A Novel Method for Ranking Knowledge Organization Systems (KOSs) Based on Cognition States

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Abstract: The purpose of this article is to delineate the process of evolution of knowledge organization systems (KOSs) through identification of principles of unity such as internal and external unity in organizing the structure of KOSs to achieve content storage and retrieval purposes and to explain a novel method used in ranking of KOSs by proposing the principle of rank unity. Different types of KOSs which are addressed in this article include dictionaries, Roget's thesaurus, thesauri, micro, macro, and meta-thesaurus, ontologies, and lower, middle, and upper-level ontologies. This article relied on dialectic models to clarify the ideas in Kant's knowledge theory. This is done by identifying logical relationships between categories (i.e., Thesis, antithesis, and synthesis) in the creation of data, information, and knowledge in the human mind. The Analysis has adapted a historical methodology, more specifically a documentary method, as its reasoning process to propose a conceptual model for ranking KOSs. The study endeavors to explain the main elements of data, information, and knowledge along with engineering mechanisms such as data, information, and knowledge engineering in developing the structure of KOSs and also aims to clarify their influence on content storage and retrieval performance. KOSs have followed related principles of order to achieve an internal order, which could be examined by analyzing the principle of internal unity in knowledge organizations. The principle of external unity leads us to the necessity of compatibility and interoperability between different types of KOSs to achieve semantic harmonization in increasing the performance of content storage and retrieval. Upon introduction of the principle of rank unity, a ranking method of KOSs utilizing cognition states as criteria could be considered to determine the position of each knowledge organization with respect to others. The related criteria of the principle of rank unity- cognition states- are derived from Immanuel Kant's epistemology. The research results showed that KOSs, while having defined positions in cognition states, specific principles of order, related operational mechanisms, and related principles of unity in achieving their specific purposes, have benefited from the developmental experiences of previous KOSs, and further, their developmental processes owe to the experiences and methods of their previous generations.

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1.0 Introduction

All KOSs stem from the same root as evidenced by their common goal (Amirhosseini 2021) of creating knowledge organizations and tools (National Information Standards Organization 2003) for content storage and retrieval. In other words, knowledge organization (Hjørland 2008; 2016) or KOSs (Mazzocchi 2018) is a generic term used for referring to a wide range of items (Zeng 2008; Mazzocchi 2018) such as lists, authority files, gazetteers, dictionaries, encyclopædias, synonym rings, taxonomies, folksonomies, classification schemes, subject headings, thesauri, and ontologies (Hjørland 2008) in which, notably, their structures are not simply a repetition of the past (Zeng 2008). KOSs attempt to model the underlying semantic structure of a domain for retrieval (Tudhope and Nielsen 2006). Thus, there are similarities and differences between various systems of knowledge organizations (Kless et al. 2014; Hjørland 2015) regarding their common goal and their specific purposes. They are similar in applying a kind of order to make content available (i.e., their goal). On the other hand, they differ in operational methods and techniques which create the specific order in their structure as well as specific mechanisms which improve the performance of content storage and retrieval system for accessing specific forms of contents (i.e., their purpose) (Amirhosseini 2021). In other words, all KOSs use particular mechanisms to create order among their internal items (such as terms, descriptors or concepts) to make them accessible This is their main and common goal. On the other hand, such mechanisms and items usually differ from one KOS to another based on their specific purposes. For example, dictionaries sort words alphabetically by relying on the data engineering mechanism, and information engineering is a mechanism for creating semantic order between descriptors in the semantic network of thesauri. Thus, although all types of KOSs are under the umbrella concept of the "Knowledge Organization System" based on their overall goals, the differences between them arise from the specific purpose of each type of KOS.

The purpose of this article is to study the process of evolution of KOSs such as dictionaries, Roget's Thesaurus, thesaurus, ontology and their types from the perspective of their desired main elements, the engineering mechanisms used to organize their main elements, their desired principles of order, their expected results and specific function, as well as the principles of unity utilized in their development. In analysing the basic or main elements in KOSs that include data, information, and knowledge, the related appropriate engineering techniques such as data, information, and knowledge engineering mechanisms are identified. The principles of order like alphabetical and semantic order which create an internal coherence and integration regarding the desired main elements in each KOS are also identified. In addition, the expected results and specific functions from the mentioned KOSs are explained during the discussion of the evolution of such KOSs. Furthermore, the principles of unity are analysed through explanation of the principles of internal and external unity in the evolutionary process of KOSs. Finally, the principle of rank unity is introduced to present a ranking of KOS according to cognition states as criteria. In this paper, the historical context of the evolution of KOSs, from the simplest to the most complex KOSs, is examined by adapting a historical method. Moreover, this article relies on dialectic models as its method of research to clarify the ideas in Kant's knowledge theory by identifying logical relationships between the categories (i.e., thesis, antithesis, and synthesis) in creation of data, information, and knowledge in the human mind. In addition, a documentary method was adapted to identify the position of KOSs in the cognition states (i.e. data, information and knowledge) and explain their related engineering mechanisms and their principles of unity in order to provide a conceptual model for ranking KOSs. Finally, the research results have been synthesized to provide a clear picture of the status, position, characteristics, and features of KOSs.

One of the oldest and simplest KOSs is a dictionary, as a system with alphabetical order of terms arranged along with information about their meanings (Merriam-Webster 2021), which the history of its compiling in the modern period dates back to 1600 AD (Landau 2001). Robert Cawdrey's *Table Alphabeticall* published in 1604, produced the first dictionary giving definitions of English words in English (Simpson 2007). In 1852, Roget introduced a multi-dimensional approach to vocabulary organization which is not a simple alphabetical list of words (Foskett 1980) but a way of finding specific words, phrases, and idioms that express a concept or semantic domain to help express the ideas of the writers (Chatterjee 1990). Roget's profound influence is still seen (Amirhosseini 2008), especially in information storage and retrieval (Foskett 1980; Chatterjee 1990). As early as 1951 (Stevens 1968; Foskett 1980), Hans Peter Luhn was acknowledged as the first person to discuss the thesaurus concept that was influenced by Roget (Foskett 1980) and the structure of faceted classification schemes (Estabrook and Haider 2017). Various types of thesauri such as micro-, macro-, and metathesaurus have developed to achieve the integration and compatibility between specialized thesauri and other controlled vocabularies in the 1980s (Amirhosseini 2008; 2021). The modern knowledge organization system that is known as the ontology (De Silva 2008) which has been developed to create highly understandable and applicable granular semantic relations between concepts (Garshol and Naito 2004) through a shared conceptualization (Gruber 1993a; 1993b) has been compiled during the second half of the 20th century (Liu and Ozsu 2008). The incompatibility between specialized ontologies (Mohapatra and Mohapatra 2014) has been resolved to achieve semantic harmonization (Jin 2018) and semantic interoperability to integrate heterogeneous conceptual relations (Shen and Chen 2012) by developing various types of ontologies such as upper, middle (Eklöf and Martenson 2006), and lower level (Bergman 2010) ontologies in the late 20th and early 21st centuries (Mascardi, Locoro and Rosso 2008).

1.1 Operational definition

In this section, the fundamental concepts and key terms utilized in analysing the themes and topics discussed in the article, especially the concepts related to the principles of unity and cognition states used to propose the ranking method of KOSs, are operationally defined.

1.1.1 The principle of unity

A semantic network is a structure that represent knowledge in an allied way as a pattern of interconnected nodes and arcs (i.e., conceptual relations) (Sowa 1991) and denotes something in the desired domain (Schubert 1991) in a major group of KOSs. Here, the principle of unity expresses the quality of the unified structure of the semantic network in KOSs. However, the principle of unity is applicable for a variety of KOSs that have an internal order between the elements that intend to establish order between them.

