Linked Open Data for Subject Discovery: Assessing the Alignment Between Library of Congress Vocabularies and Wikidata

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Abstract

Linked open data (LOD) has long been touted as a means to enhancing discovery of library resources through the use of robust links between related items and concepts. Recently, libraries have begun to experiment with LOD sources such as Wikidata and DBpedia to harness user-contributed resources and enhance information displayed in library discovery systems. The Michigan State University Libraries (MSUL) Digital Repository Team has embarked on a project to display contextual information from Wikidata and DBpedia in "knowledge cards" (informational pop-up windows) alongside subject headings with the goal of providing users with more information on items in the digital repository. This paper will briefly describe this project and outline a quality analysis initiative meant to evaluate linkages between Library of Congress Subject Heading (LCSH) and Wikidata as well as the results of this analysis. It will also address a number of challenges encountered in terms of mapping between different controlled vocabularies. Finally, it will conclude with possible next steps for improving the accuracy of knowledge cards and the LOD that supports them.

Keywords: metadata; linked data; linked open data; Wikidata; subject headings

1. Introduction

Linked data has been on the radar of libraries for over ten years. Many have started building a foundation for future implementation, such as inserting uniform resource identifiers (URI) in metadata records, publishing thesauri and controlled vocabularies as linked open data (LOD), and reconciling and linking existing library controlled vocabularies to non-library LOD datasets (Bennet, Childress, Kammerer, & Vizine-Goetz, 2016; Bushman, Anderson, & Fu, 2016; Cobb, 2016; Guenther, 2011; Neubert, 2017; Shieh & Reese, 2016). As Wikidata is being touted for its potential to be a hub for robust information and authority data, some have implemented novel services to enhance the discovery experience by using rich user-contributed information from LOD sources like DBpedia and Wikidata (Lemus-Rojas & Pintscher, 2018; Meyer, 2016; Neubert, 2017; Scott, 2017). Michigan State University Libraries (MSUL), still at the beginning stage of experimenting with LOD, has been inserting URIs into its digital repository and catalog records. Borrowing ideas from other implementations, the MSUL Digital Repository Team creates subject knowledge cards to provide contextual information, subject hierarchy browsing, and linkages to related articles in scholarly databases. Differing from other implementations, MSUL focuses on subject data because most subject headings in the digital repository already have their URIs minted. Also, providing contextual information (e.g. biographical information of a person, definition of a concept, etc.) for subjects would help repository users understand the subject matter and subsequently determine whether an item is relevant to their research. Using linked data to connect users to other sources on similar subjects helps break down information silos and highlight other potential sources of trustworthy information.

Starting from the URIs of FAST (Faceted Application of Subject Terminology) subject headings stored in metadata records in the MSUL digital repository, an AJAX (Asynchronous JavaScript

and XML) call launches a script to look up the equivalent LCSH (Library of Congress Subject Heading) URI through the OCLC FAST linked data service. Then the script will use SPARQL to look for any Wikidata entries that have the LCSH URI as equivalent concept in the "Identifiers" section. If the SPARQL query fails, the script will trace the reconciled link(s) to Wikidata in FAST authority data from a reconciliation project by OCLC (Bennett et al., 2016). The LCSH URI is used as a proxy for FAST because LCSH is more frequently linked to Wikidata than FAST. Once the equivalent Wikidata entry is found, selected data points from Wikidata and the linked DBpedia record are captured to provide contextual information. At the same time, equivalent JSTOR topical terms and medical subject headings (MeSH) linked in the "Identifiers" section in Wikidata entries are used to build search links into JSTOR and PubMed Central databases for topically related articles. Additionally, broader, narrower, and related terms are captured from FAST authority data. All these data are then rendered, on the fly, as a knowledge card and displayed next to the relevant subject heading on the repository item page. Since the "same as" link between LCSH and Wikidata is the pivot for capturing contextual information and linking to semantically related scholarly articles, it is the goal of this paper to assess the alignment between LCSH and Wikidata.

