

Topic Analysis of the Research Domain in Knowledge Organization: A Latent Dirichlet Allocation Approach

Soohyung Joo*, Inkyung Choi**, and Namjoo Choi***

*University of Kentucky, School of Information Science, Lexington, KY 40506,
<soohyung.joo@uky.edu>

**University of Wisconsin-Milwaukee, School of Information Studies, Milwaukee, WI 53211,
<ichoi@uwm.edu>

***University of Kentucky, School of Information Science, Lexington, KY 40506,
<namjoo.choi@uky.edu>



Soohyung Joo, PhD, is an assistant professor in the School of Information Science at the University of Kentucky. He obtained a PhD in information studies from the University of Wisconsin-Milwaukee. His main research areas include online resource use, information retrieval, domain analysis, and data analytics. His research work has been published in information science journals, including the *Journal of the Association for Information Science and Technology*, *Information Processing & Management*, and *Knowledge Organization*.



Inkyung Choi is a PhD candidate at the School of Information Studies at the University of Wisconsin-Milwaukee. She holds a master's degree in library and information science from the iSchool at Syracuse University. Her research interests stem from intellectual curiosity about social and cultural pluralistic perspectives, which influence ways of organizing knowledge. Her dissertation research is a mixed-methods study investigating ways in which a globalized knowledge organization system can be adapted to a culturally different regional environment and the impacts of sociocultural factors on the adaptation of the system.



Namjoo Choi, PhD, is an associate professor at the School of Information Science, College of Communication and Information, University of Kentucky. He received his PhD in informatics from the University at Albany, State University of New York. His research interests include online communities, free/libre open source software, and technology adoption and post-adoption. His research work has been published in *IEEE Software*, *Journal of the Association for Information Science and Technology*, *Library & Information Science Research*, and *Journal of the Association for Information Systems*.

Joo, Soohyung, Inkyung Choi, and Namjoo Choi. 2018. "Topic Analysis of the Research Domain in Knowledge Organization: A Latent Dirichlet Allocation Approach." *Knowledge Organization* 45(2): 170-183. 43 references. DOI:10.5771/0943-7444-2018-2-170.

Abstract: Based on text mining, this study explored topics in the research domain of knowledge organization. A text corpus consisting of titles and abstracts was generated from 282 articles of the *Knowledge Organization* journal for the recent ten years from 2006 to 2015. Term frequency analysis and Latent Dirichlet allocation topic modeling were employed to analyze the collected corpus. Topic modeling uncovered twenty research topics prevailing in the knowledge organization field, including theories and epistemology, classification scheme, domain analysis and ontology, digital archiving, document indexing and retrieval, taxonomy and thesaurus system, metadata and controlled vocabulary, ethical issues, and others. In addition, topic trends over the ten years were examined to identify topics that attracted more discussion in the journal. The top two topics that received increased attention recently were "ethical issues in knowledge organization" and "domain analysis and ontologies." This study yields insight into a better understanding of the research domain of knowledge organization. Moreover, text mining approaches introduced in this study have methodological implications for domain analysis in knowledge organization.

Received: 23 May 2017; Revised: 19 August 2017; Accepted: 16 September 2017

Keywords: knowledge organization, KO, research, topic modeling, domain analysis, research trends

1.0 Introduction

According to Andersen and Skouvig (2006, 302), knowledge organization (KO) has been a field that investigates “the organization and representation of texts in various forms of information systems for the purpose of mediating, supporting, and producing social practices that constitute every kind of information system.” Hjørland (2008) stated that KO encompasses various activities of document description such as indexing and classification, databases, archives and others. These activities of document description involve multiple stakeholders, such as librarians, archivists, subject specialists, and computer algorithms. Hjørland (2008) also observed that KO consists of multiple pillars related to library and information science, supporting learning and research activities, and concepts and theories of knowledge. The science of KO involves multi- and inter-disciplinary comprehension of knowledge and is concerned with the heuristics for conceptual ordering of that which is known or perceived (Smiraglia 2015a). In this way, prior discussions on definitions of KO imply the nature of KO is multifaceted, which includes multiple constituents, diverse objects, and activities. This complex nature of KO has resulted in various subordinate topics within the research field that are explored by researchers with diverse backgrounds and interests.

KO researchers have exerted concerted efforts to probe such diverse aspects of research topics in the KO domain. Multiple methods have been applied to understand the sphere of KO research including qualitative content analysis, bibliometric methods and natural language processing (e.g., Olson 2006; Roe et al. 2007; Smiraglia 2015a; Ibekwe-Sanjuan and Sanjuan 2010; Arboit et al. 2012). These efforts have successfully explained the nature of the KO research domain and guided the directions of KO research among the KO community. This study intends to contribute to this line of research by introducing a recent text mining approach, specifically Latent Dirichlet Allocation (LDA) topic modeling. To the best of our knowledge, LDA has not been used yet in research domain analysis in KO. LDA is an unsupervised machine-learning technique to uncover hidden topics from a large corpus of text documents by analyzing semantic relationships between observed terms (Munzert et al. 2014). Based on text mining and LDA topic modeling, topics were explored from text collected from the *Knowledge Organization* journal (KO), which is a principal scholarly venue in the KO field. More importantly, we analyzed topical trends over the recent decade to assess the changes of popular topics and identify the topics that recently received increased attention in the KO field.

2.0 Literature review

2.1 Research trends in KO

As in many other fields, there exist numerous studies analyzing publication data to identify research trends in KO. For example, by counting the references in the issues of 1991-3 of *Knowledge Organization Literature* according to its classification scheme, Dahlberg (1995) found that the bulk of references (1543/3402) fell into a few foundational classes (e.g., methodology of classing and indexing) and that there were some emerging topics (e.g., automatic classing and indexing techniques). Dahlberg (1995) further highlighted several trends in KO (e.g., the rising significance of KO automation research). In order to survey trends in one of the sub-fields in KO, subject analysis, McIlwaine and Williamson (1999) scanned and categorized relevant published works (e.g., journal articles) appearing in major venues in library and information science (LIS) over a ten-year period from 1988-98. Their findings revealed topics that were most popular during the period (e.g., universal classification systems) as well as an increase in topical diversity.

Olson (2006) performed a content analysis of the articles on organization of information (more specifically, bibliographic control as defined in Olson (2006)) that were published in *Library Quarterly* from volume 1-74 (1931-2004). The quantitative part of her study identified prominent themes throughout the volumes (e.g., cataloging codes) and also showed that the majority of the articles were published in the early years of the journal. In addition, Olson (2006) provided further discussions of the results from a thematic analysis focusing on the identified prominent themes. Roe et al. (2007) conducted two descriptive topical analyses by counting the subject terms assigned to the articles published in *Cataloging & Classification Quarterly* from volume 11 (1990) through volume 40 (2005). The results from the first analysis presented the topics that were most frequently assigned in each of the three article groups by decade (i.e., volumes 11-20, 21-30, and 31-40). The second analysis involved comparison of the first set of volumes (11-20) with the last (31-40) in terms of topical change, identified decreases (e.g., cataloging) and increases (e.g., authority control) in uses of topics. Building on Olson (2006) and McIlwaine (2003), Saumure and Shiri (2008) ran a qualitative content analysis using KO-related articles collected from the Library, Information Science, and Technology Abstracts (LISTA) database. Their findings underlined the growing role of metadata and the heightened prominence of issues pertinent to cataloging and classification since the advent of the Internet.

