Knowledge domain navigation in interdisciplinary digital landscapes

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Abstract

Knowledge domain navigation is vital to research activities, and this paper addresses the epistemological and ontological dimensions of the knowledge domain navigation framework. The paper addresses knowledge creation through the metadata record, and how interdisciplinarity affects the metadata record. The discussion of the ontological dimension focuses on semantic navigation, interoperability, and the relationship of taxonomies to interdisciplinarity. A number of digital initiative projects illustrate the concept of knowledge domain navigation.

Keywords: knowledge domain navigation, interdisciplinary research, metadata, taxonomy, information architecture

Knowledge domain navigation in interdisciplinary digital landscapes

Knowledge domain navigation is vital to research in the interdisciplinary digital information space. Researchers navigate the knowledge domains within the scope of their interdisciplinary activities as well as navigate digital libraries, databases, catalogs, and information portals in a semantically connected environment held together by metadata, taxonomy, infrastructure, and professional communities supporting research.

The conceptual framework for knowledge domain navigation has two dimensions: epistemological and ontological. The epistemological dimension identifies the intellectual condition for creating knowledge. Data, information, and knowledge in metadata records can support new knowledge creation. The ontological dimension focuses on hierarchies of interrelated concepts within and across multiple knowledge domains. Subject metadata fields are especially suited for controlled vocabularies organized in taxonomies. The framework implies a mutual and important relationship between the epistemological and ontological dimensions. The process of knowledge creation can affect domain structure and vice versa; structure can affect processes of knowledge creation.

The underlying research questions in this exploratory paper are (a) what is knowledge domain navigation, (b) how does it support interdisciplinary research in a digital environment, and (c) what is the role of metadata and taxonomy in the framework for knowledge domain navigation? The paper focuses on knowledge domain navigation in an interdisciplinary and interoperable environment where information architecture, metadata interoperability, taxonomy mapping contribute to optimize information retrieval and provide meaningful results. It presents the epistemological and ontological dimensions of the concept framework; however, the technical analyses of interoperability, taxonomy mapping, or methodological aspects of interdisciplinarity fall beyond its scope. The organization of this study is as follows: A literature review presents definitions of key concepts, metadata interoperability, taxonomy mapping, interdisciplinarity, and information architecture, all of which are vital to the framework for knowledge domain navigation. Next, the study addresses the epistemological dimension, and its relation to the interdisciplinary environment. The third section focuses on the ontological dimension and the importance of metadata interoperability and taxonomies to knowledge domain navigation. Finally, the paper will discuss a few illustrative Digital Initiatives projects at the University of Toledo Libraries.

Literature Review

Definitions

Knowledge domain navigation is a multipart concept requiring separate definitions for *knowledge*, *knowledge domain*, and related concepts. The *Oxford Dictionaries Online* defines *knowledge* as “facts, information, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject” (“Knowledge,” 2010a). In management and information sciences, *knowledge* means “objects, concepts, and relationships that are assumed to exist in some area of interest. A collection of knowledge, represented using some knowledge representation language is known as a knowledge base and a program for extending and/or querying a knowledge base is a knowledge-based system” (“Knowledge,” 2010b).

Knowledge is different from *data* and *information* in a continuum of knowledge-creating processes. *Data* means “symbols that represent properties of objects, events, and their environments” (Ackoff, 1989, p. 3). *Information* is data with meaning or context, and *knowledge* is “a collection of information [with an intent] to be useful” (Bellinger, Castron, & Mills, 2004, para. 7).

Polanyi (1966) identified two types of knowledge: tacit (personal and intangible) and explicit (public, tangible, codified) knowledge. Nonaka and Takeuchi (1995) have described four methods—socialization, internalization, combination, and externalization—used to convert tacit knowledge into explicit and vice versa on the basis of Polanyi’s work. Metadata records contain both types of knowledge, and can potentially contribute to new knowledge. Personal knowledge is also important to oral history (Ritchie, 1995), as published interviews transport tacit forms of knowledge into explicit. Cultural anthropology (Geertz, 1983) also regards local knowledge critical to interpretive studies, but does not discern between these two forms of knowledge. Much of orally transmitted knowledge remains in tacit form, as it is passed down via the method of socialization. Archival finding aids present archivists’ tacit knowledge of processed collections, which turns into explicit upon publication as an electronic document on the Web.

Knowledge domain (or *domain*) means “the content of a particular field of knowledge,” (“Knowledge Domain,” 2010b) as well as *discipline*, *subject field*, *scientific knowledge*, and *universe of discourse* (“Knowledge Domain,” 2010a). *Domain* has similar meanings in organizational and technological contexts where the domain content in archives and knowledge bases is also a representation of an organization’s collective knowledge in terms of scope and size. Specialized digital libraries, databases, and archives best represent the intellectual domains in organizational collections, as they “give a sense of limit and context to places, people, things, and ideas” (Kaczmarek, 2006, p. 217).

