphasized that this articulation was not extracted directly from the studies included in the review but was developed by the authors through a conceptual synthesis grounded in the KO literature.

This interpretation provided the basis for developing the conceptual framework presented in the following section, in which the challenges identified in the review are related to the properties of faceted structures and to the semantic capabilities required of KOS in AI-mediated environments.

4.1. Conceptual Framework for the Evolution of KOS in AI-Mediated Environments

The synthesis of the studies included in the review identified a set of recurring challenges faced by KOS in AI-mediated environments. Interpreting these challenges from the perspective of FCT showed that several classical properties of faceted structures remain conceptually compatible with contemporary requirements for semantic interoperability, the integration of different knowledge representations, explainability, knowledge governance, scalability, and the continuous evolution of KOS. Based on this conceptual synthesis, the conceptual framework presented in Figure 1 was developed.

Figure 1. Conceptual Framework for the Evolution of KOS in AI-Mediated Environments



Note. Prepare b the authors and graphically created using ChatGPT-5 (June 2026). The framework synthesizes the findings of the integrative literature review by relating the challenges identified in the contemporary literature to the properties of faceted structures and to the semantic capabilities that these properties may provide for the evolution of KOS in AI-mediated environments.

The conceptual framework represents the analytical pathway developed in this study by articulating three complementary levels of analysis: (i) the challenges identified in the literature on KOS and AI; (ii) their interpretation through the structural properties of FCT; and (iii) the semantic capabilities that these properties may provide for the evolution of KOS in digital environments. In doing so, it establishes a conceptual link between the evidence identified in the integrative literature review and the established foundations of KO.

Unlike prescriptive frameworks intended to guide the development of AI systems, the proposed framework is analytical and interpretative. It neither introduces new faceted properties nor proposes a new model of KOS. Instead, it makes explicit the conceptual relationships between the challenges identified in the literature and structural principles established by FCT. As such, it provides a conceptual basis for future investigations into the evolution of KOS in AI-mediated environments.

The implications of this framework for the evolution of KOS are discussed in the following section.

5. Discussion

The findings of this review support the interpretation that KOS are evolving from traditional mechanisms for document organization into semantic infrastructures that provide interoperability, contextualization, governance, and explainability for contemporary AI systems. This evolution reflects not merely the incorporation of new technologies into KOS but an expansion of their conceptual role, progressively positioning them as knowledge infrastructures that underpin intelligent environments. The conceptual framework developed in this study provides the basis for discussing this transformation from three complementary perspectives.

The first perspective concerns the conceptual evolution of the role of KOS in AI-mediated environments. Earlier studies (Baracho et al., 2019; Gomes & Barros, 2020; Urbieta et al., 2021) primarily describe KOS as mechanisms for semantic interoperability, system integration, and conceptual standardization. In this context, AI appears as an indirect beneficiary of these structures, with ontologies and other KOS supporting the organization, integration, and interoperability of information used by intelligent applications.

More recent studies, however, indicate a different role. Yuan et al. (2024), Gao et al. 2025), Jia et al. (2026), Azeroual (2026), and Maculan and Aganette (2025) describe KOS not only as organizational and KR mechanisms but also as the semantic infrastructures upon which LLMs, Knowledge Graphs, RAG agents, and dialogic AI systems operate. Taken together, these studies reveal a conceptual evolution in which KOS moves beyond document organization and a merely interoperability-oriented role to support KR, reasoning, and governance in AI-mediated environments.

The second perspective highlights a shift from a predominantly technological view toward an epistemological understanding of KO. The studies consistently indicate that the performance of AI applications depends not only on advances in computational models but also on the quality of the conceptual structures that support them.

Yuan et al. (2024) describe AI applications as relying on a structured conceptual chain in which concepts, characteristics, metadata, ontologies, and Knowledge Graphs represent successive levels of computational knowledge representation. Bonacin et al. (2024) complement this perspective by showing how such conceptual structures can be operationalized through knowledge engineering architectures designed for interoperability and semantic reuse.

The discussion extends beyond computational architecture. Hjørland (2026) questions the notion of semantic representation adopted by LLMs, arguing that intelligent systems require explicit epistemological foundations to represent knowledge consistently. Likewise, Thellefsen and Friedman (2025) argue that classification is not merely a statistical operation but an interpretative, historical, and social practice shaped by knowledge communities, disciplinary contexts, and processes of conceptual validation.

Collectively, these studies reposition KO from a field that provides formal structures for AI applications to one that offers epistemological foundations for their development.

Consequently, the quality of AI systems depends not only on computational performance but also on the conceptual, semantic, and epistemological quality of the KOS they rely on.