While the early efforts reviewed above mostly relied on manual or less automatic analysis and authors' knowledge of the field, researchers have begun to employ more advanced approaches in recent years (Ibekwe-Sanjuan and Sanjuan 2010). As one of the first attempts, Smiraglia (2009) used several bibliometric techniques including citation analysis, word and co-word analysis, and author co-citation analysis (ACA) to determine the characteristics and changes of a North American chapter of the International Society for Knowledge Organization (ISKO). The results of the analyses indicated that prolific North American authors had characteristics that were distinct from those of their non-North American peers, and also showed topics that were emergent in North America (e.g., knowledge organization online). In many other publications (some in series), Smiraglia has also been tracking the evolution of KO, by applying similar techniques to regional and international KO conferences (e.g., Smiraglia 2007; 2008; 2011a; 2011b; 2012; 2013a; 2014; 2015a). In order to map trends in KO research, Ibekwe-Sanjuan and Sanjuan (2010) analyzed KO-related journal articles published between 1988 and 2008 (838 out of 931 from the *Knowledge Organization* journal) with natural language processing (NLP), clustering, and information visualization techniques. They found that while the first decade (1988-97) was characterized more by mainstream topics (e.g., classification), the second decade (1998-2008) exhibited more technology-driven and specialized topics (e.g., terminology database). Arboit et al. (2012) employed both citation and social network analyses to identify the most productive authors in the five ISKO conferences from 2002-10 and then examined their relationships with the thematic categories occurring during that period.

2.2 Latent Dirichlet allocation (LDA)

LDA is a relatively recent technique proposed by Blei et al. (2003) as a generative probabilistic model for topic modeling. It has been used to discover prevailing themes in collections of scholarly textual data (e.g., journal articles) in various research fields (Blei 2012). In the LIS context, for example, Sugimoto et al. (2011) examined topical trends in all dissertations completed at American Library Association (ALA)-accredited programs from 1930 to 2009. Their LDA analyses determined not only the core themes (e.g., information-seeking behavior) during the period, but also a number of substantial topical changes over time in LIS (e.g., decreasing use of the word library and its related terms). Lu and Wolfram (2012) proposed three methods (i.e., two word-based methods, and one topic-based method using LDA) for measuring author research relatedness. They tested the proposed methods against a more traditional ACA approach with the articles of the 50 most

prolific LIS scholars, and they showed that the topic-based method yielded a more distinctive map than the others. Park and Song (2013) carried out a trend survey of LIS research in Korea by applying LDA to the articles published in four major LIS journals between 1970 and 2012 in Korea. Part of their results demonstrated that while several topics such as service and evaluation by libraries were in a growing trend, there were also topics that were in a decreasing trend. In a more recent study, Joo and Cahill (2017) employed LDA to identify topical trends in the field of school librarianship. The data was drawn from the articles published in the field's two leading journals during a ten-year period from 2006-15. They found that programing related concerns were most widely examined in the field, and that some discrepancies existed in terms of topic popularity between the two journals.

The applications of LDA to date have also included trend surveys in other research disciplines. For example, Griffiths and Steyvers (2004) used LDA to determine the topics covered by articles in the *Proceedings of the National Academy of Sciences (PNAS)*. With the topics determined, they further demonstrated how different scientific domains were related to each other, and also showed topics that gained ("hot" topics) or lost ("cold" topics) popularity over time. Zheng et al. (2006) extracted major recurring topics from a corpus of protein-related MEDLINE articles using LDA and considered the potential of the extracted topics for better indexing and retrieval in biomedical research. Wang, Joo, and Lu (2014) collected a corpus of 550 Wikipedia documents retrieved from a range of search terms relevant to data science, and then, they used the LDA topic modeling to identify twenty-five key topics in the field of data science. Choi et al. (2017) investigated topical trends in personal information privacy research by analyzing relevant articles from Scopus with LDA. Based on the trends that emerged from the analysis, they identified some gaps in the research and made recommendations for future directions. Sun and Yin (2017) applied LDA to articles from twenty-two top-tier journals in transportation research and showed topics that were becoming more popular over time. Also, they ran additional temporal analyses and found different patterns by journal and country or region.

With the ever-growing body of work in KO, it becomes difficult to assess research trends without automatic techniques. Accordingly, as reviewed above, a number of studies have already taken more advanced approaches (e.g., Arboit et al. 2012; Ibekwe-Sanjuan and Sanjuan 2010; Smiraglia 2009; 2014) and offered insights into the dynamic changes in KO research. Along with these efforts, this study takes another step forward by employing LDA to examine recent trends and developments of KO research.

3.0 Research questions

In this study, we intend to explore topics that were studied in the *Knowledge Organization* journal over the decade from 2006 to 2015, using text mining to do so. The following three research questions guide the investigation of the present study:

- 1) What are the terms that *most* frequently occurred in the *Knowledge Organization* journal for the period from 2006 to 2015?
- 2) What are the research topics that emerged from the *Knowledge Organization* journal for the period from 2006 to 2015?
- 3) How have research topics changed in the *Knowledge Organization* journal over the past ten years from 2006 to 2015?

4.0 Methods

We collected ten years (2006-2015) of published research articles from the journal *Knowledge Organization*. It is the official journal of International Society for Knowledge Organization, which was founded in 1973 by Dr. Ingetraut Dahlberg. The journal has been a critical venue for international KO researchers in representing a variety of KO related subjects. Specifically, according to its main website (<http://www.isko.org/ko.html>), the major topics the journal covers, but does not limit itself to, are theoretical foundations and practical applications associated with all types of KO such as indexing, classification and thesauri, historical reviews of KO as a discipline, education and training, and terminological issues from general to specific fields. Non-research publications such as editorials, book reviews, journal updates, news, reports of events, and inter-

views were excluded. In total, 282 published research articles were included for the analysis.

The collected text was analyzed using text mining, to be more specific, term frequency analysis and LDA topic modeling. The titles and abstracts were collected from the selected 282 articles of *KO*. In this study, we delimited the analysis to the titles and abstracts of the collected articles as full-text of research articles are likely to contain some noise (information or unnecessary text that is not directly relevant to the content). In the analysis of research article text, titles and abstracts are considered well organized portions of information and contain key topics of article content (Joo and Cahill 2017). For frequency analysis, we applied three steps of text preprocessing, which are widely applied in textual analysis, including tokenization, stopwords elimination, and stemming. We first extracted all tokens from the collected documents (tokenization), and then stopwords were removed from the corpus. Stemming was applied, which is the process of extracting base or root forms of the observed words. As to stemming, we employed Porter's word stemming algorithm (<http://snowball.tartarus.org/algorithms/porter/stemmer.html>) to transform terms into stemmed format. We calculated frequencies for stemmed terms and created a term-frequency table with the most frequently observed terms.