Knowledge domain navigation goes beyond subject browsing, which is usually limited to single domains (or subject trees) in research databases and catalogs. In interdisciplinary context, however, it involves the analysis and navigation of intellectual domains. Messina (2010) uses a *roadmapping* analogy while describing it as a problem solving technique utilizing knowledge bases. Papazoglou and Hoppenbrouwers (1999) describe a similar concept:

> The purpose of knowledge navigation is to help users negotiate a pathway through an overwhelming universe of information in order to improve their understanding. This requires locating, identifying, culling, and synthesizing information into knowledge. Knowledge navigation does this by analyzing the conceptual structure of terms extracted from document indices and using semantic relationships between terms and concepts to establish connections between terminology used in a user's request and other related terminology that may provide the information required. ("From Terms to Knowledge" section, para. 2)

Epistemology and Ontology

The *Stanford Encyclopedia of Philosophy* (Steup, 2005) defines *epistemology* as (a) the study of what knowledge is, (b) how one comes to have knowledge, and (c) what the necessary and sufficient conditions of knowledge are. *Philosophical ontology* is "the study of what is, of the kinds and structures of objects, properties, events, processes, and relations in every area of reality" (Ontology Research Group, 2007b). *Ontology* is "a structured representation of the types of entities and relations existing in a given domain that is designed to support exchange and reuse of data and information" (Ontology Research Group, 2007a). Others define *ontology* as "formal description of a domain of knowledge" (Carr, et al., 2005, p. 4) and "a description of the concepts and relationships" (Gruber, 1992, p. 1). "[Ontology can also] be viewed as a level of abstraction of data models, analogous to hierarchical and relational models, but intended for modeling knowledge about individuals, their attributes, and their relationships to other individuals" (Ontology Research Group, 2007, "Ontology," para. 1).

Ontology is distinguished from *thesaurus* and *taxonomy*, which are often used interchangeably (Gilchrist, 2003). The *Oxford English Dictionary* (*OED*) defines *thesaurus* as "a classified list of terms, especially keywords, in a particular field, for use in indexing and information retrieval" (as cited in Gilchrist, 2003, p. 8). The *OED* defines *taxonomy* as "a science [related to] classification, especially the systematic classification of living organisms" (as cited in Gilchrist, 2003, p. 8). *Taxonomy*, or subject classification (Garshol, 2004), plays an important role in arranging subjects in a hierarchical structure, and with the help of taxonomies and ontologies, researchers can identify concepts and relationships among them throughout a domain.

Interdisciplinarity

Interdisciplinary research emerged about a century ago with early experimentations in crossing domain boundaries, and new research methods emerged by the 1970s with more pervasive changes to scientific methodologies. Klein (1990) identified and described the principal approaches such as *multi*-, *cross*-, *inter*-, and *trans*-disciplinarity, presenting progressively greater levels of integration among disciplines. The relationship between *intellectual core* and *scatter* was addressed by Palmer (1996) who noted that interdisciplinary activities are focused in the *scatter*. Klein (1996) points out that boundary crossing (or migration) is more common in specific areas of interdisciplinary activities where "boundaries…shift and overlap because ideas and techniques do not exist in a fixed place. Researchers carry them as they participate in multiple groups" (p. 43).

Information Architecture

Information architecture is "the combination of [information] organization, labeling, and navigation schemes within an information system" and "[the] structural design of an information space to facilitate task completion and intuitive access to content." (Rosenfeld & Morville, 2002 p. 4). "Information space" corresponds to the knowledge domain navigated during research, and this space is held together by interwoven webs of domain content, metadata, and taxonomy. Information architecture is critical to building intuitive interfaces that facilitate easy access to information. Rosenfeld and Morville (2002) point out that large information systems will require polyhierarchies because "as the number of documents grows, you need a greater level of pre-coordination (using compound terms) to increase precision" (p. 202). Hence, the relationship of information architecture to taxonomies and interdisciplinarity is important in the framework of knowledge domain navigation.

Section 2: Epistemological perspective on content description

Interdisciplinarity and digital content

Various interdisciplinary methods have emerged in the past century and caused a shift away from monodisciplinarity. This transition resulted in new disciplines, epistemologies, methodologies, and knowledge when researchers and practitioners interact across their domain boundaries. The scope of research activities has extended beyond the clearly defined disciplines, and the resulting new knowledge is interdisciplinary (Klein, 1996). Integrative methods—*cross*disciplinary, *multi*disciplinary, *inter*disciplinary, and *trans*disciplinary—have evolved over the past century (Klein, 1990), and continue to shape intellectual landscapes as well as nascent domain content (data, information, knowledge, and non-textual material) in databases, digital libraries, and information portals. The four integrative approaches described below represent different core-to-scatter ratios (for more discussion on core and scatter, see Palmer, 1996), which in turn, result in different types of domain content and collection scope. Based on Klein's descriptions, the present study makes the following assumptions about domain contents and interpretations with respect to the disciplines.