1.1.2 The principle of internal unity

The quality and essence of the internal order between the elements, amongst which the KOS intends to establish order, is explained through internal unity. In other words, each type of KOS has a unified and coherent internal structure that is achieved by relying on a specific method(s), such as alphabetical or semantic order, as well as specific mechanisms and standards that create convergence between the internal elements, such as terms, descriptors, and concepts. This status or quality can be described and explained using the principle of internal unity.

1.1.3 The principle of external unity

The creation of interoperability between KOSs in a specific domain, or various domains such as specialized thesauri or ontologies, can be fulfilled by relying on theoretical foundations, such as the theory of the unity of science, integrative levels, structural unity, and conceptual unity as well as applying specific methods, mechanisms, and standards to achieve semantic harmonization to increase the performance of content storage and retrieval. This process results in the development of the new generation of KOSs such as micro-, macro-, and meta-thesauri or upper, middle, and lower-level ontologies that encompass specialized thesauri and ontologies respectively. This status or quality can be described and explained through the principle of external unity. However, establishment of the coordination and compatibility between different types of KOSs (such as authority files, dictionaries, encyclopædias, taxonomies, folksonomies, classification schemes, subject headings, thesauri, and ontologies) to increase the performance of content storage and retrieval indicates the concept of the principle of external unity.

1.1.4 The unity of science

This theory is based on a general hypothesis that all sciences will be finally reduced to the fundamental physical science, and the level of complexity of the sciences increases from physics to chemistry, from chemistry to biology, and finally from biology to psychology (Oppenheim and Putnam 1958). These different levels of sciences can be represented as a whole and a partial relationship (Eronen 2015). Unity of science, as a reductionism theory, has been used to organize knowledge in a hierarchical order to achieve a unified semantic system in the knowledge representation of KOSs, especially in interoperability between the KOSs (Amirhosseini 2021).

1.1.5 Integrative levels

The theory of unity of science consists of points that are in common with the theory of integrative levels regarding some generalizations or laws (Feibleman 1954) that clarify the interrelations among various disciplines of sciences. The term “integrative levels”, which was coined by Needham (1937), focuses on the classifications of sciences to interrelate different domains of human knowledge according to a hierarchical order. This theory has been applied in analysing the structure of KOSs in the development of classifications, thesauri, and formal ontologies (Kleineberg 2017), especially in the creation of the interoperability between KOSs.

1.1.6 Structural unity

Structural unity explains the concepts in the theory of unity of science and its related theory, integrative levels, more accurately (Craig 1998) and allows for a theorization of a more stylistic and structural unity of science (Morrison 2000). This is especially useful in representing conceptual schemes (UIA 1995) based on a hierarchical order (Rescher 1997) and associated relations. Structural unity, in fact, is closely related to the theory of unity of science and integrative levels. Structural unity and its related standards (i.e., ISO 25964-2 2013 and BS 8723 2005-8) and techniques such as mapping techniques have played a great role in the construction of KOSs, especially in the integration of specialized thesauri (Kuznetsov 1999) that result in huge gains for clarity, efficiency, economies of scale, interoperability, etc. (Amirhosseini 2021).

1.1.7 Conceptual unity

Structural unity focused on developing convergence of specific thesauri to develop micro-, macro- and meta-thesauri, while preserving the structure of previous semantic, hierarchical and associative relations– which were too general in nature to provide a sufficiently granular representation of the relational concepts (Amirhosseini 2021). Conceptual unity which encompasses structural unity (Wei 2015) focuses on logical species and their instances which can be represented through precise and sufficiently granular semantic relationships based on a shared conceptualization (Hopkins

2017) in an ontological perspective. Conceptual unity as an area related to the unity of science focuses on the development of the semantic interoperability to integrate heterogeneous conceptual relations (Shen and Chen 2012). In this case, conceptual unity applies some techniques such as merging to support the communication and harmonization of conceptual systems (Jin 2018) of specialized ontologies to develop novel KOSs such as lower, middle and higher-level ontologies (Amirhosseini 2021).

1.1.8 Cognition states

In this context, the cognition states are examined from Kant's epistemological point of view (Kant 1781). Kant believed that "our knowledge begins with experience", hence, cognition states begin from experience (Amirhosseini 2010) and the sense of phenomena (empirical objects of possible experience) (Kukla 2011). Cognition states have two main stages. In the first stage, phenomena are placed in the human mind through the five human senses in the form of time and space, which results in forming mind data. In the second stage, mind data is perceived by its categorization into mind categories (i.e., quality, quantity, relation and modality), which is the origin of information in the human mind. Knowledge creation in the human mind is the result of combination and integration of information into mind categories. Therefore, cognition states in the human mind include data, information and knowledge.

1.1.9 Semantic relations vs. conceptual relations

Semantic and conceptual relations can be explained in the context of semantic and conceptual representations. There are different perspectives on semantic and conceptual representations. Semantic and conceptual representations are identified as similar things or, in other words, semantic representations are a kind of conceptual representation. However, semantic and conceptual representations are two different types of representations. Semantic representations are those mental structures that are involved in the representation of word meaning. On the other hand, conceptual representations are involved in the representation of a concept or a combination of concepts (Martínez-Manrique 2010) in the mind and are called conceptual relations (Khoo and Na 2006). Here, semantic relations represent meaning of words in thesauri, and conceptual relations represent the concepts and their relations in ontologies.

2.0 Engineering mechanisms in development of KOSs

The words engine and ingenious are derived from the same Latin root "ingenerare", which means "to create" or "to contrive". Engineering is based principally on some branches of science such as system analysis. Engineers must solve problems as they arise, and their solutions must satisfy the conflicting requirements of various kinds of systems. One function of engineering focuses on development engineering which applies research results to useful purposes regarding the creative application of new knowledge (Smith 2021). KOSs utilize development engineering in their structure and functions to satisfy their specific purposes. It follows that KOSs use engineering techniques and mechanisms to support the organization of knowledge and information to make their management and retrieval easier (Mazzocchi 2018). Knowledge organization comprises of two main areas: Knowledge Organization Processes (KOPs) and KOS as a tool (Broughton et al. 2005; Hjørland 2008) to manage information and knowledge based on engineering processes and techniques (Hackathorn and Karimi 1988) through information engineering (Teixeira, Freitas Duarte and Laurindo 2014) and knowledge engineering (Otieno 2015). Therefore, engineering processes and techniques play great roles in developing KOSs and fulfilling their purposes (Otieno 2015) to generate, organize, distribute, analyze, (Godsill 2018), use, transit, and transform data, information, and knowledge (Freitas, Frederico and Córdova 2016). In addition to the role of engineering in developing KOSs and their purposes, the engineering mechanisms in development of KOSs are based on the formats and forms of the main elements (data, information, and knowledge) which they intend to organize or manage. This section attempts to explain the related mechanisms and elements in the following types of KOSs.

2.1 Engineering mechanism in dictionaries

Dictionary is a reference source or a computerized list containing words or data usually arranged alphabetically along with information about their form, pronunciation, function, etymology, meaning, and syntactic and idiomatic uses which operates in information retrieval or word processing (Merriam-Webster 2021) as well as systematizing the descriptive data (Gasparri 2019). In this way, it could be understood that words appear in the dictionary in the role of data. In this case, the data processing mechanism utilized in classical, modern and other types of dictionaries such as data dictionary (Dictionary 2020), which is also called a repository of data including design dictionary, encyclopedia, object-oriented dictionary, and knowledge base (United States Department of the Interior 2008), is data engineering which is responsible for the transportation, transformation, and storage of data (Stratis 2020). Data engineering requires knowing how to derive value from data through knowing how to move and store data in an efficient manner (David 2020) based on the specific order (U.S. Geological Survey (USGS) 2018). Therefore, in processing and storing data or words in dictionaries, the data engineering mechanism has been used to analyse data value by providing systematized descriptive data about them.