2. Literature Review

A few library projects have taken steps to utilizing linked data to enhance discovery and users' understanding of their collections. Meyer (2016a) outlines their linked data project led by the University of Wisconsin-Madison Libraries. This project leverages linked data from the Virtual International Authority File (VIAF) to populate "bibcards" that display biographical information about named individuals in bibliographic records. Meyer (2016b) suggests that libraries should make efforts "to redesign cataloging itself and experiment with additional data that relates to but is external to our core catalog metadata" (Linked Data & Libraries: Where to Begin section, para. 1). Jett et al. (2017) describe two projects undertaken by the University of Illinois at Urbana-Champaign to harness LOD to enhance online library collections. The authors state that their findings "suggest that the transformation of metadata into LOD and the inclusion in item descriptions of links can improve the connectedness… and enhance user interactions with these sources" (p. 29). The project to map the Motley Collection metadata into the schema.org vocabulary resulted in enhancing the records in that collection with additional information from external LOD services. Similarly, Laurentian University enhances their library catalog by reconciling names of musicians and musical groups to Wikidata and displays their contextual information and links to non-library resources like biographies from Discogs.com (Scott, 2017).

Success of these projects depends on the quality of reconciliation between different vocabularies, but aligning controlled vocabularies is a challenging undertaking. Van Hage (2008) suggests that "the quality of the alignment is dependent on the topic of the alignment, the type of relations, the complexity of the domain, and the kind of background knowledge that is readily available" (p. 134). Different vocabularies model the world differently, use different language to express similar concepts, and prioritize the needs of different user communities, to name a few potential issues. Further, different users may disagree on how one vocabulary should match to another. Tordai, van Ossenbruggen, Schreiber, and Wielinga (2011) tested out the ways which people ("raters") evaluate vocabulary alignment or accuracy. They found that raters perceive meanings of natural language differently as language is structured within a complicated conceptualization process. They conclude that these can cause disagreement in raters who participated in the manual evaluation of ontology alignments, regarding mappings, and suggest that it is necessary to take a careful examination in the mapping process for ontological alignments of vocabulary. They also conclude that despite these disagreements, Web applications may still be able to "make useful semantic links" (p. 71). Specifically in the context of linking FAST subject headings to Wikipedia, Bennet et al. (2016) explain an automated process to map FAST (Faceted Application of Subject Terminology) to Wikipedia articles. Using a random sample of non-subdivided FAST headings, the authors found that of the 76,000 of 183,000 non-subdivided topical FAST headings that matched to a Wikipedia article, nearly 95% were accurately matched. They also found that about 66% of the sample FAST

headings did not have an article match in Wikipedia at all. Speaking to the potential of Wikidata as a potential source of reliable information to supplement or enhance library sources, In addition to their detailed overview of Wikidata, Lemus-Rojas and Pintscher (2018) explain that information professionals may help to improve the information in Wikidata in numerous ways, including adding identifiers from library controlled vocabularies to Wikidata entries which not only adds useful information that can be repurposed by other Wikidata users (including libraries) but also validates other assertions included in Wikidata. Enhancing Wikidata with information from libraries' collections creates opportunities to create new tools and build complex queries based on the information available in Wikidata.

3. Methodology

This quality analysis (QA) project was meant to address three research questions: 1) what is the percentage of subject headings already linked from existing Wikidata entries?, 2) what is the percentage of subject headings that have knowledge cards displayed?, and 3) do knowledge cards display information from Wikidata that is an appropriate match for the subject heading? Though the MSUL digital repository uses FAST for subject display, the generation of the knowledge card, as explained above, is based on links between Wikidata and the LCSH-equivalent FAST term. Due to the heading construction principle of FAST prohibiting the mixing of facet types, subdivided LCSH headings that have multiple types of facets (e.g. a topical heading with a geographic subdivision) were out of the scope of this study.

The project team took the first step in September 2018 to set up the QA project by obtaining a list of all the subject headings used in the digital repository. The resulting list, essentially a snapshot of the repository then, contained 12,722 unique FAST subjects, including topics, personal and corporate names, events, titles, geographic, and genre headings. The headings were split into two groups: the majority of subjects were given an automated and more limited review, and a smaller selection received a more detailed, manual review. For the automated review, in response to research question 1, a script evaluated whether or not the URI of the LCSH being evaluated was recorded in any Wikidata entry.

To address research questions 2 and 3, the project team decided to limit manual review to subjects that appeared in ten or more records in the repository, which resulted in a list of 985 subjects. This was still an ambitious undertaking but would ultimately provide a useful snapshot of knowledge card quality throughout the repository. This method, rather than a random sample of subject headings, was chosen in order to maximize the impact of the manual review for users. It is possible that choosing a different sampling method would lead to different results than the ones described in this paper. A spreadsheet outlined each of the criteria the project team intended to evaluate. These included whether or not a knowledge card existed, whether the information displayed in the card was appropriate, what an appropriate link would be if it was not already displaying, and whether or not there was an LCSH URI in the Wikidata entry.