*Multi*disciplinarity:

Two or more disciplines are juxtaposed with no interest in developing new disciplines. The domain content (and metadata) is heterogeneous in scope with vaguely established or identified relationships between contents.

*Cross*disciplinarity:

Disciplines merge in this method, but perspectives in the core discipline strongly influence scholars' analysis and interpretation of concepts in the adjacent discipline(s). Domain content is, therefore, somewhat less heterogeneous than what multidisciplinary research produces due to the control of the core discipline in this environment.

*Inter*disciplinarity:

Disciplines considerably overlap in scope, and interpretations of domain content are informed by mutually shared perspectives, but connections between content and the core discipline is still recognizable. Domain content and metadata is heterogeneous with little or no bias due to shared perspectives.

*Trans*disciplinarity:

Disciplinary boundaries are blurred or non-existent due to the erosion of core epistemologies. Domain content and metadata may be highly heterogeneous. The interpretation of domain content loses the connection with the core discipline, and there is no discernible connection to any identifiable discipline. No bias is evident in this scenario.

Effects of interdisciplinarity on metadata

Interdisciplinarity presents a number of opportunities and challenges to the metadata community. Opportunities include new interpretations for existing content, cultural and intellectual diversity, and establishing new relationships to contents in related knowledge domains. If the metadata record is rich, a search on a particular concept will retrieve items associated with concepts in related disciplines. For example, concepts in cultural anthropology, psychology, and linguistics may also turn up in collections pertaining to ethnomusicology, music therapy, and sociolinguistics, respectively. However, there will be challenges due to burgeoning heterogeneous domain content as well as semantic and compatibility issues.

According to Tony Gill, the heterogeneous content in culturally diverse digital collections may lead to “cultural infodiversity” (as cited in Attig, Copeland, & Pelikan, 2004, p. 253). Crosswalks to achieve interoperability among diverse collections using different metadata standards will also be necessary. In Penn State’s Visual Image Usage Study (or VIUS), “some descriptions are simple and generic; others are richer and domain specific. Access into these descriptions is often through the lowest common denominator provided by crosswalk, ultimately leading the metadata editor into mapping madness” (Attig, Copeland, and Pelikan, 2004, p. 253).

Attig, Copeland, and Pelikan (2004) also address semantic compatibility issues rooted in the difference between metadata elements. A solution might be to create a superschema to which elements in the other schemas, and this solution might establish a dynamic link among the associated domain contents. These authors also warn that subjectivity and heterogeneity of disciplines may affect consistency in metadata values, which may present concerns at the early stages of disciplinary development. However, subjectivity in endemic in the humanities and social sciences, and it cannot be separated from certain theories and methodologies.

Knowledge creation via Metadata fields

Metadata records can facilitate knowledge creation if they contain the necessary data, information or knowledge in the appropriate fields as needed for knowledge creating processes. Archives place partially described content in their digital libraries to provide timely access to collections, but missing metadata fields may prevent users from placing the images in the correct historical, social, or geographical context. Innovative solutions to completing metadata records often involves using social networking sites and rapport with the local history community to gain knowledge of events, places, organizations, and people to establish identity of people and places on digital content without adequate description. Oral histories and ethnographic studies can also provide rich contextual information or local knowledge for orphaned material. Thus, data, information, and knowledge are available in external content, and this is partly why archivists use provenance (or history of ownership) and original order as organizing principals while processing collections.

In commercial context, knowledge bases contain data, information, and knowledge to support actions and decisions. An analysis of metadata records can significantly contribute to knowledge needed to re-develop products, understand prior failures, product design flaws, concerns, successes, and expand or develop new knowledge for future projects. As with the archives scenario, missing metadata records can be completed through research and interviews. The value of primary sources is indisputably the most important asset to organizations committed to preservation and innovation.

A metadata record can contain data, information, and knowledge in various fields. In Dublin Core, for instance, dc.date, dc.creator, and dc.coverage require data such as date, name, and geographical location, respectively. Values in these fields appear in objective form, that is, without interpretation. Descriptions in dc.description typically contain information, which presents data in specific contexts, which could be historical, geographical, cultural, political, or other. These entries should be objectively constructed, that is, without interpretation or other distracting meta-text. The dc.notes is an appropriate field to add knowledge, that is, information with intent to support action. For example, archivists processing a collection may need to add notes related to personal (or tacit) knowledge of the item, its provenance, and current condition. Archivists can add notes to flag items or collections for future preservation action. Some may use Flickr to engage the public in identifying images with missing knowledge, and while verification of community-provided information is necessary for quality control, in most cases, such feedback provides reliable knowledge about people, events, places, and organizations on undescribed photographs. The process of developing this knowledge is important to illustrate various capabilities of metadata records.