The third perspective shows that the evolution of KOS expands not only their technical functions but also the responsibilities attributed to them. Whereas earlier studies emphasized interoperability, information retrieval, and semantic integration (Baracho et al., 2019; Gomes & Barros, 2020; Urbieta et al., 2021), more recent research (Yuan et al., 2024; Gao et al., 2025; Maculan & Aganette, 2025) incorporates concerns related to explainability, knowledge governance, epistemic responsibility, and bias mitigation.

This broader role is illustrated from different perspectives. Jia et al. (2026) demonstrate experimentally that LLM performance depends on the granularity, conceptual organization, and cultural adequacy of the classification system employed. Moura (2024) argues that KOS themselves should incorporate ethical, cultural, and community-based guarantees to reduce the reproduction of historical inequalities in intelligent systems.

Similarly, Azeroual (2026) proposes a dialogic AI architecture grounded in the continuous negotiation of meaning between users and systems, whereas Thellefsen and Friedman (2025) emphasize that context, domain analysis, and communities of practice are essential to developing epistemically responsible AI systems. Together, these studies indicate that KOS are no longer limited to organizing information but increasingly contribute to knowledge governance, semantic contextualization, transparency, explainability, and epistemic responsibility in AI.

Taken together, these three perspectives indicate that the evolution of KOS results less from replacing their conceptual foundations than from expanding the range of functions they perform in AI-mediated environments. This interpretation provides the basis for examining the remaining gaps in the literature and for assessing the present study's contribution to connecting the theoretical tradition of KO with the contemporary demands of AI.

5.1. Limitations of the Analyzed Studies

The critical analysis of the studies reveals important advances in the convergence between KOS and AI while also highlighting a recurring limitation: their contributions remain largely fragmented. Overall, the studies emphasize specific dimensions of the problem—technological, architectural, or epistemological—without explicitly integrating these perspectives into a coherent conceptual framework.

Studies concerned with the development of semantic infrastructures (Baracho et al., 2019; Urbieta et al., 2021; Bonacin et al., 2024) demonstrate the potential of ontologies and semantic models to promote interoperability, integration, and information reuse. Their primary focus, however, remains the architecture and implementation of these solutions. Similarly, studies examining the use of KOS in AI applications (Gao et al., 2025; Jia et al., 2026) report improvements in information retrieval, explainability, and language model performance, while devoting comparatively less attention to the conceptual evolution of KOS itself.

From a different perspective, Hjørland (2026) repositions the debate over the epistemological foundations of KO, arguing that conceptual representation depends on disciplinary and historical contexts. This concern is shared by Gomes and Barros (2020), Thellefsen and Friedman (2025), Azeroual (2026), and Moura (2024), who emphasize context, epistemological pluralism, interpretative responsibility, epistemic justice, and knowledge governance. Yuan et al. (2024) and Rogushina and Grishanova (2022) occupy an intermediate position, demonstrating that the quality of AI systems depends directly on the quality of conceptual representation and semantic infrastructure. Nevertheless, these studies do not explicitly relate these contemporary requirements to the structural principles established by FCT.

Within this body of literature, Maculan and Aganette (2025) represent a distinctive contribution by shifting the focus from the use of KOS in AI applications to the conceptual evolution of KOS itself. By proposing to transform a faceted taxonomy into an interoperable controlled vocabulary based on SKOS, OWL, and CERIF, the study explicitly connects FCT to the requirements of the Semantic Web and AI. However, the proposal remains at a conceptual and methodological level and has not yet been empirically validated in operational environments.

Taken together, the studies consistently identify semantic interoperability, explainability, contextualization, knowledge governance, scalability, and continuous evolution as key requirements for KOS in AI-mediated environments. However, these requirements are rarely interpreted within the theoretical tradition of KO, which originally developed principles for addressing problems of this nature.

This gap defines the main contribution of the present study. The integrative literature review indicates that many challenges currently attributed to AI correspond, to a large extent, to problems of conceptual organization, semantic representation, and the evolution of KOS. From this perspective, principles such as conceptual decomposition, faceted synthesis, hospitality, terminological control, multidimensionality, explicit semantic relationships, and structural flexibility should be understood not merely as characteristics of classification systems but as conceptual foundations for addressing semantic interoperability, the integration of heterogeneous knowledge representations, explainability, knowledge governance, scalability, and the continuous evolution of KOS.

Accordingly, the principal contribution of this study is not to propose new principles for KOS but to demonstrate that many contemporary AI-related challenges can be reinterpreted as problems of conceptual organization for which FCT already provides relevant structural principles. From this perspective, the evolution of KOS in AI-mediated environments depends less on replacing their conceptual foundations than on their continuous reinterpretation and development.

5.2. FCT as a Conceptual Foundation for KOS in AI-Mediated Environments

The interpretative synthesis developed in this study indicates that the contemporary challenges faced by KOS—semantic interoperability, the integration of heterogeneous knowledge representations, explainability, knowledge governance, scalability, and continuous evolution—converge with structural properties established by FCT. Although these challenges are commonly discussed in the literature as consequences of advances in AI and LLM, the analysis presented here suggests that they correspond, to a large extent, to problems of conceptual organization and KR that have traditionally been addressed within KO.