Then, LDA topic modeling analysis was carried out to identify prevailing topics underlying the collected corpus of 282 articles. LDA is based on the assumption that a document exhibits multiple topics and each topic is represented as a distribution of observed terms (Blei, 2012). Details of the algorithm behind this method are too complex to present in this paper and is out of the scope of the study. Instead, we attempt to briefly summarize it using the graphical annotation as shown in Figure 1, which is a graphical representation of the LDA topic model. Each document exhibits

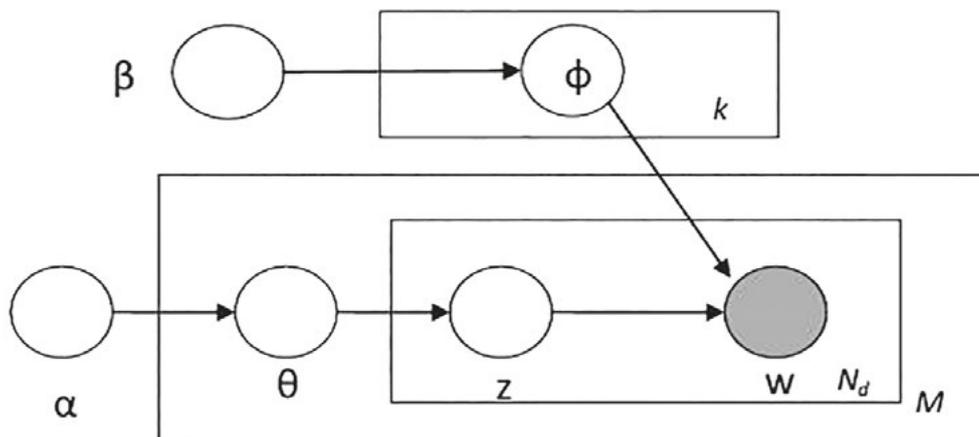


Figure 1. Graphic model representation of LDA (Lu and Wolfram 2012, 1975).

a distribution of topic “ θ ,” and each topic consisting of terms (φ) can be generated from a latent Dirichlet distribution with a prior of “ β ,” which is the same parameter of the per-topic word distribution. The LDA begins with a document “ θ_d ” from “Dir(α),” and “ α ” is the Dirichlet-prior concentration parameter of the per-document topic distribution. A word (“ w ”) in a document is supposed to be allotted to “ z ,” selected from “ θ_d .” Thus, “ z ” indicates the topic assignment for “ w ,” and the word is selected according to “ z ” and “ φ_k ” (where “ k ” = number of topics, “ N_d ” = number of words in a document). After the iterations of this procedure until it converges, hidden topics underlying the corpus can be extracted (Lu and Wolfram, 2012; Blei, 2012).

In this study, we set “ k ” as twenty in the LDA model, which is to extract twenty hidden topics from the corpus. In addition, to investigate the trends over ten years, we conducted a term frequency analysis for each year separately and computed the proportions for frequently observed terms between years. We also analyzed the proportions of topics that occurred for each year to assess the changes of topic popularity over the ten years. In this way, we not only depicted prevailing topics in *KO* holistically but also examined the popularity of such topics over time in the *KO* research domain.

5.0 Results

First, we investigated which stemmed terms occurred frequently in the ten-year analysis. In total, 26,596 tokens were observed for 3,132 unique words after removing stopwords. The top 174 terms made up about a half of the entire tokens (49.98%) while 1,269 words were ob-

served only once in the entire corpus. As shown in Figure 2, the observed terms exhibit a typical Zipf law pattern, a reverse J shape. Not surprisingly, the top four most frequent terms are “knowledg,” “infor,” “classif,” and “organ,” which showed more than 1% of the entire observed tokens. The stemming results generated “classif” and “classifi” separately even though they have the shared root of meaning. The stemming compiler transformed “classification” and “classifications” into “classif” while it does “classify,” “classified,” “classifying,” and “classifies” into “classifi.” If we combine the frequencies of “classif” and “classifi,” it totals 429, which makes up 1.613% of the corpus tokens. The analysis of term frequency reveals that “classification” or “organization” of “knowledge” and “information” were the key themes in the *Knowledge Organization* journal. Then, “system,” “research,” “librari,” “studi,” and “concept” were among the top ten frequent terms. Table 1 shows the top 100 stemmed terms occurred more than fifty times across the corpus.

Table 2 presents the result of LDA topic modeling, which extracted twenty topics from the text corpus. The most prevalent topic turned out to be “theories” concerning knowledge organization (T18). Approximately 10.6% of the articles are involved with the topics of theories or epistemology. The topics related to classification scheme or facet structure were also popular (Topic 8; 9.57%). Then, domain analysis and ontologies (T19) and library book and collection related studies (T6) were observed to be present in more than 6% of the articles. Topics showed more than 5% among the corpus include: digital archiving (T1), document indexing and retrieval (T14), taxonomy and thesaurus system (T15), web data and topic map (T16),

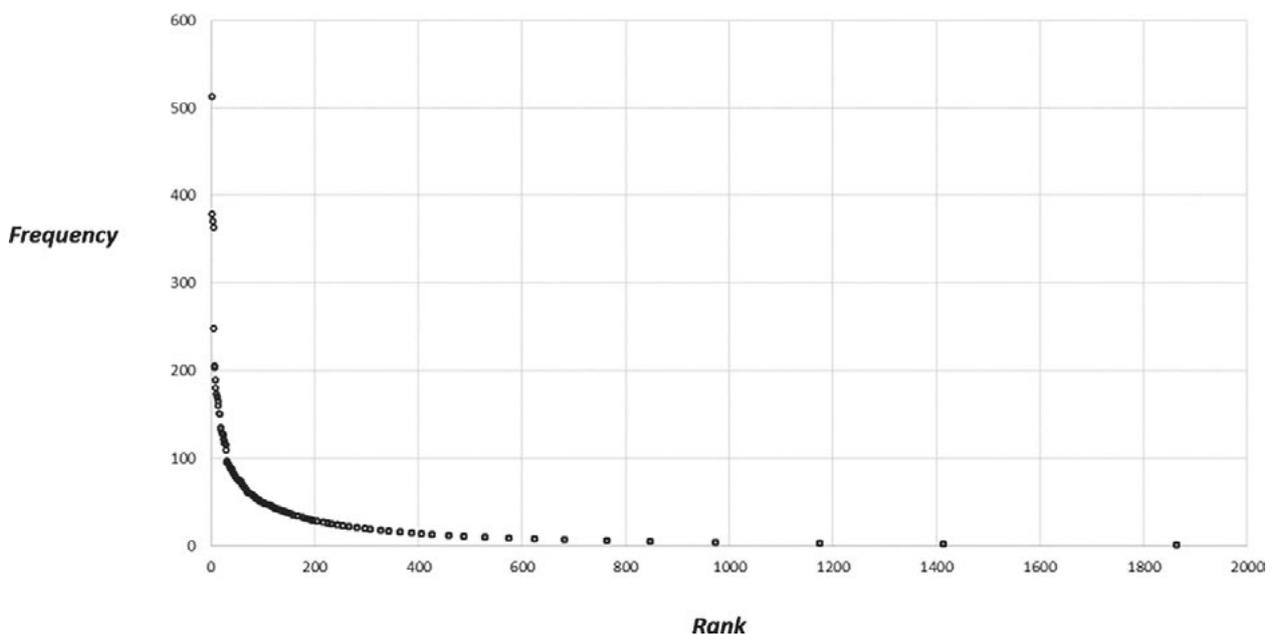


Figure 2. Term frequency pattern by rank.