Knowledge conversion

Knowledge in metadata records are created through a variety of methods and channels, but mostly via research and serendipity. Nonaka and Takeuchi (1995) describe four knowledge conversion methods that generate new knowledge. *Socialization* involves the sharing of experiences, which can be a source of data, information, or knowledge during interviews and conversations. *Externalization* involves presenting and publishing of data, information, and knowledge going into the metadata record. Some digital libraries can extract metadata from the text of published documents in PDF format, which automates the retrieval of records and achieve greater relevance to user queries. *Combination* allows users to add new knowledge to existing ones to enrich the metadata record or expand domain knowledge based on what the record presents. Finally, *internalization* presents an opportunity to bring data, information, and knowledge from research, interviews, and analysis, and add them to the metadata record while also enabling researchers and analysts to develop new tacit knowledge. As metadata creation is an iterative process, the cycle of knowledge creation also presents new opportunities for new knowledge creation. Rich metadata can inform and empower researchers to do more than simply retrieve highly relevant results, so it is important to consider metadata quality as a factor in knowledge domain navigation.

Metadata quality

Metadata quality answers to some extent a fundamental epistemological question whether there is a necessary and sufficient condition in the metadata record for creating knowledge. This study presents a case for an extended use of metadata—one that goes beyond mere description. Metadata quality rests on the accuracy, completeness, and consistency (Kurtz, 2010) of metadata, without which researchers will not be able to explore a domain fully. Metadata quality is also a condition for interoperability, through which it supports knowledge domain navigation and, ultimately, any research project. Since research aims to find answers, solve problems, and create new knowledge, metadata quality is vital to research in the interdisciplinary digital landscape.

The National Information Standards Organization (NISO) also sets expectations of metadata quality, which include conforming to industry-supported metadata standards, supporting interoperability, using authority control and content standards, clearly stating conditions and terms for use, support-long-term preservation, and having “the qualities of good objects including authority, authenticity, archivability, persistence, and unique identification”

(Park, 2009, p. 215). These qualities in metadata support critical research outcomes, which include retrieving quality information from archives, catalogs, and digital libraries.

There are two prevailing attitudes to providing metadata in the archival community: one focuses on uploading records after they are complete while another widely accepted albeit pragmatic opinion upholds the "more product, less process" position in order to reduce backlogs in cataloguing collections (Greene & Meissner, 2005). In latter case, completeness or fill rate (Kurtz, 2010) will be sacrificed in favor of quantity. A counterargument for the former position is that quantity will not add value to a collection if those records are not accessible. From the vantage point of knowledge domain navigation, it will be difficult to retrieve records if there is no metadata although if the staff anticipates completing those records, they can either wait and upload when all fields are complete or describe the collection in a way that it can be collocated in a search. Incremental completion of metadata records, therefore, offers a compromise during difficult economic times with low staffing and budget and rising expectations of digital libraries.

Section 4: Ontological perspectives

From an ontological perspective, knowledge domain navigation is that part of the research process where researchers locate and relate concepts in various domain structures. Ontologies are representations of domains in hierarchical formats called taxonomies. With taxonomies, researchers can view the structure of knowledge domains, while ontologies help researchers identify relationships among domain concepts. Organizational charts can function like taxonomies, as they represent the structure of organizations creating records. In fact, finding aids to organizational records are ideal for navigating knowledge within a given organization, as records in one area can be related to others in different areas of the organization's collections.

In the expanding intellectual landscape of interdisciplinary research, following these concept relationships is one of the salient aspects of knowledge domain navigation. Researchers do not only navigate the structure of an information portal, digital library, database, or library catalog, but also the conceptual structures of multiple disciplines. A combination of human and artificial intelligences will be needed, as researchers rely on technology and critical thinking to find resources for their work. Archives contain non-digital material that can only be viewed on site. Manual navigation characterized the research process before computers were introduced in libraries: when identifying the topic, researchers used the card catalog to locate items in the collections. All that has changed as computer technology grew in sophistication and the Internet changed information-seeking behaviors in libraries and beyond, but some limitations to this will persist for some time.