In addition to evaluating these criteria, the project team also worked on adding LC URIs to Wikidata entries that lacked them. This work was tracked in the same spreadsheet and was limited to subjects that 1) didn't have a knowledge card at all, or 2) subjects where the knowledge card was displaying an inappropriate match.

4. Results

As outlined in Table 1, the majority (88.889%) of the 12,722 subject headings evaluated in this study, are topical headings, with geographic headings accounting for 5.196%, followed by personal (2.602%) and corporate names (2.240%). "Event," "Form/Genre," and "Title" are negligibly small percentage wise.

TABLE 1: Subject headings linked from Wikidata.

Heading Types	Total	Percentage (N=12,722)	Already Linked from Wikidata	Percentage
Topical	11,307	88.889%	1,508	13.227%
Geographic	661	5.196%	366	55.371%
Event	47	0.369%	32	68.085%
Corporate	285	2.240%	100	35.088%
Personal	331	2.602%	294	88.822%
Form/Genre	6	0.047%	4	66.667%
Title	85	0.668%	25	29.412%
All Types	12,722		2,329	18.307%

The first stage of the analysis focused on determining what percentage of subject headings were already linked from existing Wikidata entries. Though topical headings account for the majority of subject terms studied, only 13.2% of them are already linked from existing Wikidata entries (see Table 1). On the contrary, "Personal name," "Event," "Form/Genre," and "Geographic" headings have 55% or higher matching rate to existing Wikidata entries with "Personal name" headings coming close to 89%. Interestingly, 97% of the topical headings that have been linked from Wikidata are non-subdivided ones (e.g. Vegetarianism) (see Table 2). Among the 2,368 subdivided topical headings (e.g. Cooking, American--Western style), only forty-five (1.9%) have been linked from Wikidata entries (Table 3).

TABLE 2: Topical headings linked from Wikidata by availability of subdivision (total topical headings: 11,307).

Topical Headings Already Linked from Wikidata (N=1,508)		Topical Headings Not Linked from Wikidata (N=9,799)	
Without Subdivision	With Subdivision	Without Subdivision	With Subdivision
1,463 (97.016%)	45 (2.984%)	7,476 (76.293%)	2,323 (23.707%)

TABLE 3: Subdivided and non-subdivided topical headings by availability of link in Wikidata.

Without Subdivision (N=8,939)		With Subdivision (N=2,368)	
Linked from Wikidata	Not Linked from Wikidata	Linked from Wikidata	Not Linked from Wikidata
1,463 (16.366%)	7,476 (83.634%)	45 (1.900%)	2,323 (98.100%)

The next stage of the analysis attempted to determine the percentage of subject headings that have knowledge cards displayed. To answer this and the subsequent question, a smaller sample was used. Among the 985 most frequently used subject headings in the digital repository, about 78% of them have knowledge cards generated based on a Wikidata entry (see Table 4). Although both "Personal name" and "Event" headings have a 100% success rate in knowledge card generation, they together account for only 1% of the 985 reviewed headings. Geographic headings, which account for 8.8% of the samples, have 93% coverage. Topical headings are the next runner up with 77% having knowledge cards. The number of topical headings that have knowledge cards is more than double the number that is already linked from Wikidata. This implies the fallback mechanism (i.e. tracing reconciled link to Wikidata through FAST authority data) helps compensate for the lack of LCSH reconciled and recorded natively in Wikidata. Similar to the previous question, there is also a sharp contrast between subdivided and non-subdivided headings in terms of knowledge card generation. Almost all (98.6%) topical headings that have knowledge cards generated are non-subdivided ones while only 9% of subdivided topical headings have knowledge cards (see Tables 5 & 6).

TABLE 4: Availability and quality of knowledge cards.

Heading Types	Number of Headings	Already Linked from Wikidata		Has Knowledge Card		Knowledge Card Showing Appropriate Match	
		Total	Percentage	Total	Percentage	Total	Percentage
Topical	842	286	33.967%	649	77.078%	581	89.552%
Geographic	87	70	80.460%	81	93.103%	80	98.765%
Event	7	7	100.000%	7	100.000%	7	100.000%
Corporate	37	20	54.054%	26	70.270%	26	100.000%
Personal	4	4	100.000%	4	100.000%	4	100.000%
Form/Genre	6	4	66.667%	1	16.667%	1	100.000%
Title	2	0	0.000%	0	0.000%	N/A	N/A
All Types	985	391	39.695%	768	77.970%	735	95.703%

TABLE 5: Knowledge card availability for topical headings by availability of subdivision (Number of topical headings studied=842).

