Domain Analysis of Domain Analysis for Knowledge Organization: Observations on an Emergent Methodological Cluster

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Abstract: Domain analysis in the science of knowledge organization (KO) is a set of techniques for identifying a specified knowledge base. Specific approaches to domain analysis for KO were formally laid out by Hjørland, in alignment with an agenda set by Dahlberg for the new science of KO. A core group of papers identifiable as domain analytical studies for KO has been analyzed twice before. This study reports an analysis of the decade-long effort by scholars to respond to the call for the use of domain analysis as a methodological paradigm in KO. The 100 articles were contributed by 80 authors from 23 countries. There were 2168 references in the cited papers. The age of citation ranged from 398 to the present; mean age of citation was 10.9 years; the number of cited works ranged from 2 to 69 with a mean of 21.6 works cited. Discourse is identified by analysis of 1177 citations to works by 280 authors cited more than once; 51 authors were cited 5 times or more. Inter-citation was used to generate an author co-citation matrix to help visualize the theoretical core. A vibrant domain around domain analysis in KO for KO has begun to generate data sufficient to make theoretical statements about domains in general and about a dozen specific domains, including KO itself. The discourse in this group takes place between the pragmatic need for a specific KOS and the classical ontological and epistemological positions in KO represented by concept theory.

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1.0 An emergent methodological cluster in knowledge organization

Domain analysis as it is understood in the science of knowledge organization (KO) is a set of techniques for identifying a specified knowledge base. Techniques for domain analysis in KO were introduced in a series of papers by Hjørland and Albrechtsen (1995; 1998), and specific approaches to domain analysis for KO were formally laid out by Hjørland (2002). A collection of cases of domain analytical research for KO comprised a special issue of *Knowledge Organization* in 2003, in which Hjørland and Hartel (2003a and b) advanced appreciation of the ontological and epistemological implications of the use of domain analysis for KO. All of these papers can be considered foundational for domain analysis in KO; Hjørland's 2002 paper clearly was catalytical, leading to a noticeable increase in the domain analytical research stream.

In 2012 I analyzed a set of papers that were identifiable as domain analytical studies for KO, many of which

cited the foundational papers mentioned above. To construct that core group of papers involved combining papers known to have cited Hjørland's catalytical work with all domain analytical papers from *Knowledge Organization* or *Advances in Knowledge Organization* (proceedings from the biennial international conferences of the International Society for Knowledge Organization (ISKO)). The core was rounded out by searching the EBSCO database *Library and Information Science Text Abstracts* for both "domain analysis" and "knowledge organization." Many bibliometric studies in the science of information are published in major journals, but these are not usually intended to be informative for knowledge organization and so were not included.

The 2012 analysis relied on methodological implications to reveal epistemological positions within the domain analysis community. Spatial implications varied from (120) "regions of dominance or control, to knowledge bases," such that "domain analysis is an empirical region." I concluded that domain analysis was critical to the future of KO as the science "in which the natural and useful blend of ontological realities results in ordered knowledge." Methods in these papers ranged from simple bibliography to complex metrical methods, including citation and co-citation analyses and term co-occurrence. Most methods employed were empirical in some way and involved determining the knowledge base through direct observation, ethnographic observation, or use of trace evidence, such as citation and term co-occurrence data from published texts.

In 2015 I revisited this group of research, updated with the addition of the most recent papers available, now totaling 100 contributions. In addition to a narration of the contents of these papers, some simple visualizations gave shape to this core research stream. Figure 1 shows the number of published studies by venue by year. The visualization shows that a slight majority of papers had appeared in ISKO conference proceedings, which is where the intension of the science of KO seems to grow (Smiraglia 2013), but about equal proportions appeared in *Knowledge Organization* the journal. The smaller segments represent consistent contributions that appear in other information venues. We also can see that the total number of domain analytical contributions has grown steadily over time.

Figure 2 shows the type of approach (from Hjørland's "eleven approaches" 2002) by year by venue. We can see that most papers in all three venues are either informetric or terminological, although a large proportion use other empirical techniques. The proportion of papers using discourse analysis has grown over time. Few papers report special classifications or literature guides.

The distribution of domains studied showed great diversity (Smiraglia 2015, 31-33). Thirty domains were studied once and 8 were studied twice. Four domains (archives, image searching, LGBT, physics, and social media were studied three times. There were 4 studies involving music and 22 that involved KO. While the breadth of domains studied is impressive, and most domain analytical research is pragmatically oriented to the design of specific KO systems (KOSs), the growth of science depends on replication and continuing analysis to build theory. It is only with these last half-dozen domains that have been studied repeatedly that domain analysis for KO has begun to approach the ability to contribute to theoretical understanding.