Semantic navigation in repositories

Koutsomitropoulos, Solomou, Alexopoulos, and Paptheodorou (2009) present a model using Semantic Web technology to enhance digital repositories aiming to "provide inference-based knowledge discovery, retrieval, and navigation…based on existing metadata and other semi-structured information" (p. 179). The model was built for the institutional repository at the University of Patras. Scalable and interoperable repositories will enable researchers using this technology to navigate across multiple knowledge domains. In fact, via the Open Archives Initiative (OAI), the contents of registered OAI-compliant repositories will be mutually accessible on a global scale. The two cases below illustrate semantic navigation in interoperable environments.

Semantic navigation is a service offered through such technologies as DSpace, Fedora, and others discussed by Koutsomitropoulos et al. (2009), and will indeed add considerable power to researchers. The process involves developing Semantic Web ontology (a structured representation of the knowledge domain) using the Web Ontology Language (OWL) and the Resource Description Framework (RDF) standard for metadata extracted from existing Dublin Core. Ontologies allow machines to establish relationships throughout the metadata record. Knowledge domain navigation is further enabled through the semantic search interface in DSpace. Query entries (including those with Boolean combinations) require identifying the valid ontological class names (or metadata fields), which may present a problem if the original metadata is incomplete or when two interoperable libraries employ disparate taxonomies in the metadata record.

Harper and Tillett (2007) discuss the use of Library of Congress (LC) classification in the Semantic Web context, and state that libraries may significantly contribute to Tim Berner-Lee's vision for the Semantic Web. Collaboration between libraries and the Dublin Core (DC) community would improve entries in the "relator terms" (crosswalk) field in corresponding catalog and Dublin Core records. The format of the metadata value is critical to optimal retrieval of records, and the Semantic Web environment would, in the opinion of these authors, improve access to these records across the structural disparities of metadata environments.

Figure 1 illustrates the use of LC subjects in repeatable DC subject fields. Although crosswalking via a "relator terms" relationship is not present, and the digital library does not use semantic links or link resolvers to the catalog, it demonstrates that researchers can simply copy and paste the subject entry into a library catalog and identify subject-relevant literature for further research. This strategy illustrates yet another method in knowledge domain navigation.

Metadata Interoperability

The National Information Standards Organization (NISO) definition for interoperability is "the ability of multiple systems with different hardware and software platforms, data structures, and interfaces to exchange data with minimal loss of content and functionality" (as cited in Chan & Zeng, 2006, Interoperability section, para. 1). Zeng and Chan (2006) address metadata interoperability on three distinct levels: schema, record, and repository. The schema level focuses on schema elements and crosswalks independently of application. The record level focuses on entire metadata records that are integrated through mapping. At the repository level, the aim is to enable cross-collection searching through mapping of specific elements (e.g., subject, relation, provenance, spatial coverage, etc.). Interoperability at these levels will enable researchers to navigate knowledge domains across a repository or multiple repositories, collections, and datasets.

As the Semantic Web infrastructure is expanding, its challenge will be to organize a multitude of information and knowledge architectures into a mutually accessible arrangement. Interoperability is the outcome of mutual accessibility between digital libraries, archives, catalogs, and other distributed and networked resources with similar and dissimilar metadata and taxonomy standards. However, as late as 2008, a survey conducted by Park and Tosaka (2010) pointed metadata interoperability has still been reported to be a major challenge in accessing information across networked resources. Many independent databases will continue to be mutually inaccessible for legal reasons and due to rigid information politics.

Use of taxonomy in the metadata record

Metadata records contain data, information, and knowledge in various fields, but the relationship of metadata to taxonomy needs more clarification. This relationship is central to understanding the ontological dimension of the knowledge domain navigation framework, since this is essentially about the high art of browsing catalogs, databases, and digital libraries, and not searching. Taxonomy is “a subject-based classification that arranges the terms in the controlled vocabulary into a hierarchy” (Garshol, 2004, p. 381). Metadata merely describes contents in a digital library; it does not classify or arrange them in hierarchies. Likewise, taxonomies do not describe content, but can appear in the metadata record, and their natural place in the metadata record is the subject field.

The direction of knowledge domain navigation can be horizontal and vertical. Researchers inspecting the subject field of a digital object may be directed to higher or lower levels of a knowledge domain structure, or hierarchy, with the help of multilevel LC subject entries in the library catalog. For instance, “Industrial Policy -- Arab Countries -- Congresses” can point researchers to higher levels of the hierarchy to locate progressively broader concepts such as “Industrial policy,” and yet another level up to “Industry.” Lower in this hierarchy are the progressively narrower concepts like “Small Business -- Arab Countries -- Congresses.” This is an example of vertical navigation, which limited to one subject tree—a single knowledge domain.

Horizontal navigation occurs between two related subject trees. For interdisciplinary works, each repetition of the subject field may represent a semantic relation to another knowledge domain where other hierarchies will allow vertical and horizontal navigation. Figure 2 illustrates this principle with subject links to other knowledge domains: Music Therapy, Music in Special Education, and Special education -- Music.