From this perspective, the contemporary relevance of FCT does not derive from the incorporation of new principles but from the reinterpretation of its established foundations in light of technological and epistemological changes in digital environments. Properties such as conceptual decomposition, faceted synthesis, hospitality, terminological control, multidimensionality, explicit semantic relationships, and structural flexibility should therefore be understood not merely as characteristics of classification systems but as structural principles for organizing KOS as semantic infrastructures that support contemporary AI applications.

This interpretation expands the scope of FCT without modifying its theoretical foundations. Rather than remaining restricted to bibliographic classification or traditional information organization systems, the theory provides a conceptual basis for understanding problems related to knowledge representation, semantic integration, contextualization, interoperability, knowledge governance, and the continuous evolution of knowledge in AI-mediated environments.

The studies analyzed consistently point to the need for semantic structures that are explicit, interoperable, contextualized, and capable of continuous evolution. However, these requirements are generally discussed in terms of specific technological solutions—such as ontologies, Knowledge Graphs, interoperable taxonomies, semantic architectures, and governance models—without recognizing that many of these demands can be interpreted as contemporary expressions of principles already established by FCT.

The principal contribution of the present study is to make this conceptual relationship explicit. Rather than proposing new principles for KOS, it demonstrates that many challenges currently attributed to AI can be reinterpreted as problems of conceptual organization for which FCT already provides relevant structural principles. Accordingly, FCT should be understood as both a historical contribution to KO and a conceptual foundation for guiding the evolution of KOS in AI-mediated environments, thereby supporting the development of semantic infrastructures that are interoperable, explainable, contextualized, and epistemologically grounded.

6. Conclusions

This study examined how recent literature characterizes the challenges faced by KOS in AI-mediated environments and interpreted these challenges through the lens of faceted structures. By combining an integrative literature review with a conceptual synthesis, the study showed that challenges such as semantic interoperability, the integration of heterogeneous knowledge representations, explainability, knowledge governance, scalability, and continuous evolution can be understood as problems of conceptual organization for which FCT already provides relevant structural principles. Based on this interpretation, a conceptual framework was developed to relate these challenges to the properties of faceted structures and to support the interpretation of KOS evolution in AI-mediated environments.

The principal contribution of this study is to demonstrate that the growing convergence between KOS and AI can be understood through the evolution of principles already established within KO. By reinterpreting classical properties of faceted structures as conceptual foundations for semantic interoperability, contextualization, explainability, governance, conceptual organization, and the continuous evolution of KOS, the study strengthens the dialogue between the theoretical tradition of KO and the contemporary requirements of intelligent systems. In doing so, it argues that the contemporary relevance of FCT lies in its capacity to provide conceptual foundations for addressing emerging AI-related challenges, reaffirming its role in the evolution of KOS.

The study has three main limitations. First, the literature review was conducted using a single bibliographic database. Second, although all eligible studies were considered during the characterization of the literature, seven could not be analyzed in full because their complete texts were unavailable. Consequently, the detailed extraction of evidence and the conceptual synthesis were based only on studies with full-text access. Third, as a theoretical-conceptual study, the proposed framework has not yet been empirically validated and therefore represents an interpretation grounded in the literature analyzed.

Future research should expand the corpus by incorporating additional databases and search strategies and conduct empirical studies to evaluate the proposed framework across different types of KOS. In particular, its application to taxonomies, thesauri, ontologies, classification systems, and Knowledge Graphs in environments involving LLMs, RAG, intelligent agents, and other knowledge-based AI applications may help assess its explanatory capacity, refine its conceptual components, and extend its applicability to real-world contexts.

More than demonstrating that AI introduces new challenges for KOS, this study argues that many of these challenges correspond to problems of conceptual organization that have long been addressed within FCT. Its contribution, therefore, lies not in proposing a new theory for KOS in AI-mediated environments but in reinterpreting established KO principles as conceptual foundations for their evolution. The conceptual framework synthesizes this interpretation by relating contemporary challenges, faceted properties, and the semantic capabilities required of KOS in AI-mediated environments.

Taken together, the findings suggest that the future evolution of KOS in AI-mediated environments may depend less on replacing their conceptual foundations than on reinterpreting them to meet the demands of contemporary digital ecosystems. From this perspective, FCT is reaffirmed not only as a historical contribution to KO but also as a conceptual foundation for understanding the evolution of KOS as semantic infrastructures capable of supporting contemporary AI applications.

Conflict of Interest Declaration

The author declares that there are no conflicts of interest related to this study. No professional, academic, or financial relationships could be interpreted as influencing the research, analysis, or conclusions presented in this article.

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