A Dialectic Perspective on the Evolution of Thesauri and Ontologies

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Abstract: The purpose of this article is to identify the most important factors and features in the evolution of thesauri and ontologies through a dialectic model. This model relies on a dialectic process or idea which could be discovered via a dialectic method. This method has focused on identifying the logical relationship between a beginning proposition, or an 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. During the creation of knowledge organization systems (KOSs), the identification of logical relations between different ideas has been made possible through the consideration and use of the most influential methods and tools such as dictionaries, *Roget's Thesaurus*, thesaurus, micro-, macro- and metathesauri, ontology, lower, middle and upper level ontologies. The analysis process has adapted a historical methodology, more specifically a dialectic method and documentary method as the reasoning process. This supports our arguments and synthesizes a method for the analysis of research results. Confirmed by the research results, the principle of unity has shown to be the most important factor in the development and evolution of the structure of knowledge organization systems and their types. There are various types of unity when considering the analysis of logical relations. These include the principle of unity of alphabetical order, unity of science, semantic unity, structural unity and conceptual unity. The results have clearly demonstrated a movement from plurality to unity in the assembling of the complex structure of knowledge organization systems to increase information and knowledge storage and retrieval performance.

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1.0 Introduction

Dialectics (ancient Greek 'dialektike') was invented by Zeno the Elea (495 – 430 BC) and is based on the testimony of Aristotle in supporting the debates on hypothetical antinomies of Parmenides (Born in 515 B.C). Plato (424-347 B.C.) developed dialectic into a high philosophical method through relying on Socratic definitions. The Socratic question and answer technique was explicitly described as "dialectical" by Plato. Plato described dialectic as a progressively more synoptic ascent through a series of "positions" until an ultimate is reached, and stated that dialectic consists of two different procedures, "collection" and "division". However, in the definition of dialect Aristotle replaced the procedure of "division" with "classification", in other words, replaced ascent by descent. Aristotle, however, abandoned the dialectic form on the basis that it does not have connection to the demonstrable, or what is true or primary, but is based on the opinion of the majority of the wise. All being said, it is worthy of mention that he sees the issue as stemming from the confusion between thought and reality which could originate from the inadequate analysis of dialectic by Plato. On the contrary the renewal of dialectic by Plotinus (205-270 BC) revived dialectic as a cognitive ap-

proach to the intelligibles (i.e., what is only understood by the intellect and not by the senses) making it an education for virtue including actions, objects and awareness (Peters 1967).

Georg Wilhelm Friedrich Hegel, the German philosopher, regards dialectic as an inherent feature of rational thought (Sayer 2013). In this manner, dialectic aims to resolve and synthesize opposing views or ideas (Wallace and Muirhead 1911). Hegel has confirmed that his dialectical method was influenced by Plato's version of dialectics (Maybee 2016). Hegel admired Plotinus (204/5 – 270 B. C.) and Proclus (412-485 B. C.), especially Proclus regarding the triadic movement. Hegel's triad hints at the idea that the third term is caused by the conflicting of two opposites. This idea is not obvious in the Neoplatonists, but it is prominent in the work of Immanuel Kant (Inwood 1992) and more especially Johann Gottlieb Fichte (Maybee 2016). However, Kant has not presented his solution as a synthesis. The terms of thesis, antithesis, and synthesis that in some way appeared in Kant's triad, were not applied in Hegel's triads. However, Hegel owes much to Fichte's triadic procedure in his dialectic argumentation (Inwood 1992). Moreover, Hegel has not used the triad in his complete works in 20 volumes and in the eight volumes of Hegel which were published for the first time in the 20th century. In fact, from Hegel's point of view, dialectics is not based solely on the thesis, antithesis, and synthesis. Hegel had discussed the triads of thesis, antithesis, and synthesis as a method or logic of philosophy in the preface of the *Phenomenology of Mind*. In this matter, Young Hegelians and Karl Marx later developed the antithesis and synthesis in the form of a dialectic argumentation (Mueller 1958). Therefore, Hegel directly and indirectly affirms that his dialectical method was influenced by the opinions and thoughts of the philosophers before him, especially regarding the triads of thesis, antithesis, and synthesis that were further spread by his followers and philosophers that came after him.

Hegel's primary objective in his dialectic is to establish the existence of a logical connection between various categories involved in the constitution of experience. The focus on synthesis, which is derived from the conflict between thesis and antitheses, in a dialectic idea and process (McTaggart 1896) and in the form of dialectic lines (Popper 1940), is perhaps the most critical characteristic of Hegel's entire system (McTaggart 1896). In Hegel's view, we do not create dialectic categories. The categories already have a logical relationship that we must discover (Stace 1955). The difficulty of understanding the contradiction concept between thesis and antithesis can be clarified through the definition of "sublation" (i.e., *Aufhebung*) in the integration of the two opposite ideas to create a new idea that is synthesis. Sublation covers three main senses: to destroy, to preserve and to raise. Hegel regularly uses the combination of all the three related senses to explain the logical relationships between ideas. Hegel refers to senses "destroy" and "preserve" as opposite senses to analyze the essence of contradiction between ideas. However, both mentioned senses lead us to the concept and the existence of preserve. Moreover, the sense of "raise", or "elevation", is an ingredient in Hegelian meaning. It means that raise sublation proceeds from the lower to the higher (or from plurality to unity) because Hegel sees a deep connection between the development of concepts and the development of things which is essential to his idealism. Therefore, sublation consists of both destroying and preserving certain aspects of the thesis and antithesis to elevate them into the higher unity of the synthesis (Inwood 1992). In other words, a dialectic method or logical relationships in historical and philosophical progress, identifies a beginning proposition or idea called a thesis, a negation of that thesis called the antithesis, and the conflict between thesis and antithesis which causes the progress of a new idea or proposition, called the synthesis. The synthesis can then be described as a new thesis which has produced a new antithesis (Popper 1940). It has been asserted that Hegel sometimes declares the contradictions to be the cause of the dialectic movement and sometimes declares them as the effect of such movement. No doubt, the contradictions are considered as the immediate cause of the movement. Now all that this implies seems to be that the contradictions first manifest in the movement, which is not at all identical with the assertion that they are caused by it, but is quite compatible with the counter-assertion that it is caused by them (McTaggart 1896) for the sake of dialectic integration (Boje et al. 2003). Dialectic can be generalized, not only to philosophy but also to science, technology, engineering, and politics (Popper 1940).

The purpose of this article is to identify the most important factors and features in the evolution of thesauri and ontologies as the knowledge organization systems (KOSs) through a dialectic model. Knowledge organization systems such as lists, authority files, gazetteers, synonym rings, taxonomies and classification schemes, thesauri, and ontologies have the same root but in the course of their evolution they do not simply result from a repetition of the past (Zeng 2008). This article focuses on logical relationships between the categories (i.e., thesis, antithesis and synthesis) based on dialectic models that have led to the clarification of ideas in the evolution of thesauri (Amirhosseini 2008) and ontologies. The arguments related to logical relations adopt a documentary method in the reasoning process and result in identification of the historical origins of knowledge organization systems as well as the explanation of ideas or factors involved in the construction of thesauri, ontologies, and their various types. In this case, this article attempts to clarify the dialectic processes in the creation of thesauri and ontologies by arguing and discussing their related categories

based on a dialectic method. The categories will identify the related steps, including the logical relationships of thesis, antitheses and synthesis. The research results are analyzed through the operation of synthesizing method to achieve the effective factors and features in the evolution of thesauri and ontologies. Hence, this research explains a dialectical perspective on the identification of the historical origins and the effective factors in evolution of thesauri and ontologies via analysis of the three categories and synthesizing related results.

In fact, there are similarities and differences between various kinds of knowledge organization systems. In this case, one of the most important roots of knowledge organization systems is dictionaries. The history of compiling dictionaries in the modern period dates back to 1600 AD. *Merriam-Webster Online Dictionary* states that the dictionary had been developed as a system with alphabetical order of terms arranged along with information about their meanings. There are similarities and differences between dictionaries and the other knowledge organization systems. They are similar in terms of applying a kind of order to make information available (i.e., their goal). On the other hand, they differ in the method of creating order to access specific forms of information (i.e., their purpose). Therefore, the history of compiling one of the first knowledge organization systems dates back to about 400 years ago. Moreover, the similarity between knowledge organization systems is caused by their common goal and their difference arises due to their specific purposes.

Knowledge organization system is a generic term that identifies various kinds of knowledge organization tools from the simplest to the most complex ones (Zeng 2008). This generic term is given because they follow a common goal while they can be distinguished from each other based on their specific purposes. It is possible to recognize the process of evolution and various kinds of knowledge organization systems based on their level of structural simplicity and complexity. The aforementioned movement from simplicity toward complexity would be the correct method for clarification of the structure of knowledge organization systems and their evolution process. However, the movement from the principle of plurality toward the principle of unity is another perspective for the characterization of various kinds of knowledge organizations. Hence it could be argued that there is a relation between the complexity concept and the principle of unity in the structure of knowledge organization system. Kant (1781) believed that "absolute unity is simplicity". This means that the movement towards complexity in the structure of knowledge organization systems leads to unity which subsequently results in simplicity. Thus, the common root and goal of various kinds of knowledge organization systems is the main factor in the formation of a common essence in information and knowledge dissemination. The evolution of this essence can be analyzed and identified in different ways. This article attempts to clarify the evolution of some kinds of knowledge organization systems such as thesauri and ontologies by relying on the principle of plurality and unity in dialectic schemes all through a historical perspective.

By adopting this method an unprecedented dialectic model is provided on the analysis of the evolution of knowledge organization systems. Moreover the logical relationship of dialectic scheme allows the features of knowledge organization systems, the principle of plurality and unity, to be discussed. In addition, the dialectic scheme has the capability to outline the progress and flow of ideas in the evolution of knowledge organization systems, identifies the historical ordered sequence of knowledge organization systems development, and ultimately recognizes the main root of all knowledge organization systems which is a reflection of their common goal of dissemination of information and knowledge.

The first section endeavors to explain the historical origins of thesaurus development; in section two, a dialectic category is clarified in the historical origins of the progress of various types of thesauri; the third and fourth sections attempt to analyze controversial debates on the main or fundamental idea in ontology construction and the origins of the progress of various types of ontology respectively. Finally, based on research results, the last section demonstrates the synthesis of discussions on the development of thesauri and various types of ontology, and lastly clarifies the various specifications and features of the logical relationships that exist in the evolution of knowledge organization systems.

2.0 Historical origins of the thesaurus

This section relies on the arguments which clarify the logical relationship between the triad of thesis, antithesis and synthesis, which also turns out to be the source that sheds a light on the origins of the ideas in thesaurus development. Figure 1 shows the logical relations between these categories in thesaurus creation.