Taxonomy support for interdisciplinary research

With the increasing importance of the role metadata and taxonomies play in semantic computing and navigation, developments in interdisciplinary activities must inform metadata and taxonomy management. Metadata records can use taxonomies developed in research and identified by publishers and subject experts, and which represent the structure of knowledge domains. Lambe (2007) describes several taxonomy forms: lists, trees, polyhierarchies, matrices, facets, and system maps. Monodisciplinary knowledge domains may rely on simple hierarchies, such as trees, while interdisciplinary domains will require more complex taxonomy forms such as polyhierarchies, matrices, facets, and system maps. Based on models provided by Lambe (2007), the present study proposes the following correspondence between taxonomy forms, integrative approaches (Klein, 1990), and knowledge domain navigation possibilities:

Multi- and *cross*disciplinarity:

Trees will be sufficient with their basic hierarchical structure to arrange concepts from each discipline and to support navigation along a spectrum of broader, narrower, and related terms.

*Inter*disciplinarity:

Trees and polyhierarchies will work here, depending on the extent of integration, to support navigation vertically (in a manner allowed in the previous model) and horizontally (to navigate between allied knowledge domains)

*Trans*disciplinarity:

Polyhierarchies and matrices work here to support navigating multidimensional structures where many-to-many relationships exist on multiple levels.

Taxonomy mapping

In interdisciplinary research, scholars usually work across disciplinary boundaries, which involve negotiating disparate taxonomies. Taxonomy mapping (Pohs, 2010) is a strategy for mapping across multiple taxonomies, which is necessary when each discipline is characterized by unique domain structures. Similar concepts are interpreted differently in different disciplines, so their place can vary in the respective taxonomies. The purpose of taxonomy mapping is to merge, collapse, or reconcile hierarchies, as there are different terms for comparable concepts and often identical terms for different concepts. In industrial application, mapping aims to generate new and simplified taxonomies across multiple domains. In scholarly research context, however, the diversity of taxonomies may require unique mapping strategies and iterative revisions thereof. Wherever feasible, taxonomy mapping will support consistency in subject description, which in turn, may simplify knowledge domain navigation.

Section 4: Related Projects

Virtual exhibit (in progress)

Unlike digital libraries, databases, and catalogs, virtual exhibits feature unique thematic arrangements and different structures for knowledge domain navigation. While virtual exhibits at the Ward M. Canaday Center for Special Collections at the University of Toledo inherit the themes from physical exhibits, the virtual exhibit functions in at the Ward M. Canaday Center for Special Collections at the University of Toledo inherit the themes from physical exhibits, the virtual exhibit functions in a *hypertext* (Fullér, 1996) environment with distributed and interlinked access points to knowledge related to the exhibit theme. Figure 3 illustrates this concept whereby each exhibit (EX) is linked to point of discovery—an archival finding aid (FA), library catalog (CAT), digital collection (DRC), or a database (DB).

OhioLINK – Digital Resource Commons (in progress)

Ohio's largest shared digital library uses DSpace as digital library in a consortium environment involving seventeen universities throughout Ohio. Navigating across the individual DRC collections is facilitated by federated searching, but the use of localized vocabularies will pose some challenges due to disparate data (or metadata) describing the same or similar content. Because all the collections are unique, there is minimal overlap between DRC collections. Figure 4 illustrates the use of LC subjects in describing archival content. This record links to a finding aid. Figure 1 illustrates a similar approach with multiple subject fields in the Dublin Core records designed for LC and localized subject headings to allow for multiple mappings between these domains. This approach was intended to allow navigation across three domains: library collections, finding aid collections, and OhioLINK digital collections. When researchers use the catalog, they may discover a finding aid and a digital collection on the subject, while the same expectations apply to users searching the OhioLINK digital collection and navigates over to the other two domains.

Geospatial knowledge archive (proposed, on hold)

A knowledge archive of geospatial project documentation would allow groups—academic departments, government agencies, military units, businesses, medical establishments, law enforcement agencies, independent researchers, and others—to share geospatial data, information, and knowledge in the form of reports, photographs, field notes, and various digital assets. Minnesota-based Foundations projects benefited from multiagency collaboration to catalog geospatial data, scientific and image resources, and such an undertaking required a "more structured and descriptive approach to describing electronic resources" (Quam, 2001, p. 182). Figure 5 presents a hypothetical interdisciplinary collaborative environment of knowledge domain relationships, as models can vary as relationships change. Each area could be an access point to the collaborating environment, and since the Zentity—the software chosen for this project—allows social tagging, which would have broadened the range for taxonomy development, and expanded ways of knowledge domain navigation.