The study reported here is based on this core of 100 papers; the citations are presented in Smiraglia (2015, 33-40). The purpose of the present analysis is to contribute to theory-building through domain analysis in KO. Specifically, here I examine as closely as possible the decade-long effort by scholars to respond to Hjørland's call for the use of domain analysis as a methodological paradigm in KO. We will see that there is a fairly coherent cluster of scholars from within KO, enhanced by a surrounding cadre of KO scholars. Together they have begun to map, as Dahlberg (2009) has challenged the community to do, the knowledge base of many different and diverse domains of research and activity. It is worth adding that none of this material is commercially indexed; the manual spreadsheet of citations from which this research was generated is available at https://lazykoblog.wordpress.com/.

2.0 Evidence: the 100 contributions

The 100 articles were contributed by 80 authors. Only 9 authors contributed more than one paper. These are shown in Table 1.

Smiraglia, Richard P.	10
Guimarães, José Augusto	4
López-Huertas, María J.	3
Beak, Jihee	2
Ibekwe-SanJuan, Fidelia	2
Hartel, Jenna	2
Furner, Jonathan	2
Deokattey, Sangeeta	2
Campbell, D. Grant.	2

Table 1. Prolific authors in the core.

Sometimes in domain analysis the group of most prolific authors is considered to represent the research front. In this case, it is more likely that the entire core should be considered to represent a research front. The authors with several papers are those whose work is approaching a theoretical stage after repeated replication. The authors with 2 or more papers are poised to reach that position should they continue to add new research to the core.