2.1 The system of alphabetical order

The idea or proposition in the development of dictionaries was the establishment of a system based on alphabetical order. This idea plays a major role in the historical progress of dictionary development in the form of a dialectic scheme. The *Merriam-Webster Online Dictionary* defines dictionary as a reference source listing alphabetically terms or names arranged along with information about their forms, pronunciations, functions, etymologies, meanings, and syntactic and idiomatic uses and also their meanings and applications. Dictionaries, in fact, organize scattered terms in texts based on an

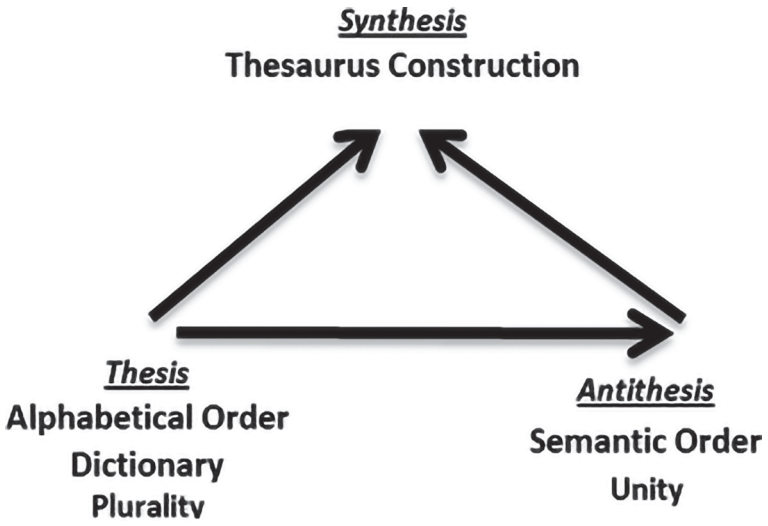

Figure 1. The logical relations between the categories in thesaurus creation.

alphabet in order to facilitate their access. The word dictionary was invented by John de Garlande's *Dictionarius* in 1220 (Forsyth 2011) which is derived from the Latin word "Dicito" meaning "word" (Erdmannn and Cho 1999). It is important to say that that Garlande's *Dictionarius,* which means, literally, "[Book] relating to words", was not arranged in alphabetical order, but in a semantic order. The fact that John de Garlande's *Dictionarius* was not merely a wordlist or a reference work but a textbook (in fact it is a prose work divided into paragraphs and arranged by thematic (i.e., semantic) content), should make us sensitive to the fact that, historically, the word "dictionary" has not always meant a list of words in alphabetical order with definitions and grammatical information attached to each entry.

The history of the compilation of dictionaries shows that there has been a remarkable determination in the course of continuous and gradual compilation of dictionaries, in the way that each of the compilers of dictionary has played a significant role in the process of their development and evolution. However, in the development and evolution of dictionaries in the modern period (1600 AD)[1], they have adopted the common mechanism of alphabetical order in the way that words are organized. The first English dictionary occurred almost inevitably as a modification of bilingual dictionaries, some of them of far greater importance. The only significance in being first in this case is that of providing an answer to the question of what was the first English dictionary (Landau 2001) to contribute to the world of dictionary development.

Robert Cawdrey's *Table Alphabeticall* published in 1604, was the first dictionary providing definitions of English words in English (Simpson 2007); "[r]epresenting what may be the least inspiring of all seminal works, Cawdrey's is generally accounted to be the first dictionary" (Landau 2001, 35). Edmund Coote's *English Schoole-Master*, which borrowed almost 90 percent of the words from Cawdrey, was a grammar, prayer book and lexicon with brief definitions, published in 1596. Thomas Thomas' *Dictionarium Linguae Latinae et Anglicanae*, a Latin-English dictionary of 1587, took about a half of Cawdrey's entries. This work also drew substantially from Cooper's *Thesaurus Linguae* of 1565. the earliest bilingual glossary to provide English equivalents for Latin or French. Although the word *dictionarius* was used as early as 1225 for a list of Latin words, no such term was applied to anything we would recognize as a dictionary until the sixteenth century.

Sir Thomas Elyot's Latin-English work of 1538 was originally called "Dictionary", then *Bibliotheca Eliotae*. The *Promptorium Parvulorum*, *sive Clericorum* (storehouse of words) the earliest known English-Latin dictionary, may have been written as early as 1440 and appeared in print in 1499. Caxton started to print a French-English glossary without a title in 1476 to 1480. In 1500, *Hortus Vocabularum*, ("Garden of words") was the first printed Latin-English dictionary based on an alphabetical list. Sir Thomas Elyot's was absorbed in 1565 by Thomas Cooper's *Thesarus Linguae Romanae et Britannicae* (Thesaurus of the Roman and the British tongues), which influenced seventeenth century monolingual dictionaries. John Floria's *A Worlde of Wordes* was the first modern language Italian-English dictionary based on a headword list and appeared in 1598.

John Bullokar's *An English Expositor* (1616) covered "hard words" in his dictionary in which he lifted many terms from Cawdrey as well as Thomas. In 1623, Henry

Cockeram's the *English Dictionarie, or, An Interpreter of Hard English Words* appeared as a Latin-English dictionary in three sections: hard words with simple equivalents, simple words with their fancy equivalents and encyclopedic information. He borrowed words from earlier Latin dictionaries, especially that of Thomas. Thomas Blount's *Glossographia or, A Dictionary Interpreting all Hard Words* (1656) was the first to attempt etymologies and used Thomas and Holyoke's *Dictionarium Etymologicum* in representing many new Anglicized Latin words. In 1658, Edward Phillips' *The New World of English Words* was a close copy of Blount. Elisha Coles' *An English Dictionary* of 1676, based on Phillips, included dialectal terms that had never before been included in a general English dictionary.

John Kersey's *A New English Dictionary* (1702), based on Phillips, acted as a turning point in English lexicography as the first dictionary to cover common words and multiple meanings (polysemy). He used Harris's *Lexicon Technicum* as a source of technical terms. In 1721, Nathan Bailey's *An Universal English Dictionary* displayed great attention to etymology and encyclopedic information, proved to be immensely popular and, like Kersey, remained in widespread use throughout the eighteen century. In 1730, Bailey's *Dictionarium Britannicum* was the standard bearer in English lexicography, until 1755 when Samuel Johnson's dictionary appeared.

Dictionnaire de l'Academie francaise (1694) influenced the standard schemes for improving the English language. Samuel Johnson, having published his *Plan of a Dictionary of the English Language* in 1747, proposed to establish a standard by making a dictionary that attempted to survey and record the language, especially the literary language. When his dictionary, by which "the pronunciation of English language may be fixed, and ... by which its purity may be preserved", was published in 1755, his brilliance and the originality of his mind resulted in the development of an idea stating that "the value of a work is through its use", especially in relying on orthography, pronunciation, grammar and illustrative quotations. In 1749, Benjamin Martin in *Lingua Britannica Reformata* proposed a theory by which the sense of the words ought to be arranged. The idea resembles that of Johnson's plan. He tried to put his theories into practice in publishing *A New Universal English Dictionary* which was a new version of Bailet's *Dictionarium Britannicum* issued in 1755, before Johnson.

In the late eighteenth century, dictionaries focused on pronunciation, and interest in correct pronunciation was prominent in the nineteenth century. However, it was not until the publication of Thomas Sheridan's *A General Dictionary of the English Language* in 1780 that a major advance was made in the dictionary treatment of pronunciation. He is "the first lexicographer who consistently respelled the entry words through pronouncing every word, even simple ones, indicating stress as well as sound." Although Bailey had already used the stress mark in 1740, James Buchanan, in *Linguae Britannicae* (1757), was the first to attempt actual pronunciations rather than simply indicating stress. John Walker's *Critical Pronouncing Dictionary and Expositor of the English Language* (1791) was one of the most popular and influential dictionaries, especially regarding its simple system of pronunciation. His work had an incalculably great effect on the correction of pronunciation in schoolbooks.

In 1806, Webster's *A Compendious Dictionary of the English Language* was based on John Entick's *Spelling Dictionary* published in London in 1764 endorsing certain changes in conformity with the principle of analogy and of etymology. Webster had ambitious plans to produce a much larger dictionary. Webster's *An American Dictionary of the English Language*, which covered scientific and technical terms as well as encyclopedic information, was published in 1828. He owed the substance of many of his definitions and citations of authority to Johnson. In 1830, Joseph Worcester's *Comprehensive Pronouncing and Explanatory Dictionary* was published, and Webster accused Worcester of having plagiarized his American Dictionary of 1828. However, both borrowed from other sources, but neither did so systematically and egregiously. The second and third editions of Webster's *New International Dictionary* as the largest lexicon in English appeared in 1934 and 1961, respectively.

The *New Method English Dictionary* of Michael West and James Endicott in 1935 was the first dictionary for foreign learners which used a controlled defining vocabulary, a practice still employed by many ESL dictionaries. This role has been adopted by Random House's *American College Dictionary* in 1947. *The Advanced Learner's Dictionary of Current English Dictionary* appeared in 1952 to cover so much ground in so many different areas that it became difficult to use. Subsequent Oxford editions of the *Advanced Learner's Dictionary* (OALD) would become larger and larger and were not seriously challenged until the appearance in 1978 of Longman's *Dictionary of Contemporary English* (LDOCE). LDOCE, based on a modern approach through selecting vocabulary form many current idioms, slang, and colloquialisms was received by learners and teachers with considerable excitement. It paid much more attention to American English than the contemporary edition of OALD. Following the publication of LDOCE in 1978 and the second volume of OALD in 1983, the rapid development of linguistic corpora resulted in two major new ESL dictionaries: Collins *COBUILD English Language Dictionary* in 1987 and *Cambridge International Dictionary of English* in 1995.

The origins of the *Oxford English Dictionary* apparently began with a suggestion from one of its three founders, F. J. Furnivall. The real beginning of the dictionary can be

placed at 1879, when James A. H. Murray, was persuaded to take over the editorship. By the time of its completion, the dictionary published in fascicles from 1882 to 1928, ran to 15,487 unnumbered pages. The *Oxford English Dictionary,* as it came to be called, "is a monumental achievement, without parallel in the English language and in all but a very few others." The *Oxford English Dictionary* not only provides a historical record of the development of meaning of each word with illustrative quotations and definitions for each sense, it also shows changes in spelling and gives by far the most complete and authoritative etymologies. A *Supplement to the Oxford English Dictionary* was published in four large volumes from 1927 to 1986. The second edition of the *Oxford English Dictionary* went online in 2000 and an entirely revised edition, the third edition, is scheduled for completion in 2020.

The early history of English lexicography is little more than a record of judicious or flagrant copying from one's predecessors, sometimes with grudging acknowledgment but more often (at least in the seventeenth century) without. Some eighteenth and nineteenth century lexicographers publicly acknowledged their indebtedness to specific predecessors. Sad to say, such honesty disappeared in the twentieth century and is not likely to be restored in the twenty-first. However, the massive task of dictionary development in the literature of each language is far beyond the power of any man and must be done through the combined action of many (Landau, 2001). Therefore, the history of dictionary development in the modern period demonstrates the gradual evolution of dictionaries from simple lists of words to the complex lexicon, the progress of mono-, bi-, and multi-lingual glossaries and the improvement of abridged and unabridged dictionaries in achieving standards for dictionaries. The common aspect of these knowledge organization systems is the use of alphabetic order to organize words. These tools cover simple and hard words, encyclopedic information, scientific and technical words, define and identify words through analyzing their etymology, multiple meaning (polysemy), orthography, spelling, pronunciation, grammar, illustrative quotations and so on. Consequently, a system with alphabetical order was the norm in the process of dictionary progress, which made the movement from the principle of plurality of scattered terms in vocabulary content towards the formation of unity in the alphabetical order of dictionaries a possibility.