Conclusion

Knowledge domain navigation is not an innovation in research methodology or technology; in fact, some may recognize an alternative term for subject browsing. That is true as long as the reference is limited to browsing catalogs, databases, and digital libraries that limit subject browsing within their own structure. With link resolvers, OAI compliance, Semantic Web languages, and XML/RDF solutions, navigating multiple digital domains will eventually become a reality. Knowledge domain navigation also involves navigating intellectual domains in ways that technology may not offer for some time. As concept, it occupies a unique position in an interdisciplinary research environment that depends on technology. It lies at the intersection of human and artificial intelligences where researchers will use technology as well as critical thinking. Despite expectations of an all-digital utopia, there are and will be political, legal, and other obstacles to making everything digital. Archives will continue to operate in the informational middle zone with lots of paper- and film-based and magnetic media gradually reformatted for digital access, but in most cases, digitization will be a part of long-term preservation projects to protect original artifacts and documents from further deterioration. Primary sources will still be an asset to organizations investing in preservation and innovation alike.

This paper aimed at sorting out the internal aspect of subject browsing by identifying the knowledge-creating capabilities of metadata records and taxonomies, and applying them in the context of interdisciplinary research. It presented a framework for knowledge domain navigation, which has epistemological and ontological dimensions. The former focused how metadata can spur knowledge creation through various processes. The description of techniques like socialization, internalization, externalization, and combination explain how personal (or tacit) knowledge transforms into more tangible one, and various metadata schemas allow metadata producers to embed such knowledge (as well as data and information) in the record for researchers. The ontological dimension places this knowledge in a hierarchical context of databases and the intellectual domain structures of various disciplines. Focusing on interdisciplinary activities was necessary because a growing body of knowledge emerges from projects that are integrative in scope, and their impact on classification schemes, controlled vocabularies, taxonomies, web ontology languages will be significant. Knowledge domain navigation will remain a part of the research process where it can benefit from human and artificial intelligences.

References

Ackoff, R. L. "From Data to Wisdom." *Journal of Applied Systems Analysis 16* (1989): 3-9.

Attig, J., Copeland, A., & Pelikan, M. (2004 May). Context and meaning: The challenges of metadata for a digital image library within the university. *College & Research Libraries, 65*(3), 251-261. Retrieved from Library Literature and Information Science Full Text.

Bellinger, G., Castro, D., & Mills, A. (2004). "Data, information, knowledge, and wisdom." In G. Bellinger (Ed.), *Systems Thinking*. Retrieved from http://www.systems-thinking.org/dikw/dikw.htm

Carr, L., Brody, T., Gibbins, N., Lyon, L., Chapman, A., & Day, M. (2005). *Study to determine the requirements for and usage of extracted knowledge for bibliometrics, domain analysis, issue tracking and community modeling* (Deliverable no. 5.1.2). Retrieved from DELOS, A Network of Excellence on Digital Libraries, WP5 Website: http://delos-wp5.ukoln.ac.uk/project-outcomes/southampton/final-delos-task-5_1_2.doc

Chan, L. M., & Zeng, M. L. (2006, June). Metadata interoperability and standardization – A study of methodology part I: Achieving interoperability at the schema level. *D-Lib Magazine, 12*(6). doi:10.1045/june2006-chan

Domain. (2010). In *TheFreeDictionary*. Retrieved from http://www.thefreedictionary.com/domain

Fullér, R. (1996). Hyperknowledge representation: challenges and promises. In P. Walden & C. Carlsson (Eds.), *The Art and Science of Decision-Making* (pp. 61-89). Retrieved from http://users.abo.fi/rfuller/cc50.pdf

Garshol, L. M. (2004). Metadata? Thesauri? Taxonomies? Topic maps! Making sense of it all. *Journal of Information Science 30*(4), 378-391. doi:10.1177/0165551504045856

Geertz, C. (1983). *Local knowledge: Further essays in interpretive Anthropology*. New York: Basic Books.

Gilchrist, A. (2003). Thesauri, taxonomies and ontologies – an etymological note. *Journal of Documentation*, *59*(1), 7-18. doi:10.1108/00220410310457984

Greene, M. A., & Meissner, D. (2005, Fall/Winter). More product, less process: Revamping traditional archival processing. *The American Archivist, 68*, 208-263. Retrieved from http://archivists.metapress.com/content/c741823776k65863/fulltext.pdf

Gruber, T. (1992). *What is an ontology?* Retrieved from http://www-ksl.stanford.edu/kst/what-is-an-ontology.html

Harper, C. A. T., & Tillett, B. B. (2007). Library of Congress controlled vocabularies and their application to the Semantic Web. *Cataloging & Classification Quarterly, 43*(3/4), 47-68. Retrieved from https://scholarsbank.uoregon.edu/xmlui/handle/1794/3269

Kaczmarek, J. (2006). The complexities of digital resources: collection boundaries and management responsibilities. In W. E. Landis & R. L. Chandler (Eds.), *Archives and the digital library* (pp. 270 p.). Binghamton, NY: Haworth Information Press.