With Knowledge Card (N=649)		Without Knowledge Card (N=193)	
Without Subdivision	With Subdivision	Without Subdivision	With Subdivision
640 (98.613%)	9 (1.387%)	102 (52.850%)	91 (47.150%)

TABLE 6: Subdivided and non-subdivided topical headings by availability of knowledge cards.

No Subdivision (N = 742)		With Subdivision (N = 100)	
With Knowledge Card	Without Knowledge Card	With Knowledge Card	Without Knowledge Card
640 (86.253%)	102 (13.747%)	9 (9.000%)	91 (91.000%)

The final stage of the analysis examined whether knowledge cards displayed information from Wikidata that was an appropriate match for the subject heading. Table 5 shows that information displayed on knowledge cards are generally an appropriate match with an average of 95.7% accuracy. Topical headings, being the type with the lowest accuracy, still achieve an 89.5% rating. Four other types, namely "Event," "Corporate name," "Personal name," and "Form/Genre," each have a perfect 100% accuracy. Unlike the previous two questions, there is no significant difference in accuracy between subdivided and non-subdivided headings. Table 7 indicates that non-subdivided headings have an 89% accuracy rate while subdivided ones have 100% (though the latter only account for 1.4% of topical headings that have knowledge cards). Moreover, among the sixty-eight topical headings that link to and display inappropriately matched Wikidata information in their knowledge cards, 58.8% of them have appropriate Wikidata entries in existence and can be corrected (see Table 8).

TABLE 7: Quality of knowledge cards for topical headings.

Number of Topical Headings with Knowledge Card	Without Subdivision (N=640)		With Subdivision (N=9)	
	Appropriate Match	Inappropriate Match	Appropriate Match	Inappropriate Match
649	572 (89.375%)	68 (10.635%)	9 (100.000%)	0 (0.000%)

TABLE 8: Availability of Wikidata entries for inappropriately matched topical headings.

Inappropriately Matched Topical Heading Knowledge Cards	Wikidata Entries Found	Wikidata Entries Not Found
68	40 (58.824%)	28 (41.176%)

4. Discussion and Challenges

Though information displayed on knowledge cards is mostly appropriately matched, errors in mapping have brought certain inherent difficulties and deficiencies in current reconciliation practices to light. Reconciling different vocabularies based on text string labels is prone to mismatching. For instance, the knowledge card for LCSH "Indian cooking" initially displayed data from Wikidata's "Indian cuisine" (Q192087), which was based on a reconciled link between FAST authority data and Wikidata. The LCSH subject is intended to represent Native American cuisine according to its authority record, while the Wikidata entry "Indian cuisine" represents "regional cuisines native to India." According to Bennett et al. (2016), OCLC did the reconciliation by comparing text strings in labels without considering additional semantics represented by other attributes. Unfortunately, using the word "Indian" to represent "Native Americans" in LCSH, besides being a culturally insensitive practice, caused the reconciliation program to conclude "Indian cooking" in LCSH and "Indian cuisine" in Wikidata were equivalent based on the co-existence of the word "Indian."

Differences in data modeling between Wikidata and Library of Congress cause difficulties in mapping. Per cataloging rules, a new Library of Congress Name Authority File (LCNAF) URI is minted every time a corporate body changes its name. For instance, there are five different URIs for the 164-year old Michigan State University in LCNAF. However, Wikidata considers Michigan State University as a single identity regardless of how many name changes happened in the past, hence it has only one entry (Q270222). URIs from LCNAF are all mapped to this Wikidata entry with different date ranges identifying their corresponding valid periods. All the historical names are listed as "aliases" while the current name is considered as the preferred label. The repository will display "Michigan State University" as the title of the subject knowledge card even though repository users are looking at any of the historical names, like "Michigan State College" (see Figure 1).