2.2 The system of semantic order

While alphabetical order gives easy access to terms in a vocabulary, it also scatters related terms. In the case of dictionaries, semantics between lexical units are limited to the implicit information offered by definitions, etymologies or usage examples. Moreover, in dictionaries only the human user is able to find out those relations among concepts (Arano 2005). The organization of terms on the basis of meaning-based relations that exist between them represents the new idea of semantic order. This system comprises an idea opposite to the idea previously mentioned in developing dictionaries (i.e., an alphabetical order), and also plays a role as an antithesis. The idea of a semantic order was the spirit behind the approach of Peter Mark Roget. In 1852, Roget introduced a multi-dimensional approach to vocabulary organization in his work entitled *Thesaurus of English Words and Phrases*. Roget provided not a simple alphabetical lists of words (Foskett 1980), but a way of finding specific words, phrases, and idioms that express a concept or semantic domain. Roget's *Thesaurus* has a conceptually based structure, where the concepts explained in the entries are used as a basis for relating and grouping together of words in different contexts. The purpose of this work was to provide assistance and help in expression of ideas and literary composition (Arano 2005). Hence, the emphasis on unity regarding semantic relations between terms as opposed to the idea of an alphabetical order offered a novel means of developing a semantic order between the related terms, particularly for the benefit of writers who often search for appropriate words to express their idea (Chatterjee 1990).

The contradiction between dictionary as a thesis and Roget's *Thesaurus* as an antithesis in the form of a logical relationship to develop thesauri can be clarified by relying on Chomsky's transformational theory and model. The technical innovation of Chomsky was to motivate different levels of analysis and representation which were formally related to each other by the device of a "transformational rule" regarding the theory of transformational grammar or Transformational-generative Grammar (TG). That is the transformation of syntactic structural analysis units to semantic structural analysis units in striking the correspondences between syntactic and semantic properties (Chomsky 2002). Chomsky's grammar was divided into two levels; surface and deep structures.

Surface structure refers to sentences as they are pronounced or written. They are the part of language that is accessible through the ears and eyes (Smith 2004). Deep structure is represented by a phrase structure tree that indicates relations between words and phrases based on a hierarchical tree diagram. The surface forms of the distinct or dispersed word or sentences (i.e., surface structures) are unified by a theoretical construct (i.e., deep structure) in the form of a related structure (Chomsky 1965; Borsley 1999). Moreover, the abstract system of a transformational model cause movement from lower level or surface structure toward a higher level or deep structure known as linguistic levels (Wu and Xu 2011) and vice versa (Chomsky 2002, 1965). It means that Chomskyan Standard Theory (Chomsky 1968,

1965) comprises deep, intermediate and surface structures, and a set of base rules that create a finite number of deep structure propositions. It also includes a mechanism that utilizes transformational rules in order to generate infinite surface structures propositions (Varotsis 2013). The higher level or deep structure is organized through thematic or semantic order as a hierarchical and coherent topic representative of the textual unit based on semantic, schematic and pragmatic systems (Molina 1995). In other words, a semantic system assigned meaning to the syntactic strings (Harley 2001). In contrast, the lower level or surface structures (Chomsky 1965) rely on the alphabetic principle in terms of the Grapho-Phonic System (Turganbekova and Uglamova 2015) while they are equipped with a "dictionary" and a "grammar" (Smith 2004) which causes plurality or diversity (Thomas 2004) in terms of the related words. In other words, there is a movement from surface structure (lower level) based on the principal of plurality toward deep structure (higher level) based on the principal of unity (Gaskin 2008). There are several similarities between the transformation of surface and deep structures of Chomsky's theory of Transformational-generative Grammar (TG) and transformation of dictionaries into Roget's thesaurus which are explained in the following section and model.

Chomsky's Transformational-generative Grammar (TG) theory has been applied in various fields of science, especially in scientific research into translation. This section adapts Nida's Translation Model (Nida 1964; Nida and Taber 1969) which is derived from the key features of Chomsky's model (Chomsky 1957). This model is applied in the analysis of the transformation of dictionaries (as thesis) into Roget's thesaurus (as antithesis) in the logical relationship between the triad of thesis, antithesis and synthesis in thesaurus development. In this case, the deep structure in Roget's thesaurus is analyzed as an opposite of the surface structure in dictionary. In this sense, the semantic order of Roget's *Thesaurus* is in contrast to the alphabetical order of the dictionary. The following model takes into account the three main elements of analysis, transfer and restructuring regarding the transformational model. The model shows that Nida reverses Chomsky's model in the stage of analysis through analyzing the surface structure by a reductive process of back-transformation (Wu and Xu 2011).

Figure 2 demonstrates the transformation, based on structural analysis, of related ideas in the development of the dictionary into Roget's *Thesaurus* which are in contrast with each other as thesis and antithesis. Dictionaries as thesis organize the surface structural units which occupy a place at the lower level. The analysis process shows the organization of dictionaries in the form of alphabetical order which causes syntax plurality between the related words from a thematic point of view. On the other hand, there is a deep structure in Roget's *Thesaurus* as antithesis which occupies a place at the higher level. In order to make it possible to access related words based on semantic order, the deep structure is organized through restructuring vocabularies based on semantic orders, especially through using hierarchical and associative relations between the related topics which results in the achievement of semantic unity. It seems that the semantic unity between the related words results in

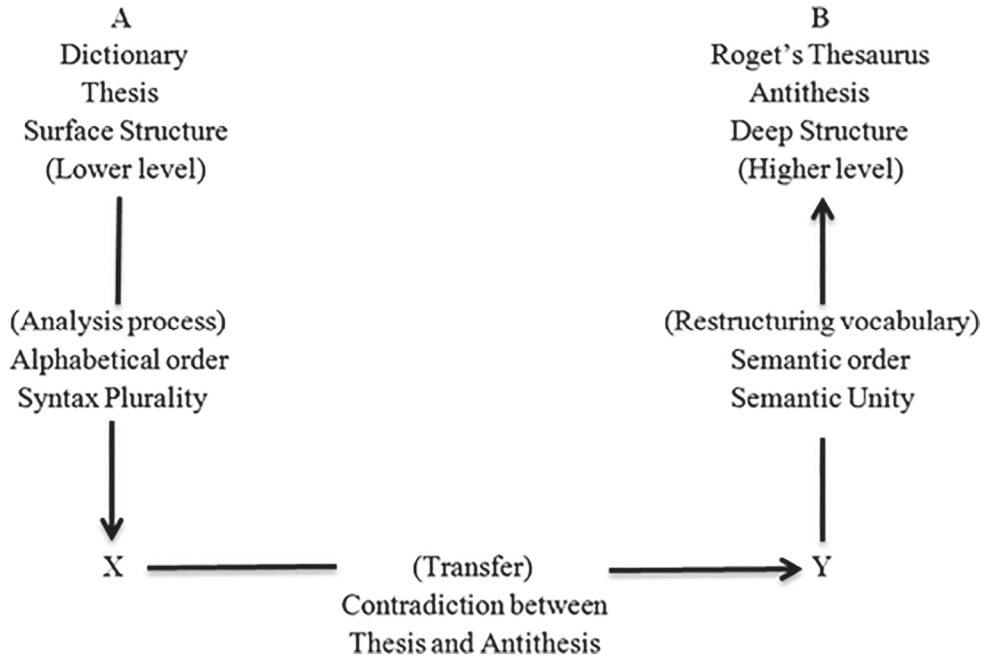

Figure 2. Contradiction between dictionary (thesis) and Roget's *Thesaurus* (Antithesis), (Nida's model).

a syntactic plurality between the words in an alphabetical order. This idea is correct; however, the pragmatic characteristic of Roget's *Thesaurus* allows access to words by using an alphabetical index in order to fulfill the syntactic unity in the integration of the two opposite ideas, preserving the idea of thesis in the essence of antithesis to create a new concept (Inwood 1992). It is important to mention that the deep structures also include a mechanism to utilize the transformational rules for identification and clarification of the semantic network between the words in surface structures based on a thematic approach (Varotsis 2013). Therefore, the contradiction between the mentioned thesis and antithesis causes the transfer of the idea of developing dictionary into the thematic organization of idea as seen in Roget's *Thesaurus*. Consequently, the scattered related terms in an alphabetical order (i.e., the principle of plurality or syntax unity) were gathered together in the form of a unified semantic system or the semantic unity after reconsideration.

2.3 Development of thesaurus construction

The idea of semantic relations between terms resulted in the evolution of a new tool, called a thesaurus, which has since operated in improving vocabulary control in the field of information storage and retrieval. The history of the development of knowledge organization systems show that about a century before the development of thesauri, there were vocabulary control tools and semantic relationship analysis systems that could have directly and indirectly contributed to the emergence of thesauri. These tools such as bibliographic classification systems and subject headings have relied on theoretical and technical debates and processes to facilitate the organizing of information, especially based on semantic relations and finding the accurate location of information in a given collection. In the context of Library and Information Science, according to Barbosa (1969), bibliographic classification and organization through establishing and using classified catalogs are understood as the process and tools of arranging books according to their subject, allowing them to be stored in a certain order in the collection (Ferreira et al. 2017).

The first classified catalog for organizing books based on a classification scheme was established in 1874 by J. Schwartz at the New York Apprentices Library (Schwartz 1876). The catalog of Boston Athenaeum of 1874 was a monumental product of this period based on the thinking of Charles Cutter (who is most clearly identified with the dictionary catalog) on how to achieve high standards through complete and carefully constructed entries. In addition to the publication of Cutter's standard *Rules for a Dictionary Catalog* in 1876, the Dewey Decimal Classification was published as the first modern classification scheme with subject index by Melvil Dewey (Hanson and Daily 2007). Dewey's writings include many contributions to the theory and practice of librarianship. First, he recognized that a systematic arrangement of books on shelves should make sense to the users; and second, he used numbers as notation symbols, which illustrated the way in which subjects were divided hierarchically, from main classes to specific topics (Estabrook and Haider 2017). In 1879, a committee was established by the American Library Association to study the problems of subject headings, a list of which would serve as an appendix to Cutter's *Rules.* In 1895, the project culminated in the publication of the *List of Subject Headings* through the use of semantic relations based on controlled language for use in the Dictionary Catalogue. This work became the Library of Congress list of subject headings in 1911 (Hanson and Daily 2007). Charles Cutter developed a classification initiative, the Expansive Classification System, in 1891, in which letters represent the subjects. The Library of Congress Classification as one of the most important classification schemes influenced by Cutter's classification scheme, was established in 1898 (Augustyn et al. 2013). The majority of the schedules were completed in the 1920s. This classification scheme relies on a pragmatic approach based entirely on the way in which the books were arranged on the shelves according their subjects (Immroth 1975). It uses both letters and numbers for its classification codes (Estabrook and Haider 2017).