2.2 Engineering mechanism in *Roget's Thesaurus*

Despite Putnam's (1970) view on the exaggeration of the idea of forming semantic theory from developmental processes of dictionaries, research results show that the development of dictionaries has led to the formation of the idea of semantic relations between words (Gasparri 2019). The traditional order between terms (i.e., alphabetical order) in dictionaries has evolved into meaning-based relations between words which represent the new idea of semantic order (Amirhosseini 2021). The idea of a semantic order was proposed by Peter Mark Roget in his work *Thesaurus of English Words and Phrases* in 1852. This work is not a simple alphabetical list of words (Foskett 1980) but has a conceptually based structure, where the concepts explained in the entries are used as a basis for relating and grouping of words in different contexts to provide assistance and help in the expression of ideas and literary composition (Arano 2005). Roget described his thesaurus as a system of verbal classification (Roget 1982) which eclipsed a rich tradition of topically based dictionaries (Hüllen 2004). *Roget's Thesaurus* is essentially a reverse dictionary (Merriam-Webster 2021) or semantic dictionary or literary thesaurus (Dextre Clarke 2019) used to organize terms as data based on a classification tree or conceptual hierarchy (Old 2004) that facilitates the expression of ideas (Hüllen, 2004) by retrieving the most appropriate word or phrase to use in a piece of writing (Oxford Learner's Dictionaries 2021). *Roget's Thesaurus* is a classification (Roget 1852) of similar words and phrases, i.e., a collocation or an idiom, which are semantically related to one another and divided into nouns, verbs, adjectives, adverbs and interjections (Jarmasz, 2012). The original system consists of six primary classes: Abstract Relations, Space, Material World, Intellect, Volition, Sentient and Moral Powers. Each class is divided into different sections, and each section contains a number of heads or concept entries. The concept classification system is in fact a taxonomy of ideas used in natural language processing (McHale 1998), machine translation (Masterman 1957; Sparck Jones 1964), and information retrieval (Driscoll 1992; Mandala et al. 1999), automatic classification of text, automatic indexing, word sense disambiguation, semantic classification, computer-based reasoning, content analysis, discourse analysis, and a range of other applications (Old 2004). If we accept that a KOS provides a schema (NKOS Working Group 1998) or framework for organizing and retrieving data, information, and knowledge, (Hjørland 2007; Soergel 2009) especially by applying semantic structures (Zeng 2008) in making a bridge between the user's information need and the available content (Hodge 2000), then *Roget's Thesaurus* is to be considered as a KOS. In this way, the semantic clusters of concepts, phrases or data that appear in the system of hierarchical semantic relations of *Roget's Thesaurus* are in the form of a taxonomy. This taxonomy, due to its capabilities and applications, has been a turning point for constructing future generations of KOSs. Therefore, words or terms in *Roget's Thesaurus*, like dictionaries, play the role of data, and the semantic system linking these terms leads to the transition of the position of this KOS from the data dimension to the information dimension. In this case, both data and information engineering mechanisms are involved in the storage and retrieval processes of data and information in this KOS.

2.3 Engineering mechanisms in thesauri

As early as 1951 (Stevens 1968; Foskett 1980), Hans Peter Luhn was acknowledged as the first person to discuss the thesaurus concept who was influenced by Roget (Foskett 1980). The similarity of the thesaurus concept in Luhn's and Roget's points of view is that both have used semantic relations to make connective relations between terms. On the other hand, in addition to the structural differences between networks of the semantic relations in *Roget's Thesaurus* and Luhn's thesaurus, Luhn's purpose in constructing the hierarchical and associative semantic relations was to apply the semantic network to information storage and retrieval. The thesaurus includes a structure of cross-references between families of notions (Estabrook and Haider 2017) based on creating semantic relations such as hierarchical and associative relations (International Organization for Standardization 2011) which have been used for the organization of information, especially in information storage and retrieval (International Organization for Standardization 2013). Dextre Clarke (2019) states that the essential core of a thesaurus is a collection of concepts represented by terms that are interlinked by semantic relations. This idea, along with the practical and technical aspects of using thesauri, especially in the web environment, led her to suggest that thesauri play a key role in organizing knowledge. This belief is valid because the conceptual content of any KOS, specifically that of a thesaurus, can clearly be remodeled as an RDFS/OWL ontology in the form of SKOS (World Wide Web Consortium 2005), in a way that allows it to play a role in organizing knowledge. However, the field of Library and Information Science and its information organizing tools can be analysed and understood through epistemology debates (Hjørland 2008). This means that regarding the relations between epistemology, information and LIS, information is the basis of operations, organization and activities (Capurro 1985). For example, the concept of "love" is defined through the semantic relations that exist between related terms in a thesaurus using an epistemological approach. But can this semantic relationship effectively explain the love between two people in the real world? If thesauri are given the ability to represent and relate instances and data of a specific proposition in the real world, then it could be deduced that they have shifted to ontological structures to achieve their knowledge organization goals. Thus, even though thesauri are primarily, originally, and inherently designed to organize information, they can be remodeled to play effective roles in organizing knowledge.

By the late 1960s and early 1970s, the development approach of thesauri resulted in the construction of thesauri for diverse subject fields (Haynes 2004) and the publication of numerous specialized thesauri. Péter Jascó (1999) claims that there is no integration between the subject vocabularies in different databases organized by different specialized thesauri. This means that the rise in the number of different perspectives on the construction of semantic relations networks in related subject fields has decreased the consistency between structures of specialized thesauri. The inconsistency between the subject schemas of specialized thesauri has led to a decrease in the interoperability of specialized thesauri and similarly, caused an increase in the heterogeneity of organized information in databases that ultimately reduces the ability to exchange information between databases. This idea and condition culminated in development of various types of thesauri (i.e., micro-, macro-, and metathesauri) (Wake and Nicholson 2001) to build the required compatibility between specialized thesauri (Dextre Clarke 2019) based on a similar engineering mechanism and to preserve the structure of previous semantic relations such as hierarchical and associative relations (Amirhosseini 2021). The effective and practical use of a thesaurus and its various types in information storage and retrieval has placed this KOS in the stage of information. Thus, information engineering was the appropriate mechanism to develop information organization management and information storage and retrieval systems (Greer 1987; Greer and Hale 1982; Greer, Grover and Fowler 2007) in a specialized thesaurus and its various types.

2.4 Engineering mechanism in ontologies

Specialized thesauri and their various types grew exponentially (Haynes 2004) through preserving the traditional structural-semantic relations, that is hierarchical and associative relations (International Organization for Standardization 2013). The traditional semantic relations were too generic (Cat 2017) to provide a sufficiently granular representation of the relational concepts (International Organization for Standardization 2013) based on a shared conceptualization (Hopkins 2017). Specialized ontologies were developed to solve the mentioned problem for sharing concepts and relations in a particular topic (Jin 2018) in knowledge storage and retrieval (Xu, Zhang and Ji 2014; Dragoni et al. 2012) to operate in knowledge management (De Silva 2008), especially in knowledge sharing in the 1980s (Gruber 1993b; 2001; 2009). In the late 20th and early 21st century, development of a large number of specialized ontologies in various scientific fields (Dombayci 2019) culminated in incompatibility between such ontologies (Amirhosseini 2021). This situation necessitated the use of some techniques in semantic interoperability to integrate heterogeneous conceptual relations (Shen and Chen 2012) in the communication and harmonization of conceptual systems in various domains (Jin 2018) and resulted in creation of different types of ontologies such as lower, middle, and upper-level ontologies (Eklöf and Martenson 2006; Bergman 2010) in early 21st century (Mascardi et al. 2007). The development and application of ontologies has followed the knowledge engineering process in organizing knowledge base systems for users' problem solving (Otieno 2015) and their knowledge-based needs (Rao 2012). Thus, the creation of ontologies has been the main factor in the transition from the information stage to the knowledge stage (Freitas, Frederico and Córdova 2016) in the evolution of KOSs. Consequently, knowledge engineering plays a great role in establishing knowledge organizations (i.e., ontology and its various types) and facilitates the process of capturing, processing, recovering, and creating specialized knowledge.