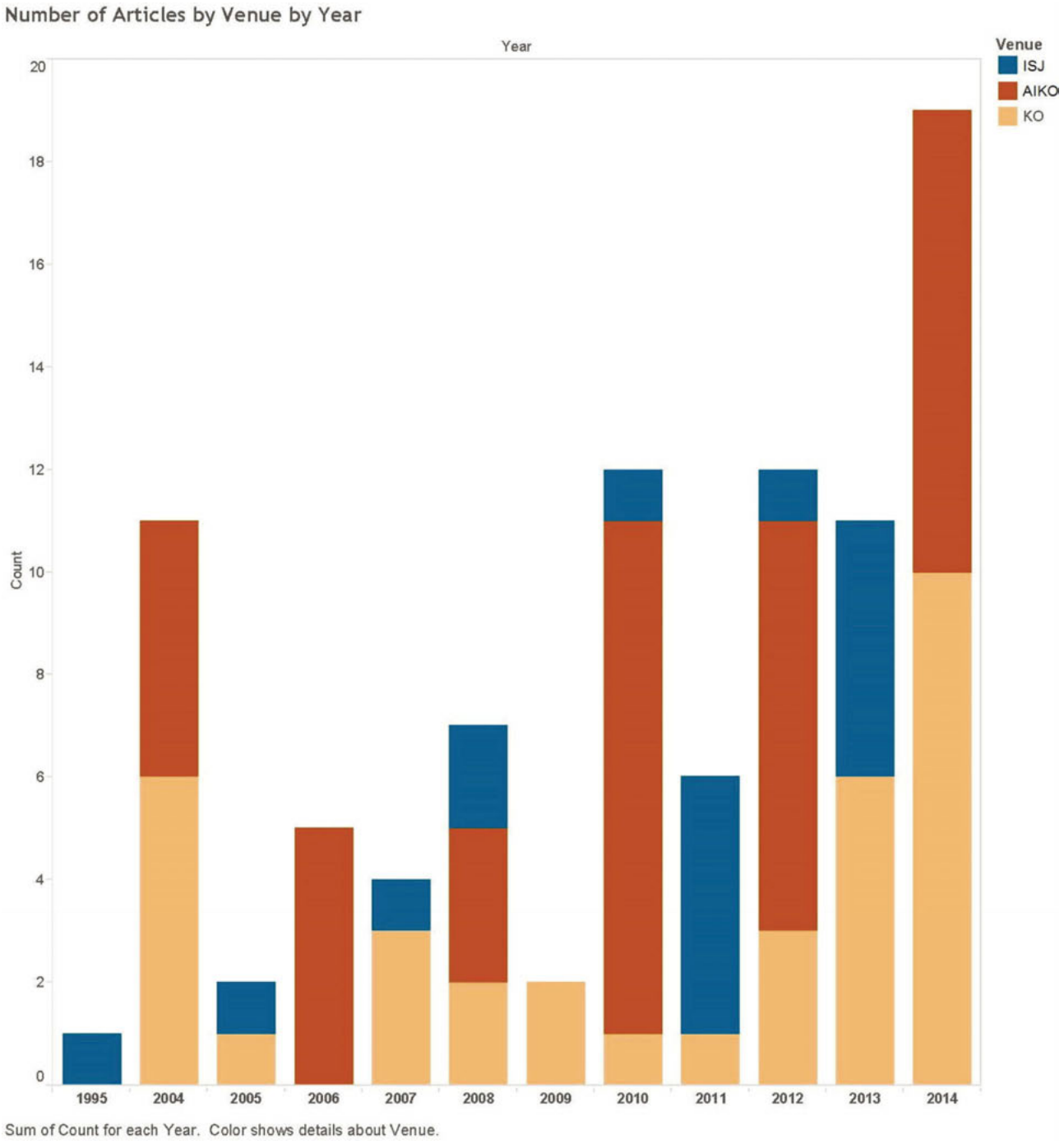

Figure 1. Number of published studies by venue by year.

The fact that there are 80 authors worldwide working on domain analysis for KO shows a well-formed, if nascent, research front. The authors come from 23 countries demonstrating a global acceptance of the research front and its methodologies (Table 2):

The United States and Brazil dominate, with India, Canada, Spain, Denmark and France all producing 4 or more contributions.

There were 2168 references in the cited papers. The age of citation ranged from 398 to the present; mean age of citation was 10.9 years (only 2 citations were to works dated before 1885, and the clear majority were to recent publications). Table 3 shows the range and mean age of cited work by country of affiliation and by venue of publication. Similarly, the number of cited works ranged from 2 to 69 with a mean of 21.6 works cited. Table 4 shows the range and mean number of cited works by country of affiliation