Paul Otlet and Henri La Fontaine adapted the Dewey system as the basis for the much more detailed *Universal Decimal Classification* which was published in 1905 (Estabrook and Haider 2017). In 1906, James Duff Brown (1862-1914), a British librarian, released his classification system, the *Subject Classification*. Henry Evelyn Bliss, a librarian at the College of the City of New York, created a classification system called the *Bibliographic Classification* or Bliss Classification published in 1940-1953 (Ferreira et al. 2017). The *Colon Classification* was the first ever faceted classification scheme to organize library collections, developed by S.R. Ranganathan in 1933 (Ferreira, et al. 2017). It is general rather than special in nature, and it can create complex or new categories or classes through the use of facets, using colons. Each main class comprises five fundamental facets, or groups: personality, matter, energy, space, and time (Augustyn, et al. 2019). Therefore, it can be said that the application and creation of systems based on semantic relations and classification schemes in information storage and retrieval in libraries has had direct and indirect effects on the creation of thesauri, especially the structure of faceted classification schemes (Estabrook and Haider 2017).

The meanings and uses of the term thesaurus, based on the conceptual structure proposed by Roget, began to be diversified (Arano 2005). The modern use of thesaurus has not been so much for the purpose of Roget's *Thesaurus* as

for controlling vocabulary in the process of analysis of information (Foskett 1980). Roget's profound influence is still seen (Amirhosseini 2008), especially in information storage and retrieval (Foskett 1980; Chatterjee 1990). The term thesaurus has its etymological root in the Latin word thesaurus, which in turn comes from the Greek word thesaurós. In both cases, the meaning was a treasury and repository (of words) (Vickery 1960; Arano 2005). As early as 1951 (Stevens 1968; Foskett 1980), Hans Peter Luhn was acknowledged as the first person to discuss the thesaurus concept as influenced by Roget (Foskett 1980) and the structure of faceted classification schemes. Luhn worked at International Business Machines Corporation (IBM) and was searching for a computer process that could create a list of authorized terms for the indexing of scientific literature. The list was to include a structure of cross-references between families of concepts (Estabrook and Haider 2017). The Du Pont organization developed the first thesaurus and indexing system used to improve information retrieval through post-coordination in 1959 (Krooks and Lancaster 1993; Lancaster 1972). A major thesaurus, and one of the earliest, is the *Thesaurofacet* (1969), a detailed list of engineering terms designed by Jean Aitchison for the English Electric Company (Estabrook and Haider 2017). According to Vickery (1960) Helen Brownson first used the term thesaurus in information retrieval context and documentation (Arano 2005) in a paper presented at the Dorking Conference on Classification in 1957 (Gilchrist 1971). A thesaurus is a controlled vocabulary of terms in natural language that is designed for post-coordinate indexing (National Information Standards Organization 2003). This definition includes the characteristics of post-coordinate use of thesauruses; that is, the demand for their terms to be interrelated when searching for the information (Arano 2005). The conceptual framework of thesauri (Kless et al. 2012) includes semantic relations such as hierarchical and associative relations (International Organization for Standardization 2011). Controlled vocabularies such as thesauri, classification schemes, taxonomies, and other kinds of knowledge organization systems (Kless et al. 2014) have been used for decades for the organization of information, information retrieval, and other purposes (International Organization for Standardization 2013). Therefore, the development of the term semantic network plays a role as a tool in information storage and retrieval in documentation. The alphabetical order in dictionaries creates a syntactic unity between words, which is of course acceptable for dictionaries. On the other hand, the alphabetical order between words causes the scattering of related words, which is a factor in creating syntactic plurality, which is the weakness of dictionaries. In contrast, Roget's *Thesaurus* helps to create a semantic unity between related words based on semantic order. The practical purpose of this thesaurus is to provide assistance to writers who often search for appropriate words to express their ideas. Thus, from the contradiction between the alphabetical order in dictionaries (thesis) and the semantic order in Roget's *Thesaurus* (antithesis), a modern type of knowledge organization system is created. Subsequently, this modern tool, or thesaurus, while solving the problems of the alphabetical order in accessing related words, helps to create a semantic network between words by maintaining and relying on a semantic order based on the principal of unity. On the other hand, thesauri maintain the ease of known term access that is afforded by an alphabetical display (Gazan 2006). Relying on a pragmatic perspective, the modern thesaurus uses semantic order to make linkages between related words based on the principle of semantic unity in order to play its fundamental role and purpose in information storage and retrieval. This system was the main factor in the development of thesauri as a synthesis and completes the arguments related to logical relationships between thesis, antithesis and synthesis in clarification of the origins of the thesaurus development.

3.0 Historical origins of the development of various types of thesauri

As stated previously, the synthesis in a dialectic model can be described as a new thesis which has produced a new antithesis (Popper 1940). In other words, a synthesis is a new idea which is formed through the confrontation of the thesis and the antithesis. As stated in the previous section, thesaurus as a synthesis, while preserving the idea of access to words in dictionaries, solves the problems associated with alphabetical order (as a thesis) in order to make it possible to access related words and creates a semantic network between them using the Roget's idea (i.e., semantic order or antithesis) which could be applied in information storage and retrieval as a novel idea. This novel idea has the capacity to play a role as a thesis in the next logical relations or dialectic model to represent the flow of an idea. This section attempts to clarify the idea of thesauri development through analyzing the principle of unity in the progress of various kinds of thesauri. Figure 3 demonstrates the logical relations between the categories in the development of micro, macro and meta-thesauri.

3.1 Development of thesauri in diverse subject fields (specialized thesauri)

One of the most important purposes in thesaurus development was to provide a map of concepts that structure a specific field of knowledge (Aitchison 2000; National Information Standards Organization 1993; Lancaster 1972). This purpose indicated how concepts or ideas about concepts are related to one another, which helps an indexer or a

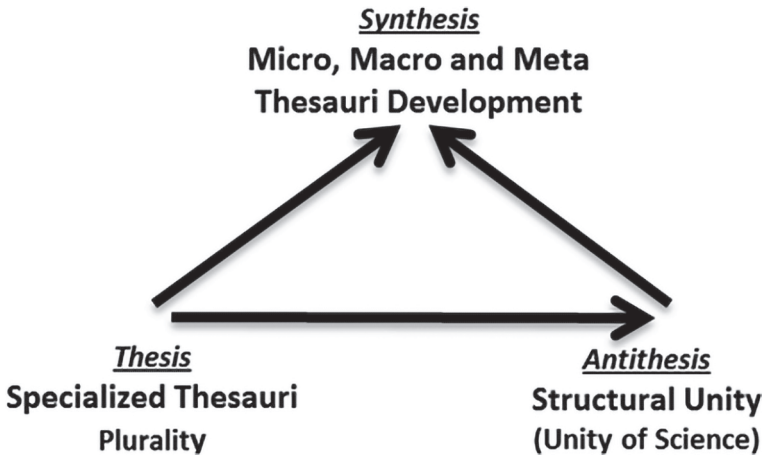

Figure 3. The logical relations between categories in the development of micro, macro and meta-thesauri.

searcher to understand the structure of the field (Foskett 1980). By the late 1960s and early 1970s, this approach resulted in the development of thesauri for diverse subject fields such as engineering, education, and medicine (Haynes 2004). The construction of thesauri was rapidly advanced in numerous fields of science. Therefore, the idea of thesaurus construction in diverse subject areas of the sciences functioned in the dialectic role of thesis to create many specialized thesauri in accordance with the principle of plurality.

3.2 Development of the principle of unity of science (structural unity)

The principle of unity of science is related to the principles of knowledge organization systems with regard to the principle of unity in organizing semantic networks. The same concepts, aims and methods in organizing and classifying knowledge in the principle of unity of science are compatible with the thought of knowledge organization systems. Some of the common concepts include the organization of knowledge, the organization of science, levels of organization, hierarchy of levels, hierarchical relations, hierarchical organization, part-whole relations and so on (Cat 2017). In 1958, Oppenheim & Putnam proposed an influential method for organizing the levels of sciences regarding unity of science. Oppenheim and Putnam (1958) believed that based on a general hypothesis, all special sciences will eventually be reduced to the fundamental physical science, for example, psychology can directly and stepwisely be reduced to physics as follow: first, psychology is reduced to biology, then biology is reduced to chemistry, and finally chemistry is reduced to physics. The levels of organization consist of hierarchical relations with wholes at higher levels and their parts at lower levels, which are introduced in order to make sense of such stepwise reduction and the right order of steps (Eronen 2015). The following figure shows the stepwise reduction and the right order of steps from physics to psychology in unity of science based on hierarchical relations.

Figure 4 shows the various levels in the relations between sciences from fundamental science to special sciences in the form of a hierarchical relationship. Unity of science relies on the thesis of reductionism that a special science, their concepts, laws, or theories, can be understood, or are explained by, the conceptual resources of another, more fundamental domain. Thus, psychology is supposed to be reducible to biology, biology is reducible to chemistry and finally chemistry is to be reducible to physics. In addition, the complexity

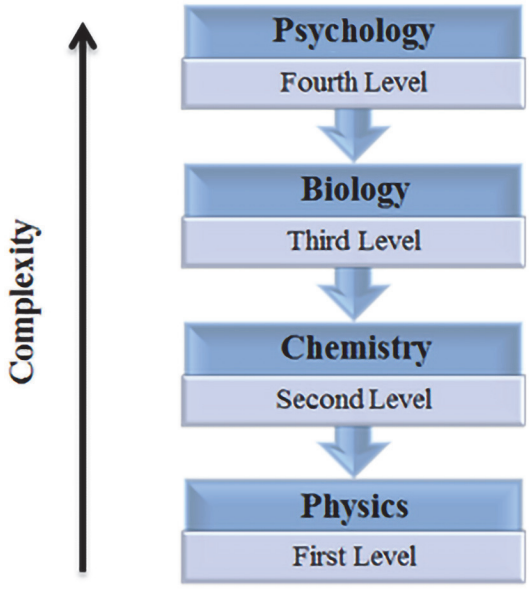

Figure 4. The hierarchical relations of sciences in the theory of unity of science.

of the sciences increases from the basic sciences to other special sciences. (Wimsatt and Sarkar 2006). Piaget (1918) has already suggested that the unity of science can be considered in terms of a circle of the sciences, where physics is the foundation for chemistry, chemistry is the foundation for biology, and biology is the foundation for psychology. Fodor (1974) believed that the assumption that the laws or theories of psychology are part of the laws or theories of physics is taken to i mply that psychological laws or theories must reduce to physical theories. He calls this picture the "generality of physics," which is the claim that every event that falls under a special science predicate also falls under a physical predicate, but not vice versa. In this hierarchy of sciences, therefore, entities at each level are composed of things of the next lower level. The higher-level causes can have lower-level effects (Eronen 2015) and each particular level includes all higher levels (Oppenheim and Putnam 1958).