3.0 The principle of internal unity in KOSs

In the previous section, the main elements, mechanisms, and techniques employed in creation and application of KOSs were discussed. The main elements clarify and determine the position of KOSs in the stages of data, information, and knowledge, and comprise the mechanisms that must follow an internal order to realize the specific applications in each type of KOSs. The system of internal order in the evolution of KOSs has been different from the simplest to the most complex ones. In other words, the simplest types of internal order systems have been used to organize the simplest of KOSs and likewise the most complex internal order systems have played significant roles in creating the most complex KOSs. The internal order system is the basis for the identification and analysis of the principle of internal unity in KOSs ranging from the simplest to the most complex ones.

3.1 The principle of internal unity in dictionaries

In the development and evolution of dictionaries in the modern period (1600 AD), they have followed a common mechanism of alphabetical order in the way that words are organized (Landau 2001) through data engineering. Dictionaries organize scattered terms in texts based on an alphabetical order to facilitate their access (Amirhosseini 2021). Robert Cawdrey's *Table Alphabeticall* published in 1604, produced the first dictionary giving definitions of English words in English (Simpson 2007). Thus, organizing words based on an alphabetical order system created an internal unity between words in the dictionary through data engineering mechanisms which facilitated their access.

3.2 The principle of internal unity in *Roget's Thesaurus*

While alphabetical order gives easy access to terms in a vocabulary, it also scatters related terms, which have therefore not been accessible in an alphabetically ordered system (Amirhosseini 2021) and that only the human factor could identify the semantic connections between concepts (Arano 2005) in dictionaries. This limitation in accessing related concepts through an alphabetical order led to the proposal of a novel idea entitled "semantic order system" in the analysis of semantic relations between words (Amirhosseini 2008) that was based on both data and information engineering. This idea crystallized in Roget's outstanding work in creating a semantic connection between concepts in 1852 (Foskett 1980). Thus, the conceptually based structure in *Roget's Thesaurus* (Arano 2005) has prepared a unified semantic network or internal unity between the related words in terms of their semantic relations for the benefit of writers who often searched for appropriate words to express their idea (Chatterjee 1990).

3.3 The principle of internal unity in thesauri

The idea of semantic relations between related terms under the influence of Roget's work led to the creation of a new tool (Amirhosseini 2008) called the thesaurus, which had been proposed by Hans Peter Luhn as early as 1951 (Stevens 1968). This KOS has operated in vocabulary control to improve information storage and retrieval (Stevens 1968; Foskett 1980). The conceptual framework of the thesaurus (Kless et al. 2012) comprises a semantic network of hierarchical and associative relations (International Organization for Standardization 2011) used for decades for applying information engineering techniques and processes (Greer, Grover and Fowler 2007) in fulfilling the organization of information, information storage and retrieval, and other purposes (International Organization for Standardization 2013). Subsequently, the system of semantic order between descriptors, which has led to the integrated and coherent semantic network in a thesaurus, has been the main factor in creating an internal unity in the thesaurus to increase the performance of the information storage and retrieval system.

3.4 The principle of internal unity in ontologies

Thesauri and their various types have focused on semantic relations such as hierarchical and associative relations (Jarrar et al. 2014), which were not precise semantic relations for organizing items and concepts in the appropriate way (International Organization for Standardization 2013). This issue needs to be articulated more clearly. Hierarchical relations in thesauri include relations of genus–species along with the part–whole relation types. Moreover, associative relations, as "unspecified semantic relations", cover any semantic-related terms with the exception of hierarchical and equivalence relations (Hjørland 2015). In this sense, The traditional thesaurus is no longer practical in modern information retrieval (Hjørland 2016). However, it is noteworthy that thesauri have played and will continue to play important roles in accordance with the purposes for which they were intended. Nevertheless, new tools were required to accurately granulate or differentiate semantic relationships from each other. In this manner, the novel idea of ontology development (Kless 2014) was formulated to initiate the move from information storage and retrieval toward knowledge storage and retrieval based on granularity in semantic relations (Amirhosseini 2021), identifying generic and specific systems (Coffey 2018), especially in distinguishing between classes and individuals (instances) (International Organization for Standardization 2013) through a shared conceptualization (Gruber 1993a; 1993b; Hopkins 2017) for use in knowledge management systems (De Silva 2008). The precise network of semantic relations (Garshol and Naito 2004) plays a remarkable role in ontology development and Knowledge Organization Processes (KOPs) (Hjørland 2008). Therefore, the sufficiently granular representation of semantic relations that brings with it a more coherent and integrated network of semantic relations, could be referred to as internal unity and be considered when determining the degree of unity in ontologies.

4.0 The principle of external unity in various types of thesauri and ontology

The intention behind creation of KOSs such as thesauri and ontologies led to the development of various specialized thesauri and ontologies in diverse scientific fields and knowledge-based areas. A considerable increase in the number of specialized thesauri and ontologies in a specific field of science and in various scientific fields caused incompatibility between KOSs and interfered with their goals regarding information and knowledge storage and retrieval. Thus, these specialized KOSs should be made compatible by relying on specific theories as well as standard methods and techniques to establish systematic relations between them and to achieve external unity.

4.1 The principle of external unity in various types of thesauri

The purpose of thesaurus development in specific fields of knowledge (Aitchison, Gilchrist and Bawden 2000; National Information Standards Organization 1993; Lancaster 1972) has resulted in the fast production and growth of thesauri in various fields, and even in a single specialized area of knowledge, in the late 1960s and early 1970s (Amirhosseini 2021). A large number of specialized thesauri in every area of human science resulted in a lack of coordination and compatibility between them in the information storage and retrieval system. Unity was the central idea in arranging compatible controlled vocabularies such as specialized thesauri in diverse subject fields to develop unified controlled vocabularies (Amirhosseini 2008). Knowledge organization research has benefited from the theory of unity of science (Oppenheim and Putnam 1958) and its related theoretical arguments (Feibleman 1954) such as "Integrative levels" (Needham 1937) in the formulation of interrelated structures, especially through applying techniques related to structural unity (Rescher 1997; Craig 1998). This has allowed the creation of interoperability between controlled vocabularies such as specialized thesauri which integrates the various types of KOSs (Kuznetsov 1999) and achieves a unified semantic system (Kleineberg 2017; Amirhosseini 2021). Unity of science, based on a general hypothesis, states that in the hierarchy of sciences (i.e., the relations between psychology, biology, chemistry, and physics), all sciences will be eventually reduced to the fundamental physical science (Eronen 2015). Moreover, the complexity of the sciences increases from physics to psychology (Wimsatt and Sarkar 2006). The theory of integrative levels interrelates different domains of the human knowledge according to a hierarchical order (Gnoli 2005) and explains that a world consisting of different things [or knowledge] originates in simple levels and evolves towards more complex levels (Foskett 1961). Furthermore, each level in this hierarchy, in its entirety exists as a part of the next more complex level. Structural unity and its related standards (i.e., ISO 25964-2 2013 and BS 8723 2005-8) and techniques (Kuznetsov 1999) have been effective factors in the development of interoperability between specialized KOSs such as thesauri (Amirhosseini 2021). In this matter, international standards have proposed different techniques such as mapping (International Organization for Standardization 2013; British Standards Institution 2005), switching, merging, and integration (Aitchison, Gilchrist and Bawden 2000) in combining KOSs such as thesauri to address the linkages between two or more vocabularies (Tomorad and Zlodi 2005) based on structural unity. This synthesis resulted in developing new unified controlled vocabularies such as micro-, macro-, and meta-thesaurus (International Organization for Standardization 2013; Zeng 2019; Zeng and Mayr 2018; Lancaster, 1986; Zeng 1992). Therefore, the mentioned theories through their support of the defined techniques and standards have been used to create integration between specialized thesauri in a particular field and also to build a bridge between different specialized thesauri in various scientific areas based on the external convergence between that exists them to prevent the scattering of various schemes of KOSs and may be termed as external unity.