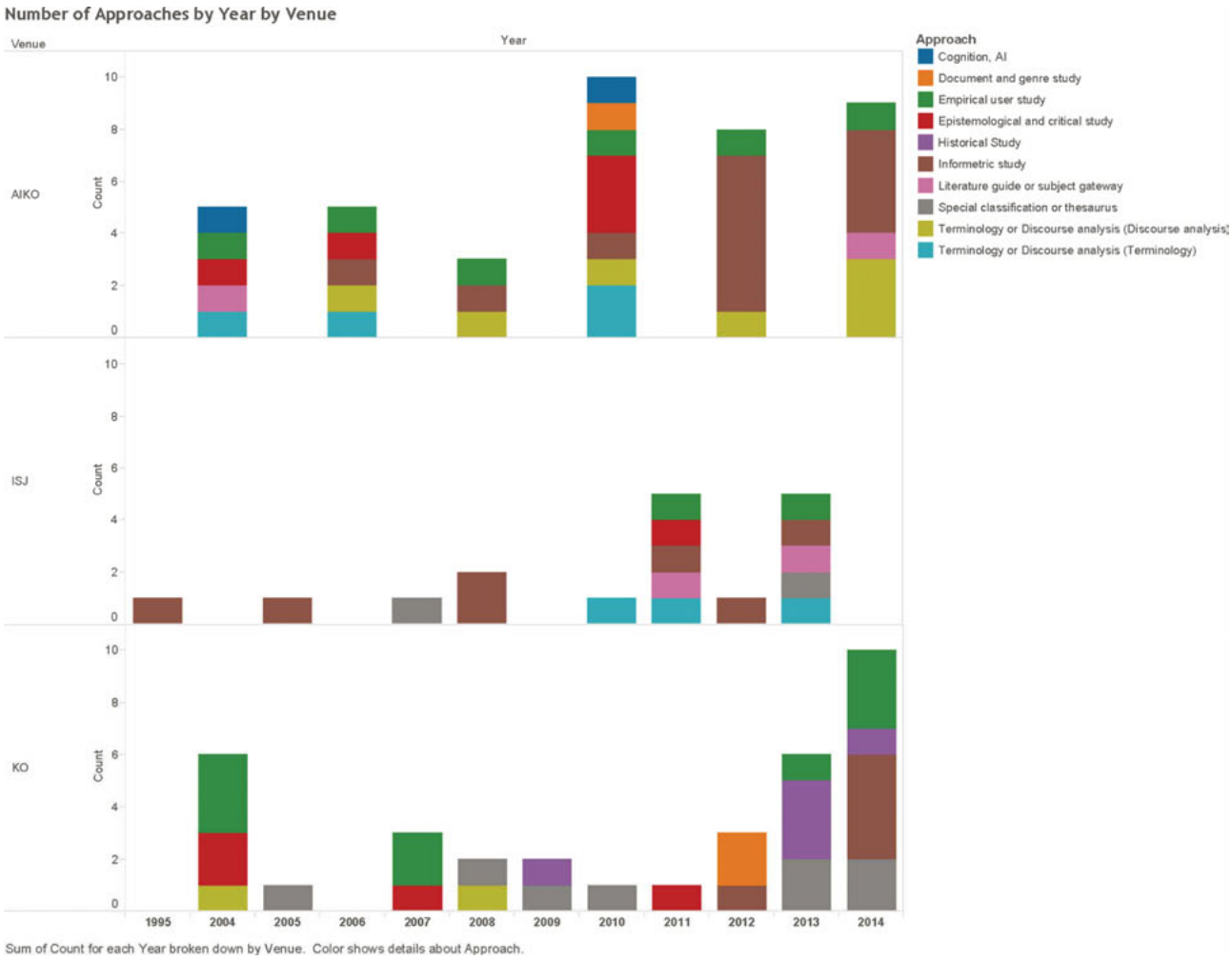

Figure 2. Approach by venue (Smiraglia 2015, 30).

and by venue of publication, each in descending order by mean. Ranges are given for countries from which more than one contribution was present in the core.

Age of cited work is an indication of the degree to which contributing authors are citing recent scholarship, a sign of scientific research, and the degree to which they are citing classical scholarly works, a sign of humanistic research. Similarly, the number of references is an indication of the same dichotomy; scientific researchers tend to cite few but recent related discoveries, while humanistic scholars tend to cite and synthesize many classical scholarly contributions. I have noted before (Smiraglia 2013) that the domain of KO can be characterized by this very dichotomy; large proportions of research in the domain are scientific and large proportions are humanistic. This tension between the two epistemic stances is part of how the domain manages to hold its diverse epistemological positions together, and in general the two clusters contribute to each other for the advancement of KO. We see this dichotomy mirrored here. Age of cited works ranges from 2.1 years from a German author to 21.8 years from a Swedish author. Contributors from the countries that have the largest numbers of papers all hover around the same mean, ranging from 8.9 years for the USA to 15.8 years for Denmark; the mean age of cited work in this group is 12.2 years, just slightly more than the overall mean of 10.9 years. Analysis by venue shows a similar range, from 2.6 years in *Desidoc* to 31.2 years in *Information Studies*; among the venues with large numbers of papers the range is from 8.7 years in *Journal of Documentation* to 14.6 years in *Journal of the Association for Information Science & Technology (JASIST)*. The mean in this group is 11.45 years, again not far from the overall mean of 10.9 years. This suggests this core of authors writing about domain analysis for KO is predominantly citing recent scholarship in a scientific profile, but also with a reasonable number of humanistic papers in the mix. There is little influence of region or venue. For example, one might reasonably have expected *JASIST, Journal of Documentation* and *Scientometrics* to fall at the lower end of this range be-

USA	33
Brazil	19
India	8
Canada	6
Spain	6
Denmark	5
France	4
China	2
Italy	2
Korea	2
Singapore	2
Taiwan	2
Bulgaria, USA	1
Finland	1
Germany	1
Hong Kong	1
Iran	1
Israel	1
Korea	1
Portugal	1
Romania	1
Sweden, Finland	1
UK	1

Table 2. Countries of contributor affiliation.

cause they are largely populated by empirical science. However, these three are all at the higher end. On the other hand, most of the conference proceedings fall at the lower end of the age range, reflecting the role of those papers as reports of ongoing research. Journal articles, at least in this research front, seem to be more encyclopedic.

A similar profile emerges from the number of works cited. The range by country is from 5 by a Romanian author to 52 by a Finnish author. The countries with the largest number of papers have a wide range as well, from 13.5 for France to 44 for Denmark; the mean in this cluster is 23. The range among venues is from 4 in *IRIS* to 42 in *Desidoc*, among the large contributors the range is from 10.2 in the proceedings of the Canadian Association for Information Science (CAIS) to 41.5 in *JASIST*. Interestingly, papers in the journal *Knowledge Organization* (*KO*) differ from those in *Advances in Knowledge Organization* (*AIKO*, the ISKO proceedings); the mean age of cited work in *KO* is 28 years but in *AIKO* it is 14, while the mean number of works cited in both is approximately 11.