Term	Rank	Frequency	Percent	Term	Rank	Frequency	Percent
knowledg	1	513	1.929%	scheme	50	76	0.286%
inform	2	379	1.425%	conceptu	52	75	0.282%
organ	3	371	1.395%	metadata	52	75	0.282%
classif	4	364	1.369%	object	52	75	0.282%
system	5	249	0.936%	propos	52	75	0.282%
librari	6	206	0.775%	languag	56	74	0.278%
research	7	204	0.767%	specif	57	72	0.271%
paper	8	190	0.714%	represent	58	71	0.267%
studi	9	181	0.681%	tool	59	70	0.263%
subject	10	174	0.654%	analyz	60	69	0.259%
analysi	11	171	0.643%	field	60	69	0.259%
domain	12	170	0.639%	vocabulari	62	68	0.256%
concept	13	166	0.624%	order	63	67	0.252%
base	14	161	0.605%	applic	64	66	0.248%
relat	15	152	0.572%	classifi	65	65	0.244%
develop	16	151	0.568%	facet	65	65	0.244%
user	16	151	0.568%	access	67	64	0.241%
differ	18	136	0.511%	repres	67	64	0.241%
approach	19	134	0.504%	record	69	61	0.229%
document	20	130	0.489%	resourc	69	61	0.229%
index	21	129	0.485%	search	69	61	0.229%
term	21	129	0.485%	archiv	72	60	0.226%
ontolog	23	128	0.481%	consid	72	60	0.226%
semant	24	123	0.462%	method	72	60	0.226%
tag	25	120	0.451%	practic	72	60	0.226%
structur	26	117	0.440%	design	76	59	0.222%
web	26	117	0.440%	examin	76	59	0.222%
scienc	28	115	0.432%	general	76	59	0.222%
model	29	109	0.410%	control	79	58	0.218%
work	30	97	0.365%	understand	79	58	0.218%
present	31	95	0.357%	book	81	57	0.214%
relationship	31	95	0.357%	cultur	82	56	0.211%
retriev	31	95	0.357%	includ	82	56	0.211%
social	34	93	0.350%	describ	84	55	0.207%
result	35	91	0.342%	topic	84	55	0.207%
map	36	90	0.338%	issu	86	54	0.203%
author	37	89	0.335%	perspect	86	54	0.203%
ethic	38	88	0.331%	taxonomi	86	54	0.203%
need	38	88	0.331%	identifi	89	53	0.199%
provid	40	87	0.327%	mean	89	53	0.199%
theori	41	85	0.320%	support	89	53	0.199%
collect	42	83	0.312%	level	92	52	0.196%
context	42	83	0.312%	construct	93	51	0.192%
data	44	82	0.308%	import	93	51	0.192%
discuss	44	82	0.308%	thesaurus	93	51	0.192%
evalu	46	80	0.301%	aim	96	50	0.188%
process	46	80	0.301%	bibliograph	96	50	0.188%
content	48	78	0.293%	methodolog	96	50	0.188%
digit	49	77	0.290%	potenti	96	50	0.188%
articl	50	76	0.286%	visual	96	50	0.188%

Table 1. Term frequency analysis of KO (terms are stemmed based on Porter Stemmer).

	1	2	3	4	5	6	7
Topic 1 (5.32%)	digit	archiv	record	access	represent	content	analyz
Topic 2 (4.61%)	research	activ	scientif	project	human	influenc	scienc
Topic 3 (3.55%)	need	develop	process	order	within	aim	main
Topic 4 (2.84%)	social	paper	cultur	critic	within	media	chang
Topic 5 (1.77%)	inform	object	design	level	repress	area	paper
Topic 6 (6.74%)	librari	book	name	number	collect	examin	given
Topic 7 (3.55%)	subject	scienc	articl	journal	search	result	origin
Topic 8 (9.57%)	classif	differ	scheme	class	facet	structur	tradit
Topic 9 (2.84%)	classifi	work	system	univers	studi	propos	consid
Topic 10 (2.84%)	concept	theori	paper	mean	characterist	framework	general
Topic 11 (3.90%)	metadata	collect	control	vocabulari	communiti	tool	element
Topic 12 (4.61%)	ethic	practic	question	profession	catalog	valu	code
Topic 13 (4.96%)	relat	semant	structur	term	present	network	base
Topic 14 (5.32%)	document	index	retriev	languag	context	term	approach
Topic 15 (5.32%)	system	evalu	develop	taxonomi	thesaurus	construct	support
Topic 16 (5.67%)	map	data	web	topic	applic	visual	servic
Topic 17 (3.55%)	relationship	model	author	current	express	conceptu	standard
Topic 18 (10.64%)	knowledg	organ	epistemolog	theoret	represent	role	foundat
Topic 19 (6.74%)	domain	analysi	ontolog	base	research	studi	approach
Topic 20 (5.67%)	user	tag	web	resourc	folksonomi	system	cognit

Table 2. Topic modeling results (k=20).

and user tagging and folksonomies (T20). Additionally, the LDA topic modeling discovered the topics of “metadata and controlled vocabulary (T11),” “ethics in KO (T12),” “semantic relationships and structure (T13),” and so forth.

To examine the changes of research topics, the corpus was analyzed over time by year. First, term frequency was computed by year, and Table 3 presents those terms that were observed more than 0.6% in each year. The results indicate that frequent term patterns differed by year. In 2006, “subject,” “classif,” and “scheme” turned out to be

the top three stemmed terms. Also, terms reflecting web environments were highly ranked, such as “web,” “metadata,” “system” and “semant.” In 2007, “inform,” “tag,” and “classif” were listed as the top three stemmed terms. Particularly, we found Munk and Mork (2007a; 2007b) contributed two research articles regarding folksonomies and user tagging to the journal. In 2008, highly ranked terms were “knowleg,” “organ,” “relationship,” “research,” “classif,” and “ontology” that accounted for over 1.26% respectively. Interestingly, there were several