4.2 The principle of external unity in various types of ontologies.

The main goal of a domain-specific ontology has relied on sharing concepts and relations in a particular topic (Jin 2018). This goal resulted in developing a large number of specialized ontologies in various areas of science to identify the most specialized and relevant concepts to link to with one another (Dombayci 2019), especially between different languages (Mohapatra and Mohapatra 2014) for effective data sharing and information flow (Muñoz et al. 2017). On the other hand, the widespread and numerous production of specialized ontologies that represent concepts in specific and often eclectic ways caused incompatibility between them. In contrast to structural unity which led to development of unified vocabulary control system in specialized thesauri by preserving the structure of traditional semantic relations, the harmonization of specialized ontologies can be defined through the principle of conceptual unity that is closely related to the theory of the unity of science and integrative levels (Amirhosseini 2021). In addition to structural unity being considered as a part of conceptual unity (Wei 2015), conceptual unity and its related theories have played a great role in formulating conceptual relations between generic and specific concepts (Coffey 2018) or classes and individuals (instances) (International Organization for Standardization 2013; Hopkins 2017) to unify the hierarchical structure of the conceptual relations regarding the harmonization between specialized ontologies (Cat 2017). Moreover, the incompatibility between specialized ontologies can be resolved through the application of some methods such as merging which achieve semantic harmonization (Jin 2018) by developing broad ontologies (Mohapatra and Mohapatra 2014) based on semantic interoperability that integrate heterogeneous conceptual relations (Shen and Chen 2012). Integration and harmonization have led to the evolution of a new generation of ontologies namely the upper (Amirhosseini and Salim 2011), middle (Eklöf and Martenson 2006), and lower (Bergman 2010) level ontologies. Therefore, the theories such as conceptual unity while preserving the principles of conceptual relations in ontologies, create semantic compatibility and harmonization in KOSs, especially ontologies. This kind of unity in creating compatibility between different types of KOSs which ultimately sparked the creation of new generations of ontologies can be called as external unity.

5.0 The principle of rank unity in KOSs

5.1 Background of KOSs' ranking methods

As was previously noted, all KOSs, ranging from the simplest to the most complex KOSs, have the same root (Amirhosseini 2021) but do not simply result from a repetition of the past in the course of their evolution (Zeng 2008). This allows KOSs to be ranked based on various criteria such as the degree of simplicity and complexity in their structure (Zeng 2008). Smith and Welty (2001) classified various kinds of KOSs based on their increasing complexity and by distinguishing between those that possess the ability for automated reasoning based on formal logic, and those that do not (Biagetti 2021). McGuinnes (2003), based on Lassila and McGuinnes (2001), proposed a particularly broad notion of ontology that ranges from so-called simple ontologies, such as controlled vocabularies, glossaries, taxonomies, and thesauri, to complex ontologies, that is the tools that present properties and restrictions of values (Biagetti 2021). Guarino (2011) emphasizes the concept of precision to define formal ontologies in comparison with traditional knowledge organization systems in the realm of knowledge engineering (Biagetti 2021). A KOS arrangement model was proposed by Marcia L. Zeng (2008) in a spectrum with increasing semantic richness to identify that thesauri, semantic networks, and ontologies are presented as members of the category relationship models, as they can represent many relationships (Biagetti 2021). Mazzocchi (2018) focused on semantic richness as a criterion for comparing and classifying different types of KOSs and many authors refer to the idea of a semantic staircase presented by Olensky (2010) (as earlier suggested by Blumauer and Pellegrini (2006)) (Biagetti 2021) and sometimes called a semantic spectrum (Hjørland 2015). In this case, glossaries (or other less structured KOSs) take a position at the lower grade, and ontologies are at the top of the hierarchy or ranking of KOSs (Mazzocchi 2018). Amirhosseini (2021) proposed a ranking method based on a dialectic scheme for determining the different levels of KOSs by demonstrating various types of unity and a general movement from plurality to unity in the evolution of KOSs.

5.2 Immanuel Kant's knowledge theory

Kant was born in Königsberg in East Prussia on 22nd April 1724 and died there on 12th February 1804 (Turner 1910). The systematic work of Immanuel Kant's knowledge theory greatly influenced all subsequent philosophy. Kant is one of the most influential thinkers of modern Europe, the last major philosopher of the Enlightenment, and the 'Father' of modern relativism. Some of the philosophical insights of Kant are integrated in post-modern philosophy (Rohlf 2020). Kant's epistemology in the *Critique of Pure Reason*, which is the source of the knowledge theory, (Kant 1781) resulted in bridging the philosophical notions of the Rationalist and the Empiricist (Capelston 1981). Kant believed that "though our knowledge begins with experience, it does not follow that it arises out of experience" (Adorno 2001). This is the most original contribution of Kant epistemology in knowledge theory that came to be known as the "Copernican revolution in philosophy" (Gardner 2000). This conveys that the human mind plays a tremendous role in creating experiences to develop knowledge. Hence, human knowledge stems from the experiences that involve the categories of the human mind. Kant proposed a table of the mind categories which comprises of twelve special set of concepts divided into four main classes of quality, quantity, relation and modality (Gardner 2000).

The epistemology of Kant in the "Critique of Pure Reason" is very complicated. Here, the researcher explains the epistemic approach of the knowledge theory in an easy flowing way based on a dialectic scheme. Hence, transcendental sense and transcendental understanding as two major stages of the knowledge theory can be clarified by application of a dialectic method to identify the logical relationship between a beginning idea called a thesis, a negation of that idea called the antithesis, and the result of the conflict between the two ideas, called a synthesis (Amirhosseini 2010).

5.2.1 Dialectical scheme in the transcendental sense

Transcendental sense comprises of material or content as well as form. Phenomena or empirical objects in a possible experience (Kukla 2011) are located as material or contents that play roles as the thesis in the transcendental sense. Time and space are the forms that are clarified as antithesis. When the form is imposed on "Phenomena", the sense-intuitions are formed in the human mind as synthesis forming mind data (see Figure 1, sub-dialectical scheme no.1), such as empirical data, for example about daily temperatures at a particular place and time (Frické 2009). For instance, a "Red light" is a phenomenon. When you see a "Red light" in a specific time and space, "Red light" plays a role as a mind data in your mind (Amirhosseini 2010; 2016).