3.0 Discourse: Co-Citation, Inter-Citation, Cited References

If there is discourse in a domain it should be possible to observe it by analyzing works cited by the authors in the domain. Our 100 papers by 80 authors included 2168 citations to relevant works. In fact, 1893 distinct works were cited; this is remarkable because relatively few works were cited more than once. There were 1177 citations to works by 280 authors cited more than once by the core authors. The top tier of this frequency distribution contains 51 authors cited 5 times or more. These are shown in Table 5.

This table contains only four of the most prolific authors in the core as given in Table 1 above—Smiraglia, Guimaraes, Lopez-Huertas, and Ibekjwe-San Juan—although all of the other authors from the core except Deokattey are cited more than once but with frequencies too low to fall into Table 5. The indication is that there is likely some evidence of discourse among the core authors as shown by inter-citation. The major evidence in Table 5 is how strong the foundational literature of domain analysis for KO is. It is also notable how influential the work of Small, McCain and White has been on domain analysis for KO; obviously they have provided primary instruction and exemplars of bibliometric methods for domain analysis. (In fact, Small's 1976 paper, "Structural Dynamics of Scientific Literature," originally appeared in vol. 3, no. 2 (1976) of this journal's predecessor *International Classification*, and thus can be considered seminal for KO. This paper has recently been reprinted in *Knowledge Organization* vol. 42, no. 4, pp. 251-59.) This accords well with the influence of metric methods seen in Figure 2 above. Taken together we can see the shape of the core community's discourse, teleologically-oriented toward ontological discovery for KO, epistemologically-oriented and grounded in bibliometrics aligned with the science of information, while at the same time remaining open to meta-disciplinary influences from other fields. The literature cited also is clearly international.

Author co-citation analysis is one approach for visualizing discourse in a domain. Usually co-citation statistics are gathered from major indexing services and used to create three-dimensional maps of nearness or distance among members of clustered groups of cited scholars. Typically in this mode the visualization shows how those citing the cited authors perceive them either as members of a closely-knit core, or as disparate entities of importance orbiting at some distance from the core. An alternative approach is to use inter-citation as a basis for author co-citation analysis, to see how the members of the core group perceive each other. In this study, inter-citation has been used to generate author co-citation maps of the domain of domain analysis for knowledge organization.

Author co-citation begins with defining a group of cited authors whose co-citation figures will be useful for visualizing a domain. In this case, the most prolific authors (Table 1) were combined with the top tier of the most cited authors (Table 5) and this group was used as a basis for co-citation analysis. As it happens, during data-gathering, it becomes clear when authors chosen for the group turn out

Country	Range	Mean age	Venue	Range	Mean age
Brazil	5.2-30.3	13.5	Canadian Association for Information Science proceedings	4.3-24.3	10.3
Bulgaria		12.8	*Advances in Knowledge Organization (ISKO proceedings)*	1.6-30.3	11
Canada	9.5-17.2	13	*Journal of the Association for Information Science and Technology*	13-16.2	14.6
China	6.9-8.3	7.6	*Journal of Documentation*	2.9-11.4	8.7
Denmark	7.8-30.6	15.8	*Knowledge Organization*	1.3--30.6	11.2
Finland		10.9	*Scientometrics*	10.8-15.1	12.95
France	5-12.2	10.2	DCMI proceedings		4.1
Germany		2.1	*Desidoc*		2.6
Hong Kong		5.5	*Information studies*		31.2
India	2.6-31.2	12	*Information Processing & Management*		9.2
Iran		13.6	*IRIS*		6.75
Israel		11.2	*Journal of Information Science*		7.2
Italy	4-12.1	8	*Libres*		10.5
Korea	7.2-10.8	9	NASKO proceedings		8
Portugal		15.8	*OCLC Systems & Services*		6.3
Romania		8.4	*Perspectivas Em Ciencia Da Informacao*		11.4
Singapore	2.9-7.2	5	*Scire*		10.3
Spain	3.6-15.1	8.9	*SRELS*		9.1
Sweden		21.8	*World Patent Information*		5.5
Taiwan	5.7-16.2	10.95			
UK		16.1			
USA	1.6-41.3	8.9			

Table 3. Age of Cited Work by Country and Venue.