Feibleman (1954) who provided some generalizations or laws of integrative levels has spoken of a kind of "super-science" [unity of science] to clarify the interrelations among disciplines like physics, chemistry, biology, psychology, and anthropology. As stated previously, Oppenheimer and Putnam (1958) have considered the idea of integrative levels to support the unity of science. Needham (1937) invented the term "integrative levels" and it was first introduced to knowledge organization in the late 1950s by the Classification Research Group (CRG). Integrative levels create classifications of the sciences which interrelate different domains of human knowledge according to a hierarchical order considered the most influential for structural analysis of knowledge organization systems like classifications, thesauri, or formal ontologies. In contrast to reductionism theories, the idea of integrative levels is a non-reductionist organization that could be defined as a developmental sequence in which entities at each new level integrate the essential properties and structures of the entities of the existing levels, while they exhibit some emergent qualities and, therefore, possess more complexity than their predecessors (Kleineberg 2017). However, the basic principles of reductionist and non-reductionist theories have a common point in adopting integrative levels to organize knowledge in a hierarchical order to achieve a unified semantic system. The aforementioned idea is recommended as a theoretical foundation to develop the structure of interdisciplinary knowledge organizations.

The above mentioned evolutionary process of science, based on the principle of unity of science as well as integrative levels, can be more precisely expressed through a related theoretical argument. This theory is called structural unity (Craig 1998). Regarding the relationship between the unity of science and structural unity, it should be mentioned that Oppenheim was not a reductionist philosopher (based on his academic projects from the 1930s through 1950s (Milkov 2013)), but rather looked forward to a more stylistic and structural unity of science. Thus, he proposed the search for shared elements of the epistemic process among substantively diverse sciences to clarify the commonalities among the sciences that abstracted from substantive differences through analyzing structural uniformities. It is perfectly commonplace to have a high-level structural unity within a theoretical domain of unity of science (Morrison 2000) and to analyze the concepts, laws and theories of sciences via a unified approach. A unified approach can be designed in variety of ways; the conceptual approach relying on structural unity (UIA 1995) is an example. Therefore, the idea of structural unity based on a hierarchical order has been taken into account in the theory of unity of science (Rescher 1997)

The theory of unity of science and the related theory of integrative levels, have played a great role in developing knowledge organization systems, especially in the integration of specialized thesauri based on structural unity. There is a great opportunity to reconstruct knowledge-based organization, such as knowledge organization systems, in order to achieve interrelated structures based on possible types of unity such as structural unity (Kuznetsov 1999). There are various techniques and standards to integrate specialized thesauri and other kinds of knowledge organizations and vocabularies (such as classification schemes, file plans, taxonomies, subject heading schemes, ontologies, synonym rings, terminologies and name authority lists) with one another by relying on structural unity. Specifically based on structural unity, ISO 25964-2 *Thesauri and Interoperability with other Vocabularies* (2013) and BS 8723-4 (2005) cover the mapping techniques between thesauri and other types of vocabularies. The related terms and concepts of two or more vocabularies can be linked with each other in terms of their conceptual relations based on these mapping techniques that rely on structural unity, to achieve huge gains for clarity, efficiency, economies of scale, interoperability, etc.

There are various models which aim to achieve integration and compatibility between different types of thesauri. In the structural unity model, all of the participating vocabularies share exactly the same structure of hierarchical and associative relationships between concepts that could be represented in different languages, notations or coding systems. The structure may be represented or expressed in any number of different languages, notations or coding systems (International Organization for Standardization 2013), especially in a symmetrical multilingual thesaurus (International Organization for Standardization 2011). However, the structural unity model is to be applied when combining the schemes of other knowledge organization systems and to address the linkages between two or more vocabularies (classification scheme, name authority list, etc.) (International Organization for Standardization 2013).

Unity is the main result of establishing a connection between words, both syntactically (dictionaries based on an al-

phabetical order) or semantically (Roget's work and thesauri in information storage and retrieval). Just as semantic unity versus syntactic unity played the role of antithesis in order to prevent the scattering of words and led to the creation of new types and generations of knowledge organizations, structural unity plays two important roles in dialectical relationships as thesis and antithesis. In the first stage, structural unity resulted in the development of specialized thesauri based on a semantic order. Thus, in the late 1960s and early 1970s, we saw the rapid production and growth of numbers of thesauri in various fields, and even in specialized fields of knowledge. Thus, once again but in a slightly different way, we encounter the scattering situation, but this time in the endless production of specialized thesauri, which reminds us of the principle of plurality. In the second stage, structural unity based on the theory of unity of sciences, seeks to create integration between specialized thesauri in a particular field, and also to create a bridge between different specialized thesauri in various scientific fields. At this stage, structural unity plays a role as antithesis based on the theory of unity of science by following the defined techniques and standards in order to create interoperability between various thesauri and other schemes of knowledge organization systems, and to prevent the scattering of various schemes of knowledge organization systems. The unity of science is the idea that all the sciences form a unified whole, while structural unity focuses on the detailed discussions of the integration found between vocabularies and the various schemes of knowledge organization systems. These ideas as an intellectual endeavor or antithesis are important drivers of the movement from plurality in developing specialized thesauri as well as other schemes of knowledge organizations (i.e., as a thesis) toward unity in mapping and integrating specialized thesauri in a field or in diverse subject fields. The antithesis clarifies a conflict between the principle of unity in developing integrated and mapped thesauri and other schemes of knowledge management systems, and the principle of plurality in developing special thesauri in diverse subject fields.

3.3 Development of various types of thesauri

Unity is the main idea in arranging compatible controlled vocabularies, such as specialized thesauri in diverse subject fields, in order to develop unified controlled vocabularies. This idea works in practice by operating four basic methods: mapping, switching, merging and integration (Aitchison et al. 2000). The combination of mapping, merging and integrating methods results in the synthesis of different thesauri (Tomorad and Zlodi 2005). This synthesis is an advance on the new unified controlled vocabularies: micro, macro and meta thesaurus. A microthesaurus is a designated subset of a thesaurus that is capable of functioning as a complete thesaurus (ISO 25964-2:2013). In other words, a microthesaurus is simply a part of a thesaurus that can function independently of its parent thesaurus. KOS vocabularies, especially thesauri, that are good resources for generating microthesauri would possess: a classificatory structure (e.g., *EuroVoc*), a faceted structure (e.g., *AAT, FAST*), or deep hierarchies (e.g., *AAT, NASA Thesaurus, STW Thesaurus for Economics*) (Zeng 2019). In general, making a new vocabulary through the derivation method, or creating a microthesaurus from a Linked Open Data (LOD) KOS is common (Zeng and Mayr 2018). In the early 1970s, Soergel (1972; 1974) proposed a universal source thesaurus to identify the essence of microthesaurus. In 1981, British Standard Institution (BSI) produced its microthesaurus, *Root Thesaurus* (Dextre Clarke 1981). Another example is the *Thesaurus of Common Topics* (TCT) developed by the Institute of Scientific, Technical and Economic Information Warsaw (Zeng 1992). The macro vocabulary approach resulted in developing the macrothesaurus described by Lancaster (1986). A macrothesaurus is constructed through the integration of specialized thesauri and related microthesauri (United Nations, Economic and Social Council 1971). Examples of macrothesauri include Integrated Multilingual Thesaurus for social sciences, constructed by UNESCO (Sager 1982) and *Universal Agricultural Thesaurus*, developed in 1989 (Andre 1989). A metathesaurus consists of a set of reference thesauri that may have more complex hierarchical structure and various indexing languages which are mapped onto one another via common hierarchically structured concepts (Zeng 1992). In other words, a metathesaurus includes specialized, micro and macrothesauri with a bridge linking them (Rada 1990). *Unified Medical Language System* (UMLS) is the most influential metathesaurus (Zeng 1992) supported by the National Library of Medicine (NLM), launched in 1986 (Simonet et al. 2010). In general, several specialized thesauri result in the construction of a microthesaurus while macrothesaurus is caused by mapping a group of specialized thesauri and microthesauri and finally, a set of the specialized, micro and macrothesauri are integrated to develop a metathesaurus. Therefore, the principle of unity is the main factor in the construction of various types of thesauri which works through integrating and mapping between different thesauri. This progressive movement microthesauri, through macrothesauri, to metathesauri constitutes a movement from plurality toward unity.

4.0 Historical origins of ontology development

The idea of creating a semantic network between terms led to the development of the thesaurus. Moreover, the principle of the unity of science and the principle of structural unity underlaid the integration of thesauri and the consequent creation of novel types of thesaurus – the microthe-

saurus, the macrothesaurus, and the metathesaurus. Therefore, the idea of producing and constructing thesauri reached its highest level in the creation of the powerful tools in information storage and retrieval. In this section, our discussion focuses on the historical origin of the principle that led to the development of the most recent form of knowledge organization system, the ontology. Figure 5 shows the logical relations between the categories in ontology creation.

4.1 Generality in the semantic relations of thesauri

In this section the synthesis, which previously played a role in the evolution of various types of thesauri, now plays a role as thesis. As mentioned earlier, specialized thesauri grew exponentially in one subject area and in diverse subject fields in the late 1960s and early 1970s. This situation led to the production of countless numbers of specialized thesauri, reminiscent of the principles of plurality. This dispersion in their production represents a thesis in the next logical relationship. In contrast, the theory of the unity of science and its related theory of structural unity, focused on developing collaboration and convergence of specific thesauri to increase their efficiency in information storage and retrieval. These theories are considered as antitheses for creation of new types of knowledge organization systems. On the other hand, new types of knowledge organizations, while maintaining the basic principles in development of specialized thesaurus (thesis), have been created by the merging and mapping techniques based on the theory of unity of science and structural unity (antithesis) in order to collaborate between thesauri. These new knowledge organization systems have had the capacity and capability to create interoperability between various thesauri and other schemes of knowledge organization systems as a novel synthesis. Thus, this new synthesis has provided the theoretical infrastructure which explains the evolution of various types of thesauri, ranging from the microthesaurus (greatest plurality, least unity) to the metathesaurus (least plurality, greatest unity). The development of micro, macro and metathesauri was caused by this movement. This kind of unity was generally derived from structural unity in the structure of thesauri. Structural unity preserved the structure of previous semantic relations (i.e., hierarchical and associative relations). The traditional structural relationships found in thesauri (hierarchical and associative) were too general in nature to provide a sufficiently granular representation of relational concepts. This means that these kinds of semantic relations have failed to embrace the precise semantic relations needed to organize items and concepts in the appropriate way. In other words, these semantic relations were not sufficiently accurate in the semantic network. If we accept that the principle of plurality hints at the tendency towards more kinds of things and the principle of unity points to the tendency towards fewer kinds of things, then "sufficiently granular representation" in semantic relations can be considered by determining the degree of unity or plurality in traditional structural relations (hierarchical and associative) in thesauri. Due to their essence, traditional structural relations cause a large number of terms to fall under general semantic relations. Thus, the number of general terms (high-level set of concepts) increases, the representation of granularity in semantic network decreases, and consequently traditional semantic relations cause the principle of plurality. It seems that related terms are organized at a level of generality which appears too broad to be useful for precisely characterizing relationships and causes an inadequacy of granularity in the semantic network. Consequently, the principal of plurality can be taken into account in traditional semantic relations regarding the increase in the number of general words. In conclusion, concepts should be related to one another through precise and appropriately granular semantic relationships; this will lead to a higher level of conceptual organization and integration of the semantic network and so leads to a higher level of conceptual unity in the resultant knowledge organization system.