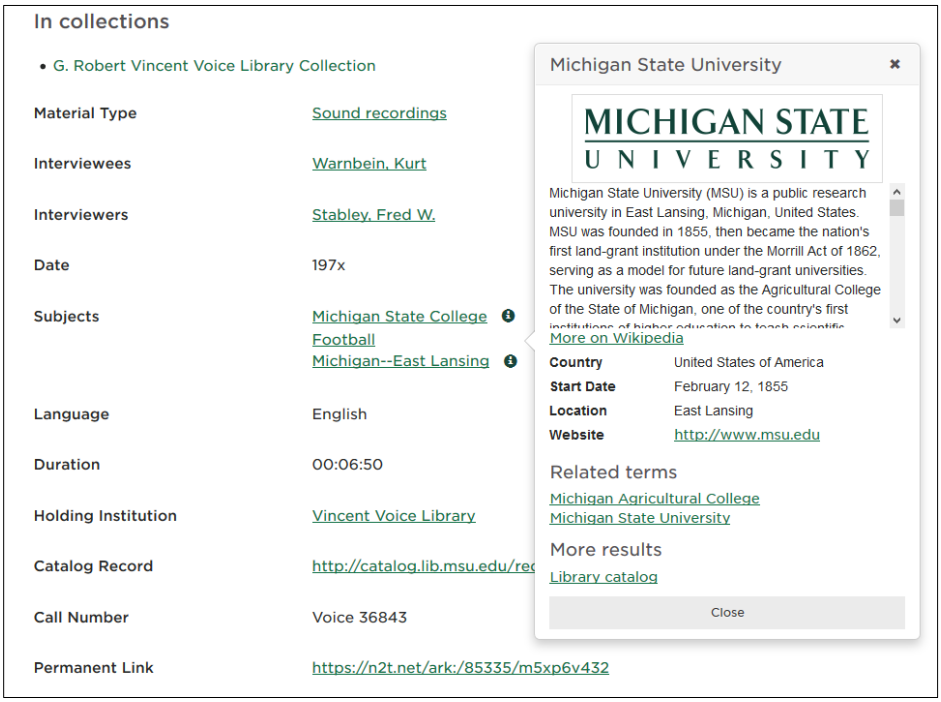

FIG. 1. Example knowledge card for Michigan State College.

On the other hand, LCSH occasionally collapses multiple taxonomic levels into a single one while Wikidata describes them separately. For example, variants of "Asparagus" (genus) include

both its synonyms ("Asparagopsis," "Elachanthera," and "Protasparagus") and "Asparagus officinalis" (species) in LCSH. However, there are separate entries for "Asparagus" as genus (Q2853420), "Asparagus officinalis" as species (Q28367), and even "Asparagus" as vegetable (Q23041045) in Wikidata (see Figure 2). Mapping from LCSH to Wikidata in this case is very difficult as the precise relationship is based on the context.

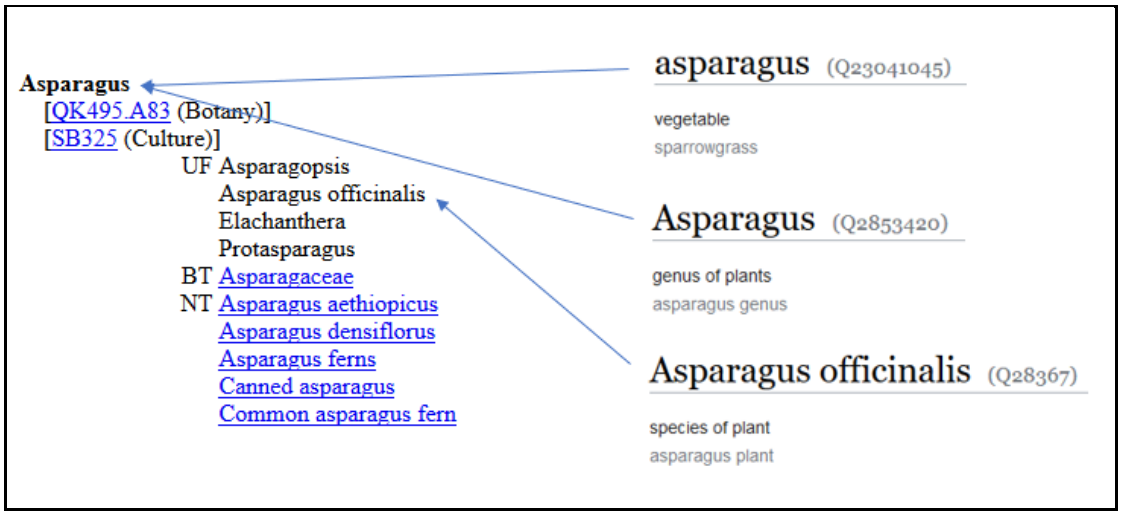

FIG. 2. Example of mapping between LCSH and Wikidata.