Country	Range	Mean	Source	Range	Mean
Finland		52	*Desidoc*		42
Sweden		49	*Journal of the Association for Information Science and Technology*	40-43	41.5
Denmark	23-56	44	*Perspectivas Em Ciencia Da Informacao*		38
Israel		40	*Scientometrics*	26-45	35.5
Korea	32-45	38.5	*Journal of Documentation*	16-24	34.6
China	16-51	33.5	*Scire*		33
Germany		30	*Journal of Information Science*		32
Canada	4.0-64	29.5	*Libres*		30
UK		25	NASKO proceedings		29
Taiwan	7.0-4.0	23.5	*Knowledge Organization*	two to 69	28.25
Brazil	8.0-40	22.9	*OCLC systems & services*		22
Portugal		22	*World Patent Information*		17
Singapore	9.0-33	21	*Information Studies*		15
Bulgaria		20	*Advances in Knowledge Organization (ISKO proceedings)*	three to 40	14
Spain	6.0-36	17.5	*Information Processing & Management*		11
Hong Kong		17	CAIS proceedings	six to 16	10.25
Iran		16	*SRELS*		9
USA	3.0-69	16	DCMI proceedings		8
India		15.25	*IRIS*		4
Italy	2.0-27	14.5			
France		13.5			
Romania		5			

Table 4. Number of Cited Works by Country and Venue.

Cited Author	Frequency	Cited Author	Frequency
Hjørland , B.	112	Ranganathan, Shiyali Ramamrita	7
Smiraglia, Richard P.	68	Rosch, Eleanor H.	7
Dahlberg, Ingetraut.	25	Stebbins, R. A.	7
López-Huertas, Maria-José	19	Svenonius, Elaine	7
White, Howard D.	17	Bowker, G. C.	6
Tennis, Joseph T.	14	Bruns, Axel	6
McCain, Katherine W.	12	Gnoli, Claudio	6
Small, Henry.	12	Huang, X.	6
Soergel, Dagobert	12	Jacob, Elin K.	6
Beghtol C.	11	Kwasnik, Barbara.	6
Guarino, Nicola	11	Mai, Jens-Erik.	6
Guimarães, José Augusto Chaves	11	Ørom, A.	6
Pejtersen, A.M.	11	Talja, S.	6
Bourdieu, P.	10	Broughton, V.	5
Hartel, Jenna	10	Chi, M.T.H	5
Gruber, Thomas R	9	Couzinet, Viviane.	5
McIlwaine, Ia C.	9	Delgado, Richard	5
Olson, Hope A.	9	Ding, Ying	5
Bates, M.J.	8	García Marco, F.J.	5
Gardin J-C.	8	Hodge, Gail	5
Library of Congress	8	Ibekwe-SanJuan, F.	5
Albrechtsen, H.	7	Moya-Anegón, Félix	5
Cabré, Maria Teresa.	7	Nielsen, Jakob	5
Gilchrist, Alan	7	Tudhope, Douglas	5
Kostoff, R.N.	7	W3C	5
Ménard, Elaine	7		

Table 5. Most cited authors

not to have been co-cited, and the group then is adjusted by removing the names of those with few or no co-citations from the matrix. In the present study, two useful maps emerged from iterative analysis. The first shows the group of authors with significant co-citation by core authors. Figure 3 is a three dimensional multi-dimensionally scaled plot of author co-citation in the core.

This map shows us how the authors in the core perceive those they co-cite most often. Hjørland's work is catalytical, and because his work is cited by almost everyone it also is co-cited with almost everyone. But we see the distance in perception that comes from citation of classical theoretical positions in a domain. That is, the others are more tightly clustered at some distance from Hjørland because they represent to some extent the active research front in this core group. Then again, we have classical references to Dahlberg in the research front—a sign of the centrality of her work that originated the domain and also a sign that her work is still considered to be of immediate relevance. The dotted lines circle clusters within the clusters. Small, one of the inventors of co-citation analysis, is clustered with Dahlberg. White, a colleague of Small's and together with McCain the most important proponent of bibliometric research in information, is, like Hjørland, cited by everyone in this research front and thus also is co-cited with everyone in the research front. Soergel is a classical author in KO, one of the first scientists to work in the domain together with Dahlberg. Basically the map in Figure 3 shows us the members of the research front, loosely clustered but co-cited sufficiently to illustrate social semantic discourse in the domain. They are grouped closely with both methodological and theoretical points of view, and the entire research front works alongside its mentor Hjørland.