5.2.2 Dialectical scheme in the transcendental understanding

Similar to sense-knowledge, transcendental understanding consists of material or content as well as form. The material of understanding is sense-intuitions and the form of understanding is the mind categories. In this step, the thesis is sense-intuitions and the antithesis is mind categories. When sense-intuitions have taken place in the mind categories, cognition states form in the human mind. Synthesis in transcendental understanding is the cognition states. There are three states regarding cognition in the human mind (Kant 1781a). The first is perception, the second is combination and finally the relation-making (Amirhosseini 2010; 2016). The cognition states in transcendental understanding are explained in the following sections:

a) Perception state: the starting point of cognition states is the perception state. The perception state forms in the human mind when sense intuition or mind data as material and content (i.e., thesis) are perceived through mind categories as form (i.e., antithesis). In other words, when sense-intuitions are unified in the form of mind categories such as quality, quantity, relation and modality, the perception state of the concepts forms (Capelston 1981) to create information in the human mind (see Figure 1, sub-dialectical scheme no. 2). For instance, "Red light" is one of the three lights of a traffic light. This statement depicts the number of "Red light" in a traffic light and thus, relates to the quantity concept of the mind categories. Moreover, the concept of a red light in a traffic light instructs the act of stopping. This proposition gives us the information that when we see this light, we have to stop to increase the quality of public transportation.
b) Combination state: after sense-intuitions were unified as mind categories, the combination state starts in the human mind. Kant believed that "Phenomena cognition is impossible without combination" (Capelston 1981), because a set of unrelated concepts or information cannot be a factor in recognition of phenomena. Thus, data and information scattered in the human mind as materials and content (i.e., thesis) are combined with each other in the context of mind categories (form or antithesis) that ultimately lead to the formation of knowledge in the human mind (see Figure 1, sub-dialectical scheme no. 3). For example, when a traffic light shows a red sign at a crossroads, your mind combines this data with the concept of red and the information that you have to stop according to traffic rules, giving you the knowledge that you have to stop.
c) Relation making state: Kant identified that a unified experience is derived from making relations between combined knowledge to fulfill self-consciousness which enables us to say "I think" (Hsieh 2004). Thus, when related concepts in the form of knowledge, as thesis, are unified in the human mind to fulfill unified experiences or cognitive unification, as antithesis, the relation making state starts to show the final synthesis. The process of union between human experiences in the form of subjective data, information, and knowledge, leads to the formation of self-consciousness and wisdom in human beings. This is the highest level of the cognition states (see Figure 1, sub-dialectical scheme no. 4). For example, when you cross a red light to allow an ambulance behind you to pass, you are linking your mind knowledge to medical priorities and performing a wise action. In Figure 1, the dialectical scheme in Kant's epistemological thought is explained:

5.3 The principle of rank unity in knowledge organization systems (KOSs)

This section attempts to rank the mentioned KOSs in a hierarchical relationship based on their desired main elements. The ranking relation between different KOSs could be explained via a hierarchical relationship framework based on the main elements (i.e., data, information, and knowledge) desired by each KOS. This hierarchical relationship can be seen in knowledge hierarchy or knowledge pyramid or the DIKW hierarchy proposed by Ackoff (1989) and the wisdom hierarchy put forward by Cleveland (1982) (Dammann 2018). The mentioned hierarchy contextualizes data, information, and knowledge with respect to one another and delineates their process of transforming into each other (Rowley 2007). In this manner, knowledge is the product of data and information (Braganza 2004) that is positioned at the highest level and is followed by information and data at the lower levels respectively (Bernstein 2009). Here, a method of ranking with the potential to determine the position of each mentioned KOS through clarification of the main elements they intend to organize, the related engineering mechanisms employed in the KOSs and KOPs, and their specific principle of unity is discussed as a presupposition for the proposal of the principle of rank unity between KOSs. In other words, the hierarchical or the ranking relation between data, information, and knowledge, can be taken into account as criteria that determine the position of KOSs in a hierarchical ranking model. This kind of hierarchical relationship between the main elements is observed in the theoretical arguments of Kant (1781) in the explanation of cognition states in his knowledge theory and epistemology. Kant believed that "our knowledge begins with experience", hence, cognition states begin from experience (Amirhosseini 2010) and sense of phenomena (empirical objects of possible experience) (Kukla 2011). In this case, sense intuition or data in a specific time and space is the base stage in the cognition states of the human mind, which is called transcendental sense (Turner 1910). Russell (1926) names this stage of cognition as mind data and also refers to it as immediate knowledge. When data is perceived and has successfully established the appropriate place among mind cat-

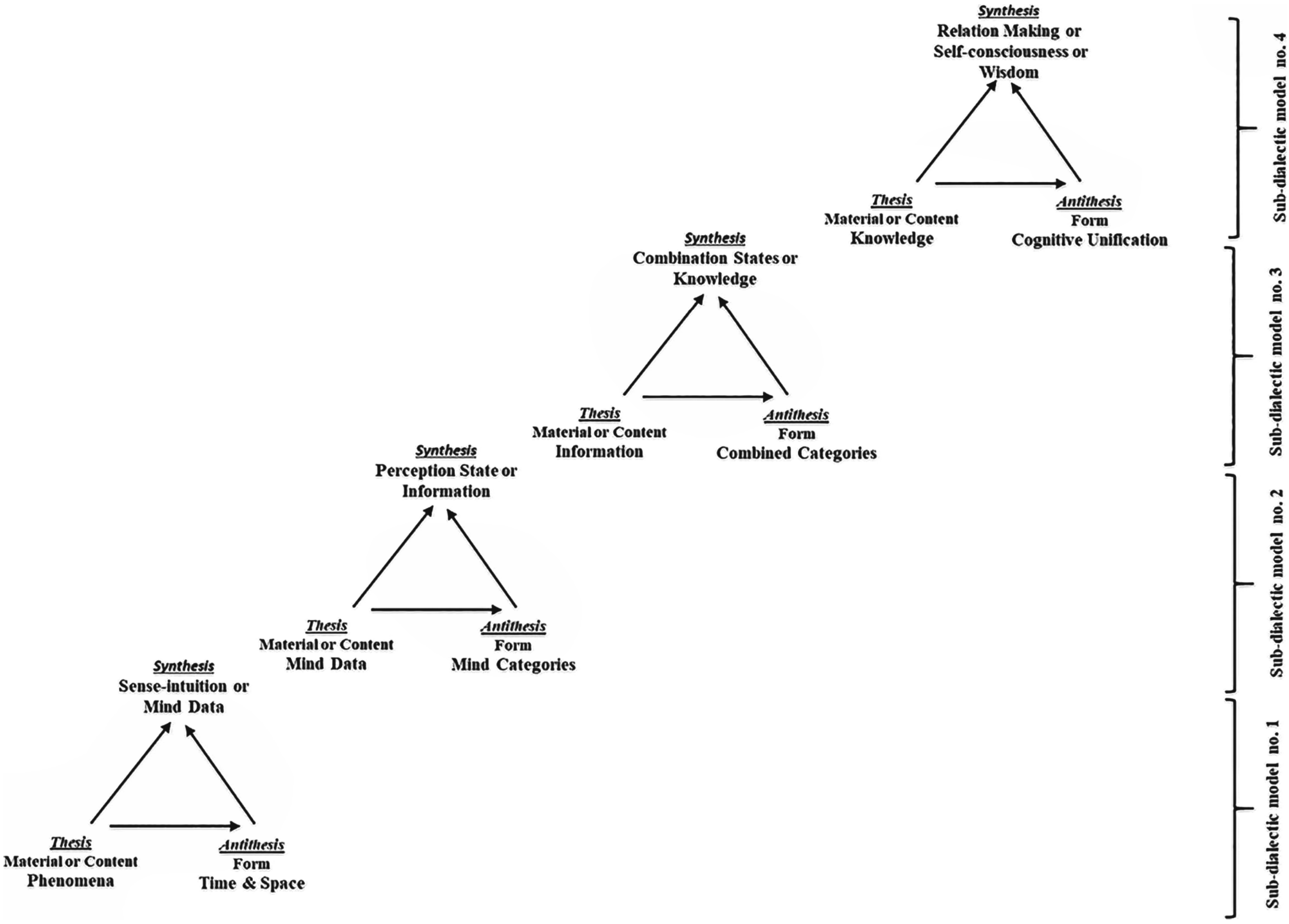

Figure 1. Dialectical scheme of Immanuel Kant's epistemology.

egories, such as quantity, quality, relation, and modality, transcendental understanding then starts and the second stage in the cognition states is formed (Coopleston 1994). This can be called the information stage. After the sense-intuitions unify in the form of categories, the combination state starts in the human mind (Amirhosseini 2010) to combine the information in transition to the knowledge stage.