On top of that, murkiness in concept hierarchy also makes mappings less clear cut. Despite the fact that "Human migration" (Q177626) is a broader concept for "Immigration" (Q131288), "Emigration" (Q187668), and "Internal migration" (Q11880444) in Wikidata, "emigration" and "immigration" are, at the same time, also aliases, defined as "alternative name for an item or property," for their broader concept (see Figure 3) (Help:Aliases, n.d.). This makes one wonder how "Emigration and immigration" in LCSH should be mapped to Wikidata. The LCSH could be mapped to both "Emigration" and "Immigration" in Wikidata as they are the constituent concepts. Or, alternatively, the LCSH concept could be mapped to "Human migration" because of its aliases. The former approach will make the generation of knowledge cards problematic, while the latter approach maps across hierarchical levels.

FIG. 3. Wikidata entry for "human migration" concept.

Differences in reference structure also contribute to occasional problematic mappings between LCSH and Wikidata. Wikidata allows users to record an "alias" to help manage synonyms and improve recall of a concept. In LCSH, this is done through cross-references. However, its scope is beyond merely variation in text strings. For example, cross-references of "Military education" in LCSH include its synonyms "Military training" and "Military art and science--Study and teaching," as well as its inverted form "Education, Military"; however, "Army schools," "Military schools," and "Schools, Military" are also listed there. In this case, the label of the activity represents both the activity itself and the place where the activity is being carried out. As a result, "Military education" has been reconciled to both "Military academy" (Q917182) and "Military education and training" (Q2351849) in Wikidata by OCLC. Among a batch of 1.9 million FAST authority records in MarcXML format dated March 18, 2019, downloaded from OCLC, 61,697 records (3.15%) have at least one link reconciled to Wikidata. Among them, about 16.77% (10,349) are reconciled to multiple Wikidata entries. Similarly, there are 1,979 LC URIs recorded simultaneously in more than one Wikidata entry as equivalent external identifier as of August 5, 2019. This one-to-many relationship causes uncertainties in the knowledge card generation process. On the other hand, mapping only to similar concepts poses a different challenge. For instance, while "Soul food cooking" is a cross-reference for LCSH "African American cooking," soul food means, per Merriam-Webster Dictionary online, food traditionally eaten by southern black Americans, which is just one aspect of all African American cooking (Soul food, n.d.). The current mapping, without any qualification, between "African American cooking" and "Soul food" (Q555997) essentially declares a narrower concept the same as its broader concept. This might give an incorrect impression of equivalency to knowledge card users.

5. Next Steps

Next steps in the project fall into two categories: 1) improvements to matching between subjects and their corresponding knowledge cards in the MSUL digital repository, and 2) user testing to improve usability of the knowledge cards. Manual correction like the project team's work to add LC URIs into Wikidata records that lacked them has improved matches for approximately 40 subjects. Newly minted URIs for name and subject authority records during regular cataloging and metadata workflows can be added to existing Wikidata entries right away instead of relying on periodic machine reconciliations. While mapping between different controlled vocabularies will always present challenges, some improvements may be made to the knowledge card display that would provide more context and transparency. For example, it may be helpful to identify whether the information in a knowledge card represents a broader or near match to the subject heading rather than implying that every knowledge card is an exact match to the corresponding subject term as is currently done. Two SKOS properties, broadMatch and narrowMatch, currently available in Wikidata for specifying "mapping relation," could be employed in future improvements to the knowledge cards to display to users that the information in the knowledge card does not represent an exact one-to-one mapping of the subject heading. Beyond the MSUL digital repository, more work can be done in the broader community to improve mapping between library-controlled vocabularies such as FAST and LCSH and Wikidata. One area for improvement would be, in addition to string matching, to look at other attributes in Wikidata records to determine the best matches for FAST and LCSH topics.

Given that mapping will never be perfect due to differences in data modeling between LCSH and Wikidata, user testing will be an important additional step in understanding what can be done to help repository users correctly interpret information available in knowledge cards. How will users interpret the knowledge card if its title is different from the original LCSH/FAST heading because the matched Wikidata entry uses a synonym? Will users be confused if the difference is a discrepancy in semantics instead of merely a variation in text string? Will adding Wikidata's "mapping relation type" (e.g. narrow/broad match) to contextualize less than exact mappings help avoid implying equivalency and prevent misinterpretation by knowledge card users? Questions

such as these will help improve the discovery experience of knowledge card users even though the alignment and mapping between LCSH and Wikidata are far from perfect.

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