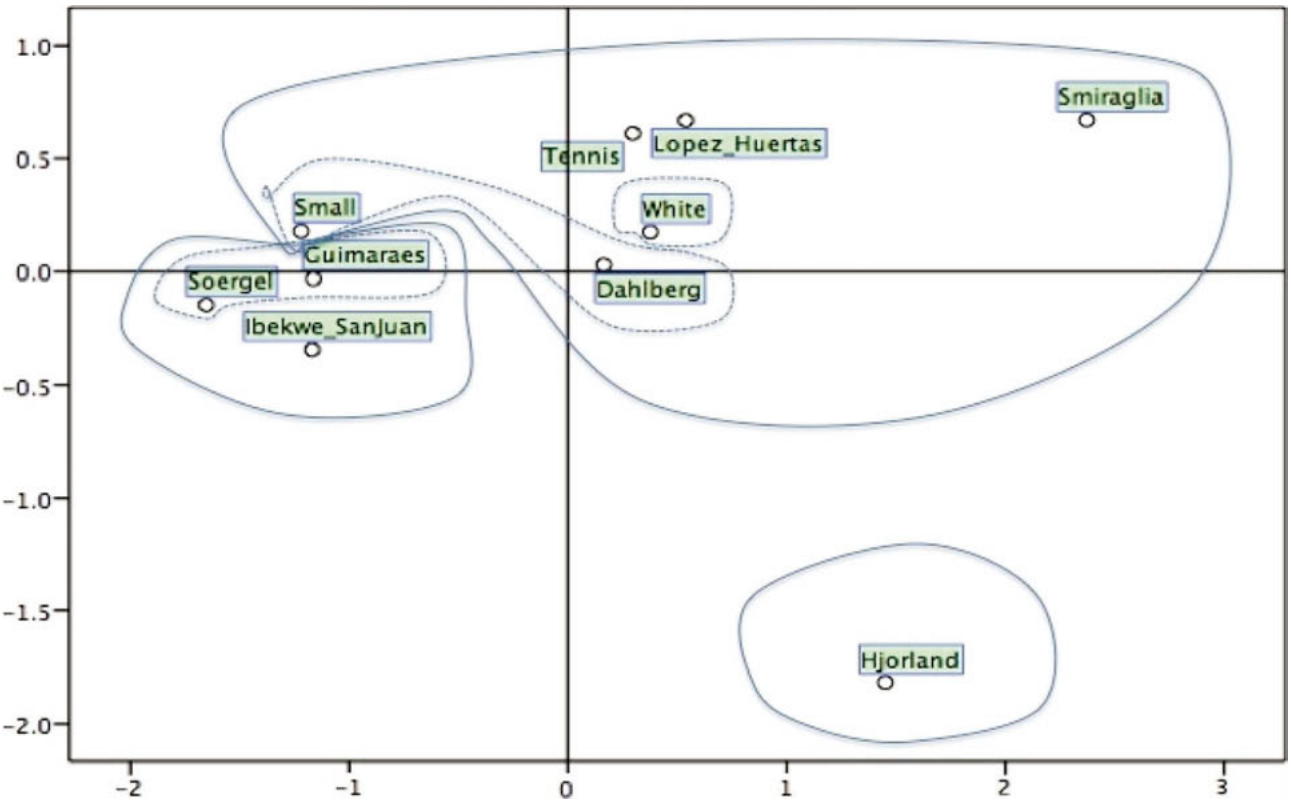

Figure 3. Author co-citation in the core (IBM-SPSS™ MDS plot stress = .03 R^2 = .9964).

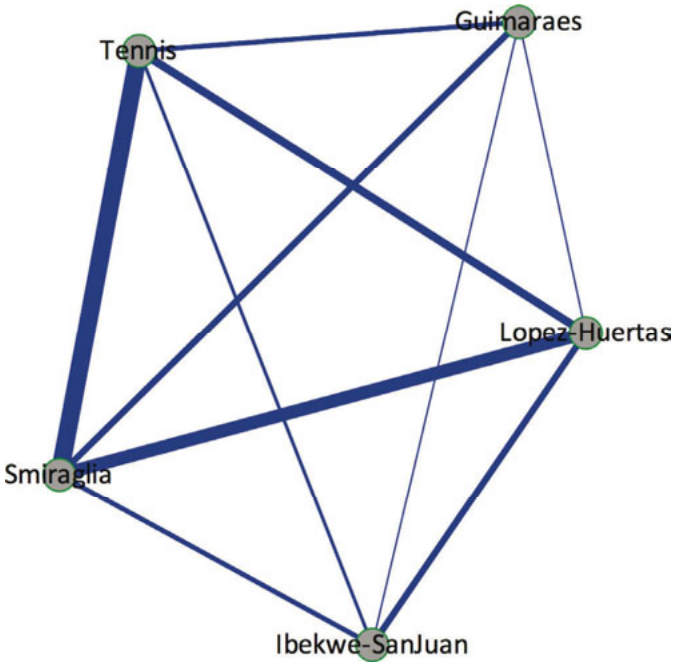

Figure 4. Gephi™ network plot of co-citation of active researchers in the core.