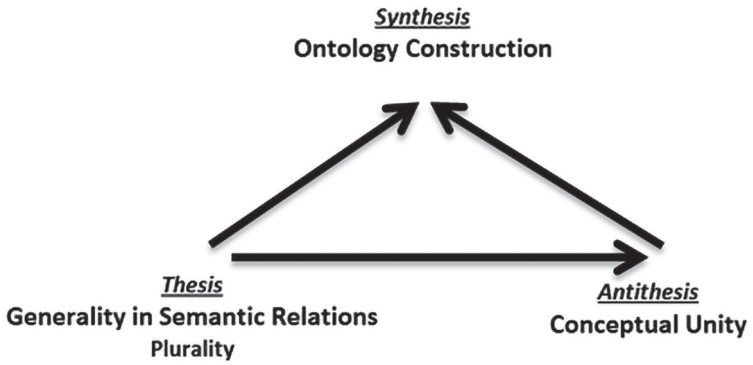

Figure 5. The logical relations between the categories in ontology creation.

4.2 Development of the idea of conceptual unity

The principle of structural unity was the source of mapping and merging of vocabularies in various thesauri in the form of a unified vocabulary control system. In this manner, an opposing idea was formulated to shift from information storage and retrieval to knowledge representation and organization to achieve a yet more precise organization of knowledge. This new idea relied on identifying the conceptual dimension in knowledge organization systems that could be useful for revising and modifying thesauri.

Conceptual unity is closely related to unity of science, and the area of unified science is often used as a synonym for "integrated science". Moreover, conceptual unity encompasses structural unity which received some attention in the field of education in the 1970s (Wei 2015). Husserl (1913) asserts that there is a conceptual unity of being, or conceptual unity of object: a unity embracing both the real and ideal. However within this unity there is a fundamental ontological difference between the two parts. This distinction can be clarified through the differences between an ideal being and a real being, being as species and being as individual respectively. The conceptual unity likewise splits into two essentially different types as general determinations are affirmed or denied of a species (ideal being), or properties are affirmed or denied of an individual (real being). In each case, something (a predicate) pertains or does not pertain to a being or object (a subject), especially in determination of the sense of the ideal object. In other words, the identity and the difference between the real and ideal depends upon the identity and difference in the sense of the predication attached to each (Mensch 1981). Thus, conceptual unity focuses on logical species and their instances which can be realized through precise and sufficiently granular semantic relationships based on a shared conceptualization (Hopkins 2017) in an ontological perspective. The ontological perspective relies on the understanding of Being [with things (object)] (Baur 1996) which is constructed out of elements derived from experience (Heidegger 1962). Moreover, conceptual unity has played the role of the standard of intelligibility, by relying on harmony (Cat 2017). In contrast, Heidegger (1962) believed that the structural unity is not something that is constructed from within experience, but is in fact an "existential-priori" unity which can be understood in terms of subjective (a subject) capacities (Heidegger 1962b). In practice, the first and the simplest kind of unity, structural unity, is when all the thesauri share exactly the same structure of hierarchical and associative relationships between terms, in which the relationships are too general in nature to represent the appropriate granular semantic relations (International Organization for Standardization 2013). In the same way, terms coming from thesauri denote the same concepts (Jarrar et al. 2014). Moreover, structural unity is based on an epistemological approach (Rysiew 2016) which is concerned with knowledge (Steup and Neta 2020). Morrison (2000) believed that structural unity is sometimes inconsistent with an account of the specific, often complicated and messy, underlying physical mechanisms at work. A scientific explanation must consist of an account of, and impart an understanding of, these underlying mechanisms. (Wayne 2002). Consequently, conceptual unity is based on an ontological foundation and focuses on the understanding of being, while structural unity relies on an epistemological approach which is concerned with knowledge. Moreover, conceptual unity embraces both logical species and their instances, real being and ideal being, species and individual, or object and subject, by making relationships between concepts based on a shared conceptualization. In contrast, structural unity can be understood subjectively (as a subject), and in practice it is the first and the simplest kind of unity for sharing the structure of semantic relations between words in thesauri, without changing their previous structure and in the same way that they existed before. Finally, in opposition to conceptual unity, which is more understandable and creates a harmony in knowledge organization systems especially ontologies, structural unity merges knowledge organization systems, especially in thesauri, by providing simple and superficial designs that are sometimes imprecision and complex. In conclusion, due to its reliance on ontological foundations in creating precise conceptual relationships between concepts through a shared conceptualization, conceptual unity has the ability to be understood and applied more frequently than structural unity in developing modern knowledge organization systems.

In developing a novel system, the principle of conceptual unity was a foundation for the focus on conceptual dimension. Conceptual relations rely on the relation between generic and specific concepts (Coffey 2018), especially in distinguishing between classes and individuals (instances) (International Organization for Standardization 2013). Prior knowledge organization systems such as the thesaurus have been challenged by their relationships between concepts, specifically in terms of establishing a high granular level of organization (Cat 2017). Therefore, conceptual unity, derived from strong theoretical arguments, resulted in the evolution of new knowledge organization systems based on conceptual relations.

4.3 Development of ontology construction

Conceptual unity as opposed to structural unity, has a strong capacity to create a system of understandable and applicable granular semantic relations between concepts through a shared conceptualization based on a high theoretical perspective (i.e., ontological foundations). The deep

philosophical, theoretical and practical foundations of conceptual unity in organizing the precise semantic relations between concepts have enabled the evolution of the modern knowledge organization system that is known as the ontology. In recent years, ontologies have been viewed as a new type of controlled vocabulary (International Organization for Standardization 2013) and a modern knowledge organization system (Kless 2014). The word "ontology" derives from the Greek roots onto- (being) and logos (word, i.e., study of) (Breitman and Leite 2003). Christian Wolff (1730) popularized (in philosophical circles) the word ontology as a "demonstrative [i.e., rational and deductive] method", and purported to investigate the most general predicates of all entities as such. Following Wolff, Alexander Baumgartens (1740) defined ontology as "the science of the most general and abstract predicates of anything". Immanuel Kant (1781) launched an epoch-making attack against rational ontology in the sense of Wolff and Baumgartens. Kant's work *Critique of Pure Reason* is the work of a man who was obsessed, and deeply distressed, by ontology. Although the concept of ontology preceded the word ontology, it can be assumed that only when such a word came into use, could philosophers begin to understand fully all the implications of the concept. The philosophical study of being goes back to ancient Greek times, arguably beginning with the pre-Socratic philosopher Parmenides. Aristotle discussed the philosophical concept of ontology; however, he did not call the science of being, ontology but used the terms first philosophy, theology, or metaphysics (Mora 1963).

Ontology has focused on the systematic study of existence (Kless et al. 2012; Fisseha 2003) and the nature of things (Welty and Guarino 2001), or the study of being (Simperl 2009). The term ontology entered computer science and artificial intelligence to formalize the kinds of things related to system or a context (Simperl 2009). In fact, the identification of concepts and their relations was known as ontology (De Silva 2008) which is an explicit specification of a conceptualization (Gruber 1993a, 1993b). Ontology played a great role in knowledge management operations (De Silva 2008), especially in knowledge sharing in the 1980s (Gruber 1993b, 2001, 2009). Some large and robust ontologies such as WordNet and Cyc (Gruber 2008) were developed during the second half of the 20th century (Liu and Ozsu 2008). In the early years of the 21st century, cognitive science studies entered the interdisciplinary field in ontology development (Razali et al. 2010). Ontology has a philosophical background with new applications in computer science and artificial intelligence when it comes to operating knowledge management systems through cognitive approaches (Amirhosseini 2016). The conceptualization applied by authors to the terms thesaurus and ontology is quite diverse, and sometimes authors confuse, oppose, complement or overlap these concepts (Arano 2005). This has led to the perception by some that thesauri as kinds of knowledge organization systems are ontologies (Tudhope 2011) which use the syntax of OWL (Kless and Milton 2010) while others have emphasized the need to re-engineer a vocabulary in order to use it as an ontology (Kless et al. 2014) as a natural successor to thesauri (Fisseha 2003). When a knowledge-rich description is needed to achieve web-based knowledge in the semantic web, thesauri turn out to provide only part of the knowledge needed (Wielinga et al. 2001). Consequently, ontology supports the aforementioned need through creating rich and precise semantics (Garshol and Naito 2004) to establish relations between concepts (Pidcock and Uschold 2016) with the application of semantic web technologies (Fensel et al. 2003) to develop ontology-driven knowledge (Daconta et al. 2003) in a specific field of knowledge (Muñoz et al. 2017; Arano 2005). In conclusion, traditional structural semantic relations (hierarchical and associative) were a basis for developing thesauri and their various types. These semantic relations which were too general in nature caused a large number of terms to fall under the head of general semantic relations. The level of generality of these semantic relations displayed the principle of plurality which can be considered as a thesis in the logical relations in creating ontologies. In contrast, concepts should be related to one another through precise semantic relationships through a shared conceptualization based on conceptual unity, which can be taken into account as an antithesis. Conceptual unity, while preserving the principles governing traditional semantic relations, has played a great role in creating precise conceptual relationships and caused the creation of the novel and modern manifestation of knowledge organization system known as ontology (as a synthesis).

5.0 Historical origins of various types of ontology

In the previous iterations of the dialectical process, structural unity was the primary principle underlying the development of various kinds of thesauri, while the principle of conceptual unity underlaid the development of ontologies. This section focuses on how the thesis- antithesis-synthesis dialectic has underpinned the development of different kinds of ontology. Figure 6 below sets out the logical relations between the three moments of the dialectic in the development of upper, middle, and lower level ontologies.

5.1 Development of ontologies in diverse subject fields

The synthesis of the former dialectical model expressed the idea of creation and development of specialized or domain ontologies based on conceptual unity in knowledge storage and retrieval. In this section, this idea can be considered as a

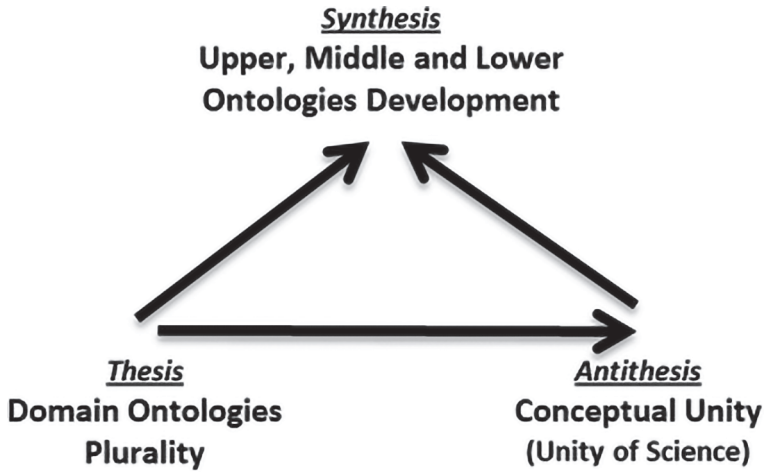

Figure 6. The logical relations between the categories in the development of upper, middle and lower levels ontologies.

new thesis. Task and domain ontologies all relate to the context of a specific domain (e.g., banking, industry) or task (e.g., accounting, sales) (Rosing et al. 2015). A domain-specific ontology is intended for sharing concepts and relations in a particular topic, area of interest (Jin 2018) and application, and a specific view point defines how a group of users conceptualize and visualize some specific phenomenon (Roussey et al. 2011; Mohapatra and Mohapatra 2014) which was developed by domain experts (Noy and McGuinness 2001), for example, information technology or computer languages, or other particular branches of science. Task-specific ontologies specify conceptualizations that are needed to carry out a particular task (Jin 2018). Many disciplines are now developing standardized ontologies which domain experts can use to share and annotate information in their fields, for example medicine (Price and Spackman 2000). A large number of specialized task and domain ontologies have been developed in various fields of science, from medical ontology to cell ontology. Different ontologies in the same domain currently arise due to different languages (Mohapatra and Mohapatra 2014). The most important reason for developing diverse and different task or domain ontologies was the identification of the most specialized and relevant concepts to link to other important concepts (Dombayci 2019) in a specific domain (i.e. from the most important ones to the most specific ones or reverse) via domain experts and users (Corcho et al. 2003) for effective data sharing and information flow (Muñoz et al. 2017). Vast numbers of specialized ontologies have been developed in various fields of sciences that have already relied on the notion of conceptual unity; this resulted in the evolution of the principle of plurality in developing a large number of task and domain ontologies.