To provide a clearer interpretation of the relationships between main elements of the knowledge pyramid and Kant's theory of knowledge, the following definitions of data, information, and knowledge can be considered: data can be supplemented with meaning to achieve information. Information can be interlinked to create knowledge (Hoppe et al. 2011). On the other side, Kant believes that information is perceived from the convergence of mass data in meaningful contexts such as quality, quantity, relation and modality, and that the convergence of related and combined information brings us to knowledge. In this matter, data becomes meaningful in order to form information when their quality, quantity, relation and modality are explained and perceived like the process of data categorization in the human mind that achieves information. Moreover, the combination or interlinkage of information results in the creation of knowledge in the human mind as personal knowledge. In this way, related concepts to the cognition states of Kant's knowledge theory (i.e., perception and combination states in creating information and knowledge in human mind) can be matched with the hierarchical levels of data, information and knowledge in the knowledge pyramid. Zimmermann et al. (2003) uses the knowledge pyramid and states the interrelations between data, information, and knowledge to clarify concepts of categorization and personalization that create information and knowledge respectively. Figure 2 demonstrates that the categorization of data leads to the development of information and that the personalization of information, through a combination process in the human mind, leads to the creation of knowledge.

Although Zimmermann et al. (2003) did not refer to a philosophical school, circle or debate to express the relationships between data, information, and knowledge, their proposed model can be used to infer a connection between the knowledge pyramid and Kant's knowledge theory. As stated previously, the adaptation of knowledge theory and the

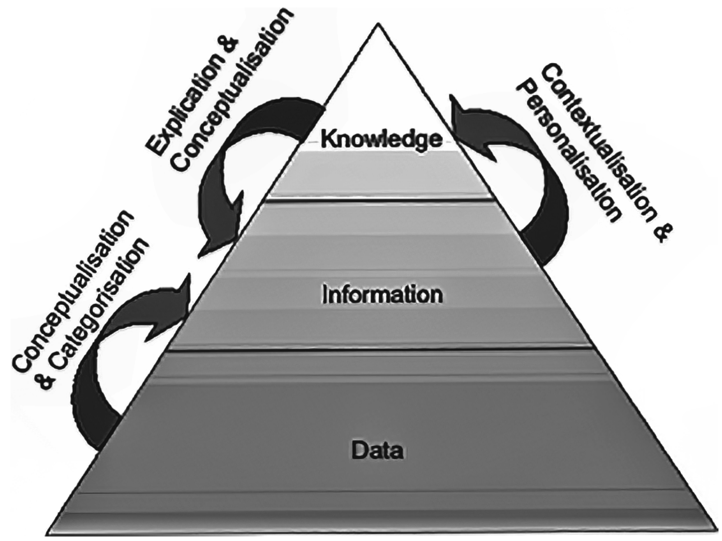

Figure 2. The interrelation between data, information, and knowledge (Zimmermann et al. 2003).

knowledge pyramid can be utilized for ranking of KOSs by a novel ranking method that determines the levels or the ranks of each KOS in the hierarchy or the ordered staircase of data, information, and knowledge. Consequently, it could be stated that there is a hierarchical or ranking relationship between data, information, and knowledge, and this could be considered as unity of ranks (a rank unity) in KOSs. Figure 3 endeavors to show the proposed ranking method, the principle of rank unity, and to display the position of discussed KOSs from the perspective of main elements or cognition states (data, information, and knowledge), the desired engineering mechanisms, the principles of order, and the principles of unity in each of the KOSs.

At first glance at the above figure, we find a rank or rank position based on cognition states or main elements (data, information, and knowledge) between the KOSs discussed in this study. KOSs provide a framework or schema for storing and organizing data, information, and knowledge about the world and thoughts for understanding, retrieval or discovery, reasoning, and many other purposes (Soergel 2009). In this manner, they can be ranked by clarifying their purposes, main elements, engineering mechanisms, and the utilized principles of unity. In Figure 3 the simplest and the oldest KOSs are dictionaries, in which the desired main element is word (data) which is organized by means of a data engineering mechanism based on alphabetical order to create the necessary internal unity. The next rank belongs to *Roget's Thesaurus*, which fulfills its principle of internal unity by relying on the idea of a semantic system between words or data through data and information engineering that help writers in finding appropriate words to express their thought. The thesaurus, influenced by the idea of semantic system, establishes a semantic network by hierarchical and associative relations between terms in creating and organizing informational units. This network is organized by using information engineering methods based on the principle of structural unity in creating internal unity in specialized thesaurus to help increase the performance of information storage and retrieval. Various types of thesauri (i.e., micro-, macro-, and meta-thesauri), while preserving traditional semantic relations, prepare the infrastructure for compatibility between specialized thesauri via information engineering methods and the related standards based on the principle of structural unity to create the external unity between controlled vocabularies. Traditional relationships in thesauri were too general and not sufficient to increase the performance of knowledge storage and retrieval. For this reason, specialized ontologies, through knowledge engineering mechanisms, have established precise and granular conceptual relationships based on the principle of conceptual unity to create the internal unity and the integration between concepts to increase the performance of knowledge storage and retrieval systems. In the last stage, the formation of various types of ontologies such as low, middle, and upper-level ontologies creates coherence, compatibility, and interoperability which provide the specialized ontologies with external unity. Therefore, in the developmental process and evolution of KOSs and based on the principle of rank unity, each of the mentioned KOS occupies a special position in the cognition states based on its desired main elements (data, information, and knowledge). Moreover, each of the mentioned KOS, while having their own methods and mechanisms of convergence (i.e., the principles of internal and external unity), have borrowed from the ideas and techniques used in the previous KOS. Finally, in their process of evolution, ontologies and their various types have held the