2006		2007		2008		2009		2010	
subject	1.96%	inform	1.22%	knowledg	3.78%	knowledg	2.21%	classif	2.09%
classif	1.56%	tag	1.14%	organ	1.93%	classif	2.03%	inform	1.41%
scheme	1.49%	classif	1.07%	relationship	1.85%	librari	1.61%	relat	1.27%
web	1.25%	develop	0.99%	research	1.77%	collect	1.37%	system	1.18%
differ	1.17%	term	0.99%	classif	1.60%	system	1.01%	knowledg	1.00%
metadata	0.94%	metadata	0.91%	ontolog	1.26%	index	0.95%	subject	0.86%
origin	0.94%	differ	0.84%	inform	1.09%	classifi	0.89%	udc	0.82%
system	0.94%	document	0.84%	structur	1.09%	philosophi	0.83%	map	0.77%
inform	0.86%	design	0.76%	base	1.01%	inform	0.72%	studi	0.77%
semant	0.86%	folksonomi	0.76%	design	0.93%	paper	0.72%	base	0.73%
index	0.78%	librari	0.76%	librari	0.93%	retriev	0.72%	research	0.73%
organ	0.78%	relat	0.76%	relat	0.93%	context	0.66%	concept	0.68%
record	0.70%	user	0.76%	approach	0.84%	differ	0.66%	evalu	0.68%
term	0.70%	creat	0.69%	control	0.84%	metadata	0.66%	organ	0.68%
applic	0.63%	knowledg	0.69%	studi	0.76%	order	0.66%	thesaurus	0.68%
librari	0.63%	number	0.69%	system	0.76%	organ	0.66%	develop	0.64%
resourc	0.63%	system	0.69%	vocabulari	0.76%	web	0.66%	domain	0.64%
		tool	0.69%	develop	0.67%	approach	0.60%	paper	0.64%
		analysi	0.61%	semant	0.67%	model	0.60%	resourc	0.64%
		descript	0.61%			philosoph	0.60%	servic	0.64%
		express	0.61%			studi	0.60%	term	0.64%
		organ	0.61%						
		paper	0.61%						
		present	0.61%						
		research	0.61%						
		subject	0.61%						
2011		2012		2013		2014		2015	
inform	1.75%	inform	1.86%	knowledg	2.51%	knowledg	1.86%	knowledg	1.49%
classif	1.56%	organ	1.32%	organ	1.79%	inform	1.64%	domain	1.28%
system	1.18%	knowledg	1.26%	inform	1.31%	organ	1.09%	inform	1.22%
knowledg	1.14%	classif	0.99%	classif	1.13%	research	1.03%	analysi	1.16%
user	1.03%	system	0.99%	ontolog	1.13%	studi	0.96%	organ	1.03%
paper	0.95%	concept	0.93%	relat	1.10%	tag	0.90%	classif	1.00%
organ	0.91%	paper	0.90%	index	1.00%	develop	0.88%	paper	0.88%
term	0.91%	ethic	0.84%	concept	0.89%	analysi	0.85%	studi	0.85%
model	0.84%	librari	0.81%	analysi	0.86%	paper	0.80%	ethic	0.82%
base	0.76%	document	0.78%	domain	0.86%	classif	0.72%	user	0.73%
web	0.72%	develop	0.75%	paper	0.82%	domain	0.72%	concept	0.70%
differ	0.68%	relationship	0.72%	research	0.82%	base	0.69%	research	0.70%
semant	0.65%	studi	0.66%	system	0.82%	scienc	0.69%	scienc	0.70%
document	0.61%	research	0.60%	librari	0.72%	system	0.69%	content	0.61%
propos	0.61%			differ	0.69%	approach	0.66%		
result	0.61%			model	0.69%	librari	0.61%		
				subject	0.69%	social	0.61%		
				base	0.65%				
				data	0.62%				

Table 3. Most frequent terms for individual years (observed more than 0.6%).

articles that directly addressed the issues of “knowledge organization” in that year. For example, Hjørland (2008) defined the domain of KO in an article titled, “What is Knowledge Organization (KO)?,” and also, Zeng (2008) discussed different aspects of knowledge organization sys-

tem (KOS) with relevant examples. In 2009, “knowledge,” “classif,” “library,” “collect,” and “system” were among most frequent terms. Interestingly, there were several articles concerning classification and philosophical issues in the context of library collections. That explains why terms

“classif,” “library,” “classifi,” and “philosophi,” were observed with high frequency in 2009. In 2010, we found that most popular terms were “classif,” “inform,” “relat,” “system,” and “knowledge,” which showed proportions of 1% or more respectively. In particular, several articles were contributed to the subject of classification in 2010 (e.g., Osinska 2010; Gnoli 2010; Jacob 2010).

In 2011, again, “classif (1.56%)” was one of the most common terms. Interestingly, the term “user (1.03%)” was ranked fifth, which reflects the occurrence of a relatively larger number of research papers related to users in 2011. For example, Petric et al. (2011) investigated user profiling on a digital library while Kipp (2011) compared user, author and professional indexing. In 2012, the term “ethics” was relatively more highly ranked than in other years. In particular, several articles covering the issues of ethics in KO were published in volume 39 issue 5. In 2013, “ontology” was listed amongst top five most frequent terms. The 2013, volumes included several articles concerning ontologies and domain analysis. In 2014, the top five terms turned out to be “knowledge,” “inform,” “organ,” “research,” and “studi.” In 2015, the terms “domain” and “analysi” were ranked highly, which revealed the prevalence of domain analysis research.

Next, we investigated the trends of topics extracted from the LDA method over the period of analysis. Here, we only interpreted the extracted topics showing more than 3% of the entire document set. As shown in Table 4,

we did not observe strong, explicit linear patterns of increase or decrease of topic proportions, but certainly, there were certain popular topics in individual years. For example, the topic of digital archiving (T1) reached a temporary acme in 2013, but it was rarely observed between 2006 and 2007. Library collection related research (T6) exhibited three high humps in its pattern by showing intermittent popularities over the period. Similarly, T8 (classification scheme and facet structure) also presented irregular patterns. The topic relevant to metadata and controlled vocabularies (T11) was consistently popular across the ten years while relatively more popular in 2007 and 2015. The topic related to ethics (T12) was most popular in 2015. In particular, volume 42 issue 5 contains the “Proceedings of the 3rd Milwaukee Conference on Ethics in Knowledge Organization.” T12 was also popular in 2012 and 2013. T3 (semantic structure and relationship) has steadily occurred across the ten years while it was most popular in 2014. Similarly, T14 (document indexing and retrieval) was also discussed steadily across the period of analysis, except for 2008 and 2010. The topic of taxonomy and thesaurus systems (T15) showed a peak in 2010. The topics relevant to epistemology and theories (T18) were observed unceasingly across the ten years. That topic (T18) was most prevalent in 2013, the year when a special issue was published focusing on theory driven research, “Special Issue: Paradigms of Knowledge and its Organization: The Tree, the Net and Beyond,” edited by Fulvio Mazzocchi and Gian