5.2 Development of the principle of unity of science (conceptual unity)

The development of different types of specialized ontologies in diverse domains of knowledge represents the principle of plurality, which forms the thesis of a new cycle of dialectic. Opposed to this thesis is a movement towards integration of different domain ontologies and the harmonization of specialized ontologies: this is an antithesis tending towards unity. The harmonization of specialized ontologies can be defined through some theoretical concepts such as unity of science, integrative levels and conceptual unity. The similarities and differences between structural unity and conceptual unity have been explained in section 4.2. Moreover, the idea of the unity of science and the theory of the integrative levels were identified in section 3.2 as well as the principal of conceptual unity which was clarified in section 4.2. The hierarchical organization of sciences is comprised of compositional levels, such that things at a higher level are composed of the things in the following lower level. Simply put, the wholes occupy higher levels and their parts are at lower levels. Oppenheim and Putnam (1958) proposed the following list of levels: social groups, living things (multicellular), cells, molecules, atoms, and elementary particles. In this hierarchy, entities at each level are composed of the things in the next lower level: elementary particles at the lowest level, atoms at the next higher level, and so on (Eronen 2015). The principle of the unity of science regarding the hierarchical organization of sciences is that the levels are compositionally related (Cat 2017), wholes are at higher levels and their parts at lower levels (Eronen 2015). The idea of the unity of science consists of the conceptual unity that focuses on the conceptual relations between generic and specific concepts (Coffey 2018) or class and individuals (instances) (International Organization for Standardization

2013) that are unified in the hierarchical structure of conceptual relations. The mentioned theoretical arguments are closely related to the concept of unity in the conceptual relations of ontology. Thus, the hierarchical levels in the theoretical idea can play a role in realizing the hierarchical layers or levels in ontologies and in developing various types of ontologies in the form of a unified structure. The aforementioned theoretical framework can illuminate how the principle of unity occurs in the conceptual relations found in ontologies. Most notably, the important role of hierarchical layers or levels in the constitution of the unity of science can also be discerned in the hierarchical levels in ontologies as well as in the different layers of ontologies forming part of the informational landscape today. Just as these hierarchical layers reflect a drive towards unity in science, so do they represent a movement towards greater unity in the realm of ontologies.

In addition to the theoretical arguments regarding the unification of specialized ontologies, different kinds of ontologies should be defined to enable operational analysis to create unity between specialized thesauri. Ontologies can be distinguished in terms of their breadth and depth (deep and broad ontologies). Deep ontologies are very efficient, effective and useful for describing a particular task or domain, but typically will not be of much use outside the scope of the task(s) or domain(s) for which they were designed. On the other hand, broad ontologies, which cover a wide range of different tasks, are highly reusable across many tasks, but the general essence of these types of ontologies makes their use very cumbersome, and the resulting expressions hard to understand (Aben et al. 1994). Deep ontologies are called core domain ontologies, domain ontologies, task ontologies or specialized ontologies that are associated with more restricted fields of interest (Jin 2018). Since domain ontologies represent concepts in very specific and often eclectic ways, they are often incompatible. On the other side, broad ontologies include low, middle and top-level ontologies. Moreover, top-level ontologies, foundation ontologies, broad general-purpose ontology and general ontologies have been taken into account as the synonyms for upper level ontologies. The incompatibility between different types of specialized or deep ontologies such as domain or task ontologies can be resolved through application of some methods such as the merging method to achieve semantic harmonization, with a view to developing broad ontologies. For instance, the method of merging specialized ontologies with the help of a common foundation, or top-level, ontology providing a set of basic elements which require specific meanings, alleviates the incompatibility (Mohapatra and Mohapatra 2014). This foundation results in the semantic interoperability to integrate heterogeneous conceptual relations (Shen and Chen 2012) in a unifying framework for representing and integrating knowledge and may support the communication and harmonization of conceptual systems in various domains (Jin 2018). Additionally, if the construction of a large ontology is required, several existing ontologies can be integrated to develop a large domain in the form of a broad general-purpose ontology (Noy and McGuinness 2001). Last but not least, top-level or foundational ontologies remain closest to the original philosophical notion and idea of ontology. This type of ontology aims to provide conceptualizations of general notions in the domain of discourse. In the development of various types of ontologies, the specialized ontologies which were developed via a principle of plurality should therefore be integrated to develop harmonized large ontologies to create a unified thought of knowledge based on theoretical and technical methods.

5.3 Development of the various types of ontologies

The contradiction between the principle of pluralism inherent in the development of different ontologies in diverse subject fields (thesis) and the principle of unity inherent in the hierarchical ordering of different kinds of ontologies (antithesis) has led to the evolution of new kinds of ontologies. In other words, based on the principle of plurality, a large number of specialized or deep ontologies emerged in the subject field of science as well as in various scientific fields (thesis). On the other hand, the widespread and numerous productions of specialized ontologies caused an incompatibility between them. Based on the theory of unity of science and related theories, conceptual unity and integrative levels, while preserving the principles of conceptual relations in ontologies, there is the possibility of integration of specialized ontologies to create a semantic harmony between them through techniques such as merging (antithesis). This integration has led to the evolution of a new generation and kind of ontology such as lower, middle and upper level ontologies (synthesis). For instance, the principle of unity between heterogeneous concepts which creates a harmony among conceptual relations, and forms unified knowledge-based systems such as BFO has led to the creation of top level ontologies (Grenon and Smith 2004) as a kind of broad ontology. Through the operation of these ontologies, recall is significantly improved while precision is also preserved in knowledge storage and retrieval (Xu et al. 2014; Jain et al. 2011; Mascardi et al. 2008, 2010; Kwak and Yong 2010; Dragoni et al. 2012). There are a few types of broad ontologies which have different roles (Mizoguchi 2003). According to their level of abstraction, ontologies can be divided into three groups: upper, middle (Eklöf and Martenson 2006) and lower level (Bergman 2010) ontologies. Upper ontology: foundational or top level ontologies are generic ontologies with higher levels of abstraction (Kitamura 2006). They define basic notions like objects, relations, events, processes and so on (Roussey et al. 2011).

Upper level ontologies consist of basic and generic concepts and specific relations which provide the basic structure to address a broad range of domain areas (Amirhosseini and Salim 2011). Lower level, domain ontologies or domain specific ontology contain knowledge about a specific domain (Heer et al. 2009; Nisha 2008). The lower ontologies can extend the general concepts in the upper ontology, define additional concepts in a particular domain (Ye et al. 2007), draw the relationships between those concepts and model a specific domain (Bateman et al. 2010; Noah 2005; Nazri et al. 2010). This ontology covers domains (i.e., lower levels) and sub-domains (i.e., lowest levels) for example, medicine and pediatric medicine (Obrst et al. 2003; Mohd et al. 2008, 2009). Middle level ontology serves as a bridge between universal concepts expressed in the upper ontology and domain-specific concepts in a domain ontology (or lower level ontology) (Eklöf and Martenson 2006). This type of ontology covers concepts which are neither generic, like the upper ones, nor specific like the lower or the domain ones (Amirhosseini and Salim 2011). Therefore, the new idea is expressed that various types of ontologies (i.e., upper, middle and lower levels ontologies) have been developed regarding the principle of unity for the fulfillment of a comprehensive understanding of science and knowledge and to increase recall and precision in knowledge storage and retrieval.

6.0 Synthesizing of discussions in a dialectical scheme in the evolution of thesauri and ontologies

This section focuses on the synthesis of the discussions that summarize the various points of view related to the creation of thesauri and ontology. These discussions are presented as the logical relations that exist between the various categories in the evolution of knowledge organization systems. In the development of thesauri, ontologies and their various kinds, the use of a dialectic model has clarified the roles of different ideas in each of the categories of thesis, antithesis and synthesis. This dialectical model is divided into four sub-dialectic models. The most important ideas and their roles in logical relationships are demonstrated in the following dialectic model. Figure 7 shows the logical relations between categories in the creation of thesauri and ontologies.

The above figure clarifies the logical relationships in drawing the flow of ideas that triggered the evolution of knowledge organization systems from dictionaries to other types of ontologies. The most important features in the evolution of knowledge organization systems reflected in the dialectic model can be divided into three groups.

1. Unity is an important principle in the evolution of knowledge organization systems and played a major role as an antithesis in the four sub-dialectic models. The principle of unity caused the development of novel systems of integrated semantic networks between terms and concepts. The idea of unity was in conflict with the idea of thesis which relied on the principle of plurality. The idea of contradiction between thesis and antithesis can be clarified through the definition of sublation in the integration of the two opposite ideas for creation of a new idea, that is synthesis. From the contradiction between the thesis (the principal of plurality) and antithesis (the principal of unity), we can recognize the main two senses of sublation process, that are destroy and preserve as opposite senses in analyzing the essence of the contradiction between ideas. The principle of unity in contrast to the principle of plurality, while rejecting some of the principles of the thesis and antithesis, preserves some of their fundamental principles. On the other hand, the sense of rise or elevation results in movement from the principal of plurality toward the principal of unity elevating them into the higher unity of the synthesis. In other words, a new concept or idea emerges that leads to the evolution of the various types of knowledge organization systems which is demonstrated in Figure 7.

Figure 7 shows that in the first sub-dialectic model, the semantic order (antithesis) in contrast to the idea of an alphabetical order (thesis) in dictionaries underlies the development of Roget's *Thesaurus*, which is used by writers for expression of ideas. The idea of semantic order while preserving the principal of the syntactic unity in the unification of scattered words based on specific order, results in the development of a novel generation of knowledge organization systems known as the thesaurus (synthesis), which is developed and based on semantic relations between terms. Thesauri rely on semantic order in creating semantic relationships between terms, at the same time maintaining the ease of known term access that is afforded by an alphabetical display. On the other hand, with the rapid growth of specialized thesauri in particular scientific fields, we have seen the dispersion and incompatibility between such thesauri. Thus, the synthesis in creating specialized thesauri in the previous step becomes a thesis based on the principle of plurality. In contrast, the idea of the compatibility development between specialized thesauri is formed by relying on structural unity and integrative levels based on the theory of the unity of science. In the analysis of integration between thesis and antithesis in the second sub-dialectic model, while preserving the basic principles of semantic relations development in specialized thesauri, relying on the above theories and standard techniques such as merging, the interoperability between specialized thesauri result in developing new kinds of thesauri known as micro, macro and metathesauri.