Klein, J. T. (1990). *Interdisciplinarity: history, theory, and practice*. Detroit: Wayne State University Press.

Klein, J. T. (1996). Crossing *boundaries: Knowledge, disciplinarities, and interdisciplinarities* Charlottesville: University Press of Virginia.

Knowledge. (2010a). In *Oxford Dictionaries Online.* Retrieved from http://oxforddictionaries.com/ view/entry/m_en_us1261368#m_en_us1261368

Knowledge. (2010b). In D. Howe (Ed.) *Free On-Line Dictionary of Computing.* Retrieved from http://foldoc.org/knowledge

Knowledge domain. (2010a). In *TheFreeDictionary*. Retrieved from http://www.thefreedictionary.com/Transmembrane+domain

Knowledge domain. (2010b). In *WordNet.* Retrieved from http://wordnetweb.princeton.edu/perl/ webwn?s=knowledge%20domain

Koutsomitropoulos, D. A., Solomou, G. D., Alexopoulos, A. D., & Papatheodorou, T. S. (2009, December). Semantic Web enabled digital repositories. *International Journal on Digital Libraries, 10*(4), 179-199. DOI:10.1007/s00799-010-0059-z

Kurtz, M. (2010, March). Dublin Core, Dspace, and a Brief Analysis of Three University Repositories. *Information Technology and Libraries, 29*(1), 40-46. Retrieved from http://www.ala.org/ala/mgrps/divs/lita/ital/292010/2901mar/kurtz_pdf.cfm

Lambe, P. (2007). *Organising knowledge: Taxonomies, knowledge, and organisational effectiveness*. Oxford: Chandos Publishing.

Messina, M. (2010, April 22). Roadmaps and knowledgebase navigation (KnowNav™) [Web log post]. Retrieved from http://www.angelpitchguy.com/ 2010/04/roadmaps-and-knowledgebase-navigation.html

Nonaka, I., & Takeuchi, H. (1995). *Knowledge-creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.

Ontology Research Group. (2007a). Ontology. In *Glossary.* Retrieved from http://org.buffalo.edu/ Gloss.html

Ontology Research Group. (2007b). Philosophical ontology. In *Various meanings of the term 'ontology.'* Retrieved from http://org.buffalo.edu/OntologyDefs1.html

Palmer, C. L. (1996, Fall). Information work at the boundaries of science: Linking library services to research practices. *Library Trends, 45*(2), 165-191.

Papazoglou, M. P., & Hoppenbrouwers, J. (1999). *Knowledge navigation in networked digital libraries.* Paper presented at the 11th European Workshop on Knowledge Acquisition, Modeling and Management. DOI: 10.1007/3-540-48775-1_2

Park, J. (2009). Metadata quality in digital repositories: A survey of the current state of the art. *Cataloging & Classification Quarterly, 47*(3), 213-228. Retrieved from doi:10.1080/01639370902737240

Park, J., & Tosaka, Y. (2010 September). Metadata Creation Practices in Digital Repositories and Collections: Schemata, Selection Criteria, and Interoperability. *Information Technology and Libraries*, *29*(3), 104-116. Retrieved from Library Literature and Information Science Full Text.

Pohs, W. (2010, Fall). *Taxonomy Mapping* (SLA Webinar Series). Retrieved from http://wiki.sla.org/download/attachments/74842131/PohsTaxonomyMapping101104.pdf

Polanyi, Michael. *The Tacit Dimension.* Garden City, N.Y.: Doubleday, 1966.

Quam, E. (2001). Informing and evaluating a metadata initiative: Usability and metadata studies in Minnesota's Foundations Project. *Government Information Quarterly,18*, 181-194. doi:10.1016/S0740-624X(01)00075-2

Ritchie, Donald E. (1995). *Doing oral history.* London: Twayne Publishers.

Rosenfeld, L., & Morville, P. (2002). *Information architecture for the World Wide Web* (2nd ed.). Cambridge [Mass.]: O'Reilly.

Steup, M. (2005). Epistemology. In E. N. Zalta (Ed.) *Stanford Encyclopedia of Philosophy* (Spring 2010 Ed.). Retrieved from http://plato.stanford.edu/entries/epistemology/

Zeng, M. L., & Chan, L. M. (2006, June). Metadata interoperability and standardization – A study of methodology part II: Achieving interoperability at the record and repository Levels. *D-Lib Magazine, 12*(6). doi:10.1045/june2006-zeng