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
T1	0.0%	0.0%	6.7%	6.7%	6.7%	6.7%	13.3%	33.3%	13.3%	13.3%
T2	0.0%	0.0%	0.0%	7.7%	0.0%	15.4%	38.5%	15.4%	23.1%	0.0%
T3	0.0%	0.0%	0.0%	20.0%	10.0%	10.0%	20.0%	20.0%	20.0%	0.0%
T4	0.0%	0.0%	0.0%	12.5%	12.5%	0.0%	25.0%	0.0%	37.5%	12.5%
T5	0.0%	0.0%	20.0%	0.0%	0.0%	20.0%	0.0%	0.0%	40.0%	20.0%
T6	0.0%	5.3%	0.0%	21.1%	0.0%	0.0%	26.3%	10.5%	10.5%	26.3%
T7	10.0%	0.0%	10.0%	0.0%	10.0%	20.0%	0.0%	0.0%	20.0%	30.0%
T8	14.8%	0.0%	3.7%	7.4%	14.8%	11.1%	18.5%	11.1%	3.7%	14.8%
T9	12.5%	0.0%	0.0%	25.0%	12.5%	12.5%	25.0%	0.0%	12.5%	0.0%
T10	0.0%	12.5%	0.0%	0.0%	12.5%	25.0%	12.5%	12.5%	12.5%	12.5%
T11	9.1%	18.2%	9.1%	9.1%	9.1%	9.1%	9.1%	0.0%	9.1%	18.2%
T12	7.7%	7.7%	0.0%	0.0%	0.0%	7.7%	15.4%	15.4%	0.0%	46.2%
T13	7.1%	7.1%	14.3%	7.1%	14.3%	7.1%	7.1%	7.1%	21.4%	7.1%
T14	6.7%	6.7%	0.0%	13.3%	0.0%	20.0%	13.3%	6.7%	20.0%	13.3%
T15	13.3%	0.0%	6.7%	6.7%	33.3%	0.0%	6.7%	0.0%	13.3%	20.0%
T16	0.0%	6.3%	0.0%	6.3%	25.0%	18.8%	12.5%	12.5%	6.3%	12.5%
T17	0.0%	10.0%	10.0%	10.0%	10.0%	0.0%	30.0%	10.0%	10.0%	10.0%
T18	3.3%	6.7%	13.3%	3.3%	6.7%	6.7%	13.3%	26.7%	16.7%	3.3%
T19	0.0%	5.3%	10.5%	0.0%	5.3%	10.5%	0.0%	21.1%	15.8%	31.6%
T20	6.3%	12.5%	0.0%	0.0%	6.3%	31.3%	0.0%	12.5%	12.5%	18.8%

Table 4. Topic trends for the years between 2006 and 2015.

Carlo Fedeli (volume 40 issue 6). T19 (domain analysis and ontologies) was found to be most popular in recent years, especially from 2013 and 2015. To be more specific, domain analysis became one of the main topics in *KO* after 2013. Particularly, volume 42 issue 8 was published as a special issue, titled “Domain Analysis Revisited,” specifically covering the subject of domain analysis. “User related studies” (T20) was most popular in 2011, which reaffirms the findings from the term frequency analysis. Figure 3 shows the five topics that received increased attention recently. It indicates that “ethics” and “domain analysis” were the topics with most increased popularity over the decade in the *KO* research domain.

Finally, we computed the proportions of top fifty most frequent terms by year (Table 5). The top two terms with *most* increasing patterns turned out to be “domain” and “analysi.” This suggests that domain analysis was a recent hot topic in the journal. Also, the term “ethic” was another popular term that exhibits recent increased *popularity* in the journal. On the contrary, the terms “classif,” “differ,” and “subject” exhibited a decline over the past ten years in the *Knowledge Organization* journal.

6. 0 Discussion and conclusion

Based on text mining, this study explored research topics that appeared in the *Knowledge Organization* journal for the past decade from 2006 to 2015. We extracted all terms from the titles and abstracts of 282 research articles and made a corpus of stemmed terms after tokenization, stopwords elimination and stemming. Then, we tallied frequencies of

those terms from the corpus and identified popular topics in the journal based on LDA topic modeling. Term frequency analysis identified popular terms that occurred in the journal over the ten years. The top four terms, which showed more than 1% of the entire corpus respectively, are “knowledge,” “inform,” “organ” and “classif.” These four terms well represent the fundamental nature of *KO* research, which covers the key concepts of “organization or classification of knowledge and information.” Also, most frequent terms implied key issues that were *popular* amongst *KO* researchers for the period of analysis. For example, terms related to libraries, domain, subject, user, index, ontology, semantic, web, and tag, among others were ranked within the top thirty most frequent terms. Some of these terms represent recent web environments. For instance, terms such as semantic, web, ontology, user, and tag are closely related to recent discussions of semantic web and collaborative indexing, which have been popular in the latest decade. Also, we can infer that domain analysis became one of the hot topics recently, as the terms “domain” and “analysi” were ranked eleventh and twelfth respectively. Terms concerning ethics and theories were ranked within the top fifty most frequent terms, revealing that ethical issues and theories were frequently discussed in the *Knowledge Organization* journal. This implies that the journal has been a scholarly venue, which focuses on theoretical contribution in *KO*, beyond the channels for practitioners.

LDA topic modeling provided a semantic level analysis of terms in the *KO* research domain and uncovered hidden topics underlying the journal. Topic modeling results revealed that a number of articles were concerned with

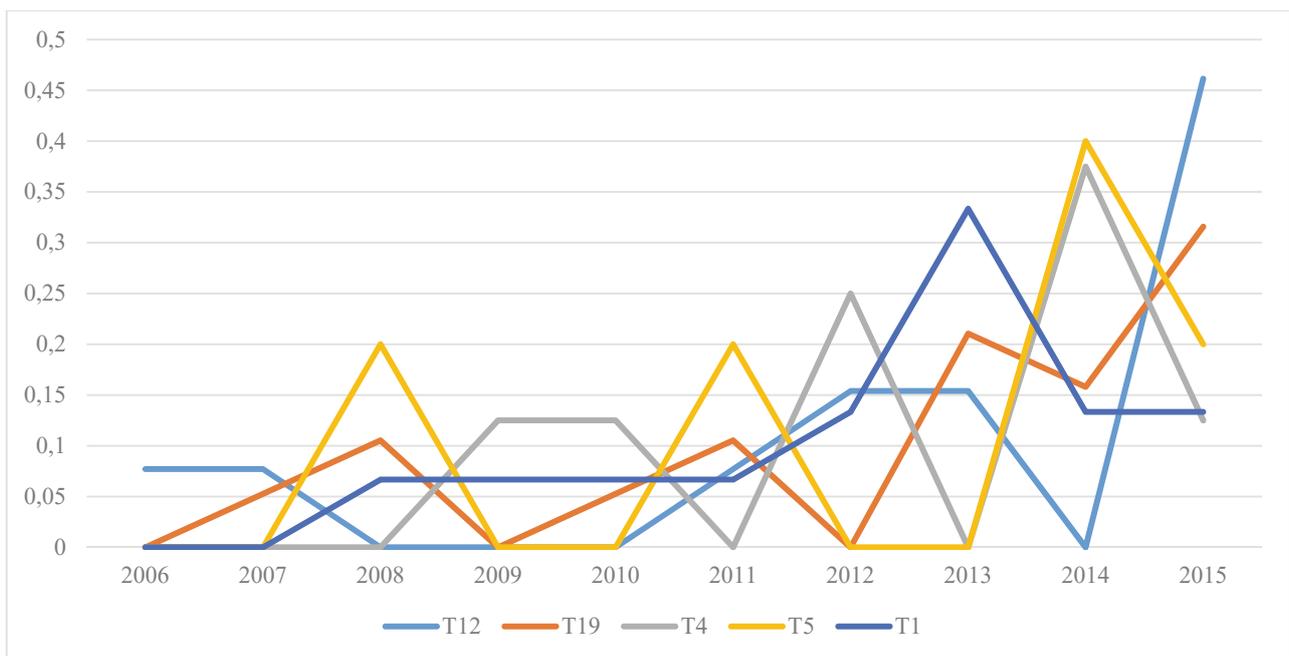


Figure 3. Top 5 increasing pattern topics (T12, T19, T4, T5, and T1).