The traditional structural relationships did not include the precise semantic relations which resulted in an increase in the number of general words (principal of plurality). In contrast, concepts should be related to one another through

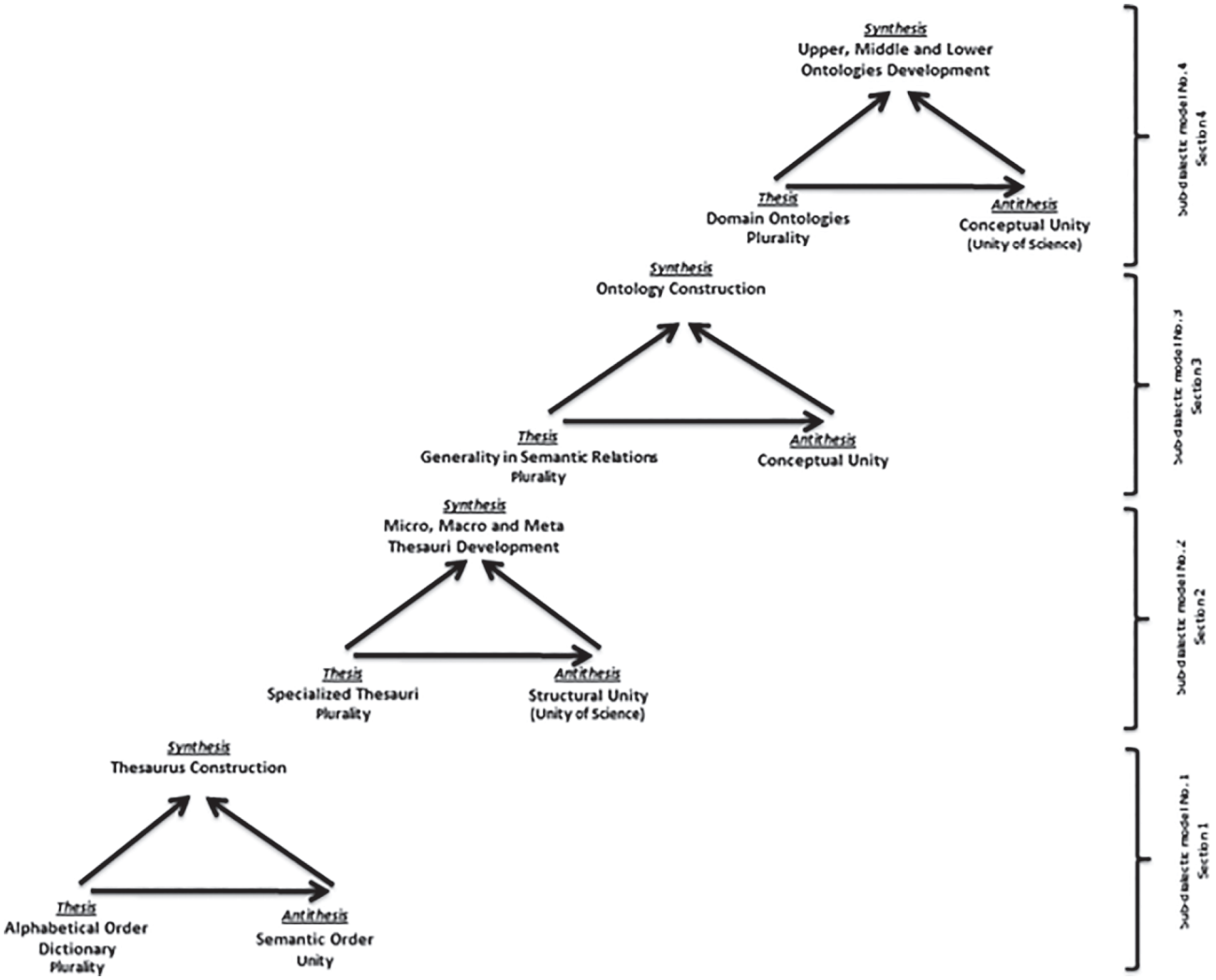

Figure 7. The logical relations between the categories in creation of thesauri and ontologies.

appropriately granular semantic relationships to allow more integration in the semantic network based on conceptual unity (Antithesis). Therefore, in the third sub-dialectic model, the novel knowledge organization systems known as ontologies created by a higher level of conceptual organization, preserve the basics of the formation of semantic relationships in thesauri (thesis) based on conceptual unity. On the other hand, the dramatic development of ontologies in a scientific field and in different scientific fields led to the production of a large number of specialized ontologies. Thus, the synthesis of ontology creation in the previous dialectic model became a thesis based on the principle of plurality in the fourth sub-dialectical model. The diversity in the production of ontologies caused an incompatibility between them and the formation of an antithesis in this regard. Thus, in order to form interoperability between specialized ontologies, new kinds of the compatible ontologies were created through relying on the theory of unity of science and its related theories such as conceptual unity and integrative levels as well as the application of practical techniques such as the merging method. These novel syntheses are called lower, middle and upper level ontologies. Consequently, the movement from plurality toward unity has been taken into account in the evolution of knowledge organization systems to increase the performance of information and knowledge storage and retrieval based on theoretical arguments and technical operations.

2. The main origin of the ideas: in addition to the concept of unity in the flow of thought and ideas in the evolution of thesauri and ontologies, the dialectical model of the creation of knowledge organization systems encompass a strong historical and philosophical background. The history of the evolution of ideas in the creation of knowledge organization sys-

tems dates back to 1600 AD, when alphabetical order was accepted as the basis for creating a syntactic unity between words in dictionaries. In this article, dictionaries have been determined as the origin of the movement of ideas from the alphabetic order (syntactic unity) to the semantic order (semantic unity). The movement of ideas has been identified through analysis of the logical relations between ideas in four dialectic schemes. In this way, knowledge organization systems are created based on specific ideas intended for them, which range from the simplest type of order (alphabetical order) to the most complex types (semantic order). In the development of ideas of knowledge organization system, we find that the two elements of thesis and antithesis have played an important role in the creation of new generations of knowledge organization systems as synthesis. The synthesis formed in each of the dialectical scheme appears in the next step or dialectical scheme as a thesis. This new thesis also becomes another synthesis in the logical relations between ideas, through the process of sublation. Therefore, the origin and evolution of ideas in the creation of knowledge organization systems historically dates back to about 400 years ago. The evolution of knowledge organization systems can be identified through a dialectical movement by analyzing the logical relations between ideas. The dialectical movement of ideas that can be clarified based on dialectic schemes is itself a philosophical artifact, which shows the logical course of the relationships between ideas in the creation of various kinds of knowledge organization systems.

3. The evolution of structure and application: the various types of knowledge organization systems have followed specific aims which have also played a major part in their structure. Dictionaries have organized words in an alphabetical order to allow easy access to terms in a vocabulary. Roget's *Thesaurus* presented a multi-dimensional approach to vocabulary organization through the unification of related terms to provide assistance and help with the expression of ideas and literary composition. Thesauri embrace a specific structure in organizing the terms' semantic network for the sake of increasing the efficiency of information storage and retrieval performance. Finally, the structure of conceptual relations was developed between concepts in ontologies for increasing the effectiveness of recall and precision when organizing and representing knowledge. Thus, each of the knowledge organization systems has targeted a specific purpose in the form of an appropriate structure. Subsequently, in the evolution of knowledge organization systems, the tools of knowledge organization have complemented one another in an evolutionary process to achieve a more practical usage with an increase in storage and retrieval performances of data, information and knowledge.

7.0 Conclusion

The dialectic scheme has the capacity and the capability to clarify the evolutionary processes involved in various kinds of natural and artificial phenomena. This article attempted to recognize the most effective factors in the creation of ideas and developmental processes associated with the evolution of knowledge organization systems. This process results in the recognition of the historical origins of various types of knowledge organization systems and identifies their evolution. Moreover, with the establishment and the existence of a logical connection between various ideas, experience becomes a key factor in recognizing the strengths and weaknesses of the evolutionary process of knowledge organizations and further prepares the capacity to predict ideas and related productions in the form of a scientific conjecture. Here, the most important features derived from the arguments related to the logical relations in the evolutionary process of knowledge organization systems are explained as follow:

1. The identification of ideas: the dialectic scheme has presented a model which identifies the main ideas in the triad of thesis, antithesis and synthesis and additionally clarifies the origins of ideas that played critical roles in the evolution of knowledge organization systems.

2. The principle of unity: the core point of the dialectic model is the principle of unity in knowledge organization systems, which is explained in three points of view as follows: firstly, knowledge organization systems have their unified structure based on the semantic network between terms and concepts, secondly, the evolutionary process of knowledge organization systems shows that these tools were created through the operation of the principle of unity, and, finally, various kinds of theories and methods were applied to integrate the structure of knowledge organization systems, namely alphabetical order, semantic unity, unity of sciences, structural unity and conceptual unity.

3. The principle of plurality: the construction of thesauri and ontologies in diverse subject fields were occasioned by the principle of plurality. The concept of pluralism resulted in the realization of novel ideas in the development of various types of knowledge organization systems.

4. The contrast between plurality and unity: logical relationships between categories shows that theses have relied on the principle of plurality, and antitheses have depended on the principle of unity. A conflict between these ideas enables the progress of a new idea, for instance, the conflict between generality in semantic relations based on structural unity and conceptual unity brings about the novel idea of

ontology creation. Moreover, this conflict between ideas can be explained through the movement from plurality toward unity in the development of knowledge organization systems and their types.

5. The performance of knowledge organization systems: the dialectic model has the capacity to show the movement from simplicity to complexity (i.e., from dictionaries to ontologies) or the movement from plurality toward unity (i.e., from thesaurus in diverse fields of science to micro, macro and meta-thesauri). This potential culminates in improvement of the performance of information and knowledge storage and retrieval in terms of recall and precision.

In this article, the dialectic model has been used to examine the process of evolution of some of the most prominent tools of vocabulary control, namely, dictionaries, thesauri, and ontologies. However, the dialectic model can also be applied in other forms of knowledge organization systems such as lists, authority files, gazetteers, synonym rings, classification schemes, folksonomies, taxonomies and topic maps (Zeng 2008) to determine their related categories (i.e., thesis, antithesis and synthesis) and identify their roles in the process of evolution of knowledge organization systems.

Notes

1 This section has focused on the development of dictionaries in the modern period since 1600 AD, and the development of early or ancient lexical and word lists (i.e., premodern period) has not taken into account in the discussions on the history of dictionaries compilation. The source of discussions was the second chapter entitled "A brief history of English lexicography" In *Dictionaries, The Art and Craft of Lexicography* by Sidney I. Landau, 2nd ed. Cambridge: Cambridge University Press, 2001, pp. 46-97.

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