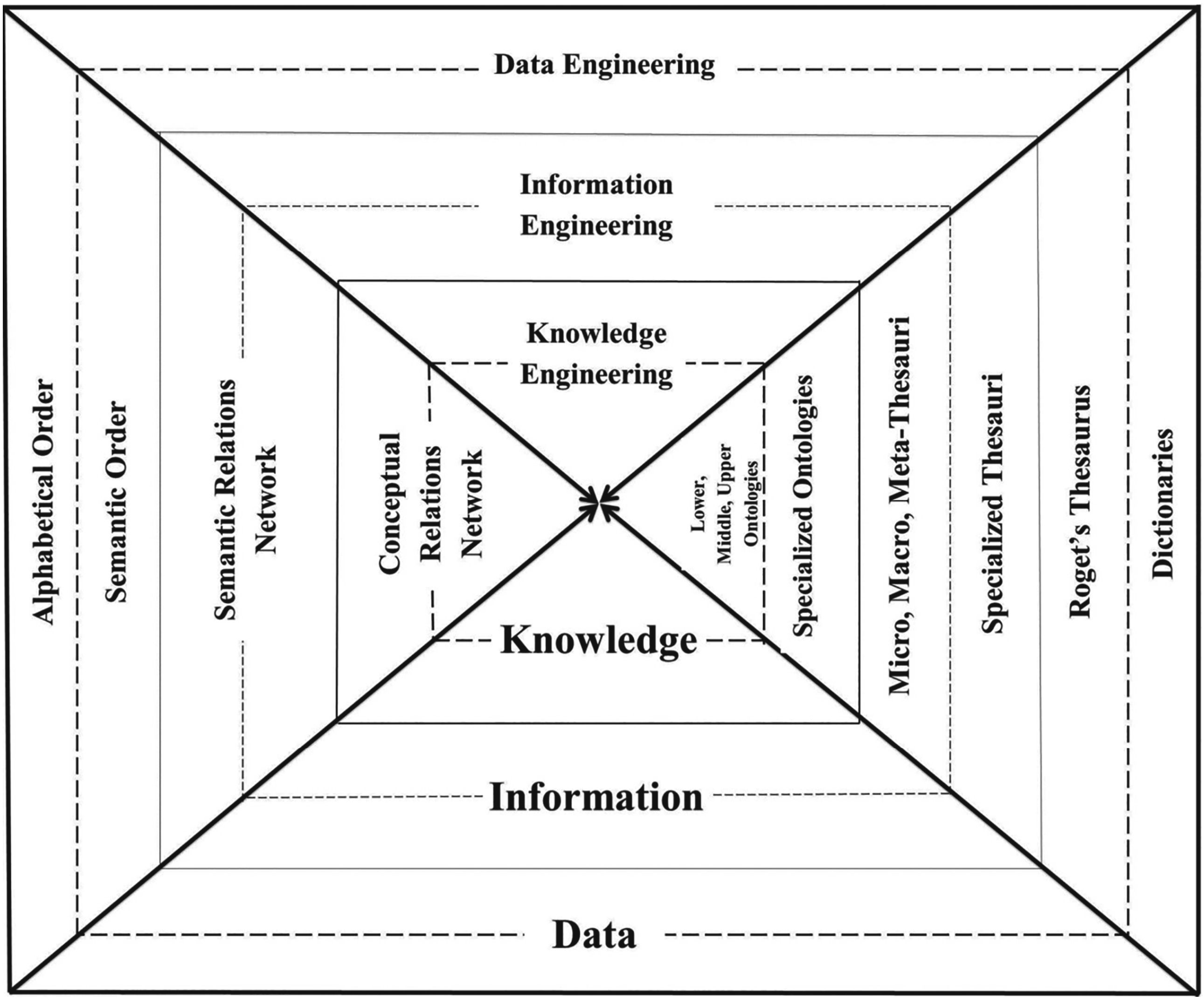

Figure 3. The conceptual model of the principle of rank unity in knowledge organization systems (KOSs).

highest position with respect to the cognition states or main elements (data, information, and knowledge) in increasing the performance of information and knowledge storage and retrieval to create knowledge-based systems.

6.0 The synthesis analysis of KOSs development and evolution

The synthesis of the results of the mentioned discussions in the development and evolution of KOSs is clearly expressed in Table 1, through specifying the main elements desired in KOSs, the principles of order and their related operational mechanisms in arranging the related main elements, the various types of unity in KOSs evolution, the results of the realization of unity in KOSs and their specific functions.

The synthesis of the results in Table 1 shows that each of the KOSs has its specific place in the cognition states or main elements (data, information, and knowledge). In addition, each of the KOSs follows the principle of a definite order, such as alphabetical order, semantic order, and conceptual order to establish the arrangement of its main element. Moreover, KOSs rely on particular operational mechanisms such as data, information, and knowledge engineering to establish an order between their main elements. The arrangement of the main element in each of the KOSs plays a great role in achieving the expected result and also in yielding the specific function from a KOS through the use of particular mechanisms for the realization of the principle of order. Finally, the results show that the three types of the principle of unity, including the principles of internal unity, external unity, and rank unity could be identified in the development and evolution of KOSs. The principle of internal unity in each KOS is achieved by relying on a specific principle of order through implementing the relevant mecha-

KOSs	Cognition states or Main elements			The principle of order	Operational mechanism	Expected result	Specific function	The principle of unity
	Data	Inform-ation	Know-ledge					
Dictionaries	√			Alphabetical order	Data engineering	Alphabetical system of words	Provide information about words	Internal unity
Roget's Thesaurus	√	√		Semantic order	Data and information engineering	Semantic system of word	Provide meaning-based relations between words to help express writers idea	Internal unity
Thesauri	√	√		Semantic relations network	information engineering	Semantic network system between descriptors	Information storage and retrieval	Internal unity (Structural unity)
Various types of thesauri	√	√		Semantic relations network	information engineering	Semantic network system between descriptors	Information storage and retrieval	External unity (Structural unity, Unity of science and Integrative levels)
Ontologies	√	√	√	Conceptual relations network	Knowledge engineering	Semantic network system between concepts	knowledge storage and retrieval	Internal unity (Conceptual unity)
Various types of ontologies	√	√	√	Conceptual relations network	Knowledge engineering	Semantic network system between concepts	knowledge storage and retrieval	External unity (Conceptual unity, Unity of science and Integrative levels)

Table 1. The synthesis analysis of the result in KOSs evolution process.

nism to establish the arrangement of the desired main element in the KOS. The principle of external unity employed to prevent incompatibility between KOSs is achieved when coherence and interoperability is formed between KOSs such as specialized thesauri and ontologies, as well as other controlled vocabularies and authority lists based on specific methods, standards, and related mechanisms. As stated in the principle of rank unity, the position of KOSs in the cognition states (data, information, and knowledge) has a key role and acts as a criterion in their ranking.

7.0 Conclusion

The synthesizing analysis of the article results show that there are similarities and differences between KOSs. Their similarities reside in their common goal to create a specific order among the main elements they intend to organize. They do this by relying on engineering mechanisms and principles of unity. In other words, in following the principles of unity, the main elements (data, information, and knowledge) are organized through using engineering mechanisms (data, information, and knowledge engineering) to construct the desired knowledge organization and provide the required access to the desired content. On the other hand, there are differences between KOSs, and these are based on their purposes in achieving expected results and specific functions. For instance, dictionaries are developed to provide information about words, *Roget's Thesaurus* to help express writers' ideas, and thesauri and ontologies assist with iimproving the performance of information and knowledge storage and retrieval. The results of the analysis and study of the development and evolution of KOSs are as follows:

- KOSs follow the specific principle of order in organizing their desired main elements.
- Specific engineering techniques, methods, and mechanisms are used in organization of the aforementioned main elements.
- Application of the principle of order is based on the theoretical foundations of the principles of unity by relying on engineering mechanisms in organizing the main elements in KOSs.
- The principles of structural unity and conceptual unity play significant roles in creating internal unity in thesauri and ontologies respectively.
- The principles of structural and conceptual unity, along with the theory of the unity of science and integrative levels, using standard techniques and methods, have played fundamental roles in creating compatibility and interoperability between different KOSs in developing various types of thesauri and ontologies to achieve external unity.
- Cognition states can be used as criteria in determining the position and rank of each of the KOSs by relying on the principle of rank unity.
- KOSs have been developed to organize and disseminate their desired data, information, or knowledge to fulfill their practical purposes.

In conclusion, the simplest to the most complex types of knowledge organizations while having defined positions in the cognition states, specific principles of order, related operational mechanisms, and related principles of unity in achieving their specific purposes, also have a common goal to create their desired knowledge organization based on a systematic evolutionary relationship and further, their development processes owe to the experiences and methods of their previous generations.

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