An interesting question then is what might we discover by looking just at the small group of authors in the core who are active researchers? Figure 4 is a Gephi network plot visualization of this group. The visualization is a close-up of what we perceived to be the active core before, now with the classical authors removed. We have to remember we are looking at positioning of these authors as perceived by all of the authors in the core as represented by their co-citation. All of these authors have papers in the core analyzing the domain of KO. A simple explanation is that these authors have produced the bedrock analyses of key concepts in both the intension and extension

of KO over time. By focusing our viewpoint we have simply made it easier to see how influential this group of authors has been and continues to be.

Here the specific connections, reflecting perceptions in the core, are visible. The strongest connections are the vectors between Smiraglia and Tennis (originator of the definitions of extension and intension in the core in his 2003 paper "Two Axes for Domain Analysis"), and between Smiraglia and Lopez-Huertas. Lopez-Huertas has written several doman analyses of KO research in Spain. Ibekwe-SanJuan has studied KO globally, but with different methodologies than Smiraglia has used, and the two cite each other regularly. Guimaraes has studied the KO domain globally and has used the same sources as Smiraglia but with different methodologies, leading to different but theoretically complementary results.

4.0 Conclusions: Tension is good

Clearly the first conclusion must be that this research is limited by the choice of which papers constitute the core of domain analysis, in KO, for KO. Other researchers might constitute the core differently. However, everything domain analytical in either the journal *Knowledge Organization* or the proceedings *Advances in Knowledge Organization* has been included.

There clearly is a vibrant domain around domain analysis in KO for KO. Many domains have been studied; about a dozen have been studied enough to begin to make theoretical statements. That others will come along seems clear from the pace of growth in use of domain analytical methods for KO. Also, there clearly is discourse in this group. The discourse takes place between the pragmatic need for a specific KOS, which leads to studies of domains as diverse as astronomy and gourmet cooking, and the classical ontological and epistemological positions in KO represented by concept theory. There is acknowledgment of Hjørland's catalytical call for more domain analysis. There is discourse with the information bibliometric community, but also, there is change in the use of those methods for KO research. Thus it turns out to be a complex discourse that draws on tools from the science of information, and that combines empirical statistical analysis of ontological indicators with the epistemological stances of KO.

Of course, Dahlberg called from the beginning for KO to emerge as a science (Dahlberg 2006) by taking up research that could identify all concepts; she has often reiterated this as the core mission for KO (see Dahlberg 2009). As fundamentals of KO, Dahlberg (2006, 12) posited "the construction of concept systems," but also, "the correlation to, or the mapping of, units of such a concept system with objects of reality." The methodological axes for this new science were to be (13): a "mathematical-statistical approach …, [a] mathematical conceptual approach …, [and, a] concept-theoretical approach." These three axes are all representative of the empirical methods for domain analysis called for by Hjørland (2002) and updated by Smiraglia (2015, 97). The science of KO is the research activity that undergirds the construction of KOS. This science is aligned closely with the science of information, together with which it occupies a position within the science of science (Dahlberg 2006, 17). To date we have 100 papers by 80 authors who have responded directly to Dahlberg and Hjørland's calls for the evolution of an empirical science of concepts and concept-extraction. We have theoretical knowledge of perhaps a dozen disciplines as a result of this work, some of which involves replication. We have an opening to theoretical understanding as well, because the methodologies developed by this nascent research front have proven to be effective, especially when used together as a form of methodological triangulation.

In the domain of KO at large tension is what holds the ever-evolving intension within the extension. The tension between empirical and humanistic approaches is primary in KO; this tension has become an important part of the structure of the domain. As the intension is stretched by application research to new domains of knowledge, the extension of KO is maintained by this constructive tension between empirical studies and humanistic analyses. Domain analysis for KO is a part of this repeated evolutionary stretching of the intension, which in turn informs and strengthens the theoretical boundaries of the extension. Domain analysis for KO is a very vibrant field of research and development not only for KO as a science but for humanity at large.

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KO KNOWLEDGE ORGANIZATION

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International Journal devoted to Concept Theory, Classification, Indexing and Knowledge Representation

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(4) discussing questions of education and training in classification
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