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Linear Slope
domain	0.16%	0.15%	0.42%	0.30%	0.64%	0.53%	0.15%	0.86%	0.72%	1.28%	0.095
analysi	0.16%	0.61%	0.50%	0.12%	0.23%	0.42%	0.42%	0.86%	0.85%	1.16%	0.082
inform	0.86%	1.22%	1.09%	0.72%	1.41%	1.75%	1.86%	1.31%	1.64%	1.22%	0.067
ethic	0.00%	0.00%	0.08%	0.06%	0.05%	0.00%	0.84%	0.24%	0.05%	0.82%	0.066
scienc	0.00%	0.08%	0.34%	0.24%	0.27%	0.19%	0.42%	0.24%	0.69%	0.70%	0.064
knowledg	0.47%	0.69%	3.78%	2.21%	1.00%	1.14%	1.26%	2.51%	1.86%	1.49%	0.050
paper	0.47%	0.61%	0.50%	0.72%	0.64%	0.95%	0.90%	0.82%	0.80%	0.88%	0.045
studi	0.31%	0.30%	0.76%	0.60%	0.77%	0.53%	0.66%	0.38%	0.96%	0.85%	0.045
organ	0.78%	0.61%	1.93%	0.66%	0.68%	0.91%	1.32%	1.79%	1.09%	1.03%	0.043
data	0.00%	0.15%	0.08%	0.36%	0.27%	0.38%	0.12%	0.62%	0.56%	0.24%	0.043
concept	0.47%	0.38%	0.34%	0.42%	0.68%	0.53%	0.93%	0.89%	0.45%	0.70%	0.041
social	0.16%	0.38%	0.34%	0.06%	0.36%	0.19%	0.48%	0.38%	0.61%	0.30%	0.026
content	0.39%	0.08%	0.34%	0.00%	0.18%	0.11%	0.45%	0.24%	0.24%	0.61%	0.024
base	0.39%	0.08%	1.01%	0.24%	0.73%	0.76%	0.57%	0.65%	0.69%	0.43%	0.023
theori	0.08%	0.53%	0.25%	0.06%	0.09%	0.53%	0.21%	0.34%	0.16%	0.58%	0.020
model	0.39%	0.08%	0.25%	0.60%	0.32%	0.84%	0.15%	0.69%	0.24%	0.46%	0.019
evalu	0.08%	0.30%	0.00%	0.30%	0.68%	0.30%	0.12%	0.21%	0.32%	0.36%	0.017
provid	0.23%	0.15%	0.42%	0.24%	0.41%	0.30%	0.51%	0.38%	0.29%	0.36%	0.016
research	0.23%	0.61%	1.77%	0.48%	0.73%	0.49%	0.60%	0.82%	1.03%	0.70%	0.016
map	0.31%	0.23%	0.25%	0.00%	0.77%	0.46%	0.36%	0.31%	0.16%	0.46%	0.011
author	0.16%	0.46%	0.42%	0.06%	0.23%	0.34%	0.54%	0.24%	0.48%	0.24%	0.010
ontolog	0.08%	0.30%	1.26%	0.42%	0.05%	0.57%	0.24%	1.13%	0.56%	0.09%	0.007
articl	0.16%	0.23%	0.42%	0.30%	0.45%	0.38%	0.27%	0.17%	0.11%	0.52%	0.006
relat	0.31%	0.76%	0.93%	0.12%	1.27%	0.46%	0.39%	1.10%	0.40%	0.52%	0.001
discuss	0.47%	0.30%	0.59%	0.18%	0.14%	0.30%	0.27%	0.34%	0.37%	0.49%	-0.001
tag	0.47%	1.14%	0.00%	0.00%	0.55%	0.42%	0.30%	0.17%	0.90%	0.46%	-0.001
present	0.47%	0.61%	0.34%	0.24%	0.18%	0.38%	0.30%	0.55%	0.50%	0.33%	-0.003
document	0.23%	0.84%	0.50%	0.42%	0.32%	0.61%	0.78%	0.45%	0.50%	0.30%	-0.004
user	0.55%	0.76%	0.42%	0.36%	0.55%	1.03%	0.48%	0.55%	0.19%	0.73%	-0.005
process	0.47%	0.15%	0.17%	0.48%	0.36%	0.34%	0.33%	0.58%	0.19%	0.12%	-0.008
need	0.39%	0.38%	0.50%	0.54%	0.18%	0.27%	0.27%	0.41%	0.27%	0.43%	-0.010
result	0.55%	0.46%	0.17%	0.48%	0.18%	0.61%	0.24%	0.41%	0.50%	0.21%	-0.011
work	0.55%	0.15%	0.59%	0.42%	0.45%	0.34%	0.36%	0.31%	0.40%	0.33%	-0.011
retriev	0.16%	0.53%	0.25%	0.72%	0.36%	0.46%	0.36%	0.10%	0.42%	0.21%	-0.012
develop	0.55%	0.99%	0.67%	0.48%	0.64%	0.30%	0.75%	0.41%	0.88%	0.40%	-0.018
approach	0.47%	0.53%	0.84%	0.60%	0.36%	0.57%	0.42%	0.41%	0.66%	0.30%	-0.018
index	0.78%	0.53%	0.17%	0.95%	0.36%	0.30%	0.30%	1.00%	0.32%	0.21%	-0.027
digit	0.55%	0.38%	0.08%	0.30%	0.32%	0.23%	0.42%	0.27%	0.19%	0.06%	-0.027
structur	0.47%	0.23%	1.09%	0.48%	0.55%	0.53%	0.42%	0.41%	0.42%	0.15%	-0.031
context	0.31%	0.46%	0.59%	0.66%	0.23%	0.27%	0.33%	0.24%	0.24%	0.21%	-0.031
system	0.94%	0.69%	0.76%	1.01%	1.18%	1.18%	0.99%	0.82%	0.69%	0.33%	-0.031
web	1.25%	0.08%	0.08%	0.66%	0.41%	0.72%	0.30%	0.38%	0.42%	0.27%	-0.034
relationship	0.00%	0.23%	1.85%	0.18%	0.32%	0.42%	0.72%	0.14%	0.19%	0.12%	-0.037
librari	0.63%	0.76%	0.93%	1.61%	0.55%	0.53%	0.81%	0.72%	0.61%	0.43%	-0.038
term	0.70%	0.99%	0.34%	0.30%	0.64%	0.91%	0.48%	0.21%	0.42%	0.40%	-0.040
collect	0.39%	0.46%	0.08%	1.37%	0.18%	0.49%	0.27%	0.03%	0.19%	0.18%	-0.043
semant	0.86%	0.53%	0.67%	0.36%	0.32%	0.65%	0.24%	0.48%	0.53%	0.15%	-0.045
subject	1.96%	0.61%	0.42%	0.18%	0.86%	0.57%	0.54%	0.69%	0.56%	0.58%	-0.065
differ	1.17%	0.84%	0.59%	0.66%	0.36%	0.68%	0.27%	0.69%	0.45%	0.24%	-0.069
classif	1.56%	1.07%	1.60%	2.03%	2.09%	1.56%	0.99%	1.13%	0.72%	1.00%	-0.082

Table 5. Proportions of term occurrence for individual years (top 50 terms) and their linear trends over 10 years (ranked by linear slope based on the least squared method).

theories in KO. This indicates that the *Knowledge Organization* journal is a scholarly venue that emphasizes theories related to KO. We observed that many of the articles covered relevant theories in KO. For example, Hjørland, Olson, Fox and Tennis are representative scholars who contributed their theory-driven work to the *Knowledge Organization* journal. One of the strengths of the *Knowledge Organization* journal lies in its coverage of discussion of theoretical and philosophical foundations in KO, in addition to practical matters or empirical findings. Also, the LDA analysis results affirmed that traditional classification and facet structure related research were considered important steadily in the *Knowledge Organization* journal for the decade. According to the LDA results, domain analysis and ontologies became another popular area of interest among the KO community. In this area, Smiraglia (e.g., 2013b; 2015b) has been a leading scholar, and other researchers, such as Castanha et al. (2014) and López-Huertas (2015) also contributed to the studies of ontology and domain analysis. The LDA topic modeling results also uncovered diverse topics that were discussed in the KO research domain over the past ten years. For example, the *Knowledge Organization* journal covered the topics of digital archives, document indexing and retrieval, taxonomy and thesaurus, topical mapping, user tagging and folksonomies, and so forth, between 2006 and 2015.

To examine topic trends we analyzed the proportions of topics by year from 2006 to 2015. The results did not present explicit linear patterns over time for most topic cases. Rather, irregular patterns were observed for most topics. Certainly, we observed particularly popular topics in each year. For example, the topics of user tagging and folksonomies were more likely to be observed in 2011, when it was around the time tagging was popular in KO with the increased use of social media tools. Several researchers, such as Kipp (2011), Rafferty (2011), Mai (2011) and Park (2011), contributed to the area of user tagging, social tagging and folksonomies in 2011. In addition, we identified the topics for domain analysis and ontologies received increased attention recently. Domain analysis is an area that has exhibited increasing popularity since 2013. The patterns revealed by the terms “domain” and “analysis” had the greatest increase in probabilities in recent years. Smiraglia has led this area in the ISKO community by contributing both theories and methodologies relevant to domain analysis (e.g., Smiraglia 2013b; 2014; 2015a; 2015b).

The topic of “ethical issues” was discussed a lot in 2015, and it was partly due to a special issue that includes publications from the 3rd Milwaukee Conference on Ethics in Knowledge Organization. Both the 2012 special issue from the second ethics conference and the 2015 special issue from the third ethics conference have the term, “ethic,” in the top ten. The 2015 special issue presented terms directly

related to T2 (ethics in KO) such as “ethic,” “practice,” and “valu,” while the 2012 special issue involved more terms of “social,” “culture,” and “critic” representing T4 (social cultural issues in KO), which discussed the social and conceptual background of ethical issues in KO. This implies that special issues of *Knowledge Organization* may have an impact on the direction of research trends within KO or, conversely, may reflect areas where a critical mass of interest has developed.

This study also yields a methodological contribution to KO. To the best of our knowledge, the present study is the first attempt to employ LDA topic modeling to explore research topics in the KO field. KO researchers have exerted efforts to understand the research domain of KO based on different methods, such as qualitative content analysis (e.g., Olson 2006; McIlwaine 2003; Saumure and Shiri 2008), bibliometric techniques (e.g., Smiraglia 2009; Arboit et al. 2012), and natural language processing and clustering (Ibekwe-Sanjuan and Sanjuan 2010). The LDA method has not been widely introduced yet to the KO field. LDA topic modeling is an unsupervised machine learning technique that can be used to objectively discover hidden themes or topics underlying a large set of textual documents in a certain domain (Blei 2012; Munzert et al. 2014). As shown in this study, text mining based on the LDA approach can be useful to explore research topics in the KO domain. This method is advantageous when a discipline consists of multiple facets of research agenda like KO. As the body of KO research products is getting bigger, automatic data collection and text mining analysis have become imperative to assess the domain of KO. The benefit of using text mining is that it directly examines the content of documents by analyzing relationships among observed terms objectively. Moreover, text mining can be used for other types of domain analysis in KO research, not limited to research topic analysis. Domain analysis basically classifies and identifies different hierarchical or categorical structures of a certain domain consisting of multiple facets. Based on text analysis, we can create a term-document matrix, which enables us to calculate correlation coefficients between documents. Using correlation information among documents, we can automatically cluster or classify documents, which will be useful for domain analysis. In addition, supervised machine learning techniques, such as the “support vector machine” algorithm, can be applied to classify information objects in a particular domain into different categories automatically based on unique characteristics and features of the objects of interest.

This study has several limitations. First, the discipline of KO is an international, interdisciplinary research field, and the *Knowledge Organization* journal is one of the channels that the KO community uses. Even though the *Knowledge Organization* journal is one of the most representative scholarly venues in KO, 282 articles from the journal do not represent

the entirety of the KO research domain. ISKO and regional ISKO individual chapters provide other scholarly communication venues, such as conference proceedings, and KO researchers also publish in other LIS journals. The current study did not investigate those additional venues. Also, this study is limited to the analysis of topics, but it did not examine the relationships among authors in the field. Second, not all topics generated by LDA topic modeling were apparent or discernible. It was not easy to clearly interpret and label all topics extracted. This limited the interpretation and understanding of the findings. Third, the dataset included articles published in special issues. In trend analysis, those special issue articles might have caused somewhat biased results and interpretation. These limitations illustrate a need for future research to investigate topics by researcher to identify the relationships between topics and key researchers. In addition, it is necessary to expand the documents of the KO research domain to include major conference proceedings in ISKO and regional ISKO individual chapters as well as other LIS journal articles to which KO researchers have contributed. Because now all issues of the *Knowledge Organization* journal are available online, we also can extend our analysis of KO to all the journal issues. In carrying out an LDA analysis for the whole corpus of KO journals, we expect to discover dynamic topical trends over time more holistically. In addition, as discussed, the analysis of special issues along with topical trends will discover the impact of social factors on the development of KO research. We plan on a next study to examine the relationships among key researchers based on their publication content using an extended LDA model, which incorporates authors into LDA. All these planned efforts will contribute to the drawing of a better portrait of the KO research domain.

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