Boosting the Identifier Ecosystem of the University of Colorado Boulder Faculty

Chris Evin Long

Unique author identifiers play a crucial role in scholarly communication, enabling the correct attribution of authorship and the promotion and discovery of scholarly works. Identifiers benefit both the individual faculty member and their campus community as well. Academic library catalogers play an essential role in ensuring a robust identifier profile for the faculty on their campus and in growing and maintaining the broader identifier ecosystem. This study provides the most thorough analysis to date of the faculty identifier ecosystem of an R1 public university, examining the prevalence of five identifiers among the university's faculty and using this information to determine practical ways that its cataloging team can boost the local and global identifier ecosystem, as well as providing guidance to other cataloging agencies interested in a similar endeavor.

The expansion of catalogers' involvement in name authority control systems beyond creating Name Authority Cooperative Program (NACO) records can be seen as a natural evolutionary step, but in general they have ventured into this ecosystem without a comprehensive understanding of the landscape. Previous researchers have examined the prevalence of faculty identifiers, but their studies have either involved a limited number of faculty or academic disciplines, or they did not investigate the Wikidata database. This lack of guidance leaves cataloging managers in a quandary. Although there is certainly merit in experimenting with non-NACO endeavors like International Standard Name Identifier (ISNI) records and Wikidata items, it is unclear how best to assess the benefits and challenges of incorporating new efforts into workflows and determine which identifier programs provide the best value. This paper expands on previous research by offering the most thorough analysis to date of the faculty identifier ecosystem of an R1 public university, the University of Colorado Boulder (CU Boulder). The study includes all CU Boulder personnel designated as faculty in the 2019/2020 academic year and, for each person, examines the existence of researcher identifiers from the Library of Congress Name Authority File (LCNAF), the OCLC-hosted Virtual International Authority File (VIAF), ISNI, Wikidata, and Open Researcher and Contributor ID (ORCID) databases. The reasons for selecting these five identifier systems are explained later in the article. The study also breaks down the data by both the faculty member's academic rank and primary academic unit. In addition to providing insight into CU Boulder faculty's current identifier environment, the information will be used to consider how best CU Boulder's catalogers can channel their identifier creation efforts into non-NACO activities. This approach will provide guidance for other cataloging agencies seeking practical ways to make meaningful contributions to the local or global identifier ecosystem.

Chris Evin Long (chris.long@colorado.edu), Professor and Faculty Director of Resource Description Services, University of Colorado Boulder University Libraries, https://orcid.org/0000-0003-3953-7940.

Background

Catalogers in the Program for Cooperative Cataloging (PCC) community have been encouraged in recent years to move their traditional authority control work of creating name authority records (NARs) for the NACO Program toward an identity management model. This aspiration was first expressed in the PCC's 2015 strategic planning document *Vision, Mission, and Strategic Directions: January 2015– December 2017*. A pivotal emphasis of this transition involved shifting the PCC's authority control practices from "an approach based on creating text strings to one focused on managing identities and entities. . . . This string-based approach works somewhat well in the closed environment of a traditional library catalog, but not in an open environment where data are shared and linked, and so require unique identifiers."[1] To implement this new direction, the PCC established a partnership with the International Standard Name Identifier International Agency (ISNI-IA) and initiated the PCC ISNI Pilot that allowed its members to engage in identity management activities within the ISNI database.[2] Twelve US academic libraries participated in the project from 2017 to 2018, creating and revising ISNI identifiers for individuals and organizations. This project was deemed a milestone event for the community since it was "the first initiative that enabled the PCC to explore a new path for creating internationally recognized identifiers for individuals and organizations outside of the PCC NACO program."[3]

On the heels of the successful ISNI trial, the PCC's 2018 strategic plan sought to accelerate the pace of change from authority control to identity management. Strategic Direction 3 (SD3) encouraged members to apply their understanding of linked data, and Strategic Direction 4 (SD4) called for an acceleration of ubiquitous identifier creation and identity management. These strategic directions signaled a shift in focus from experimentation to implementation, envisioning "an environment where identity management work activity is characterized by much greater proportions and numbers of entities receiving identifiers."[4] The PCC's first step in meeting SD3 was the URIs in MARC Pilot, launched in 2019. Pilot participations increased the linkability of both authority and bibliographic records by adding identifiers in MARC 024 fields, including Real World Objects (RWO), Uniform Resource Identifiers (URIs), and conventional library identifiers from traditional and nontraditional sources. The PCC's next pilot project addressed SD4, which specifically mentioned Wikidata as a potential strategic partner.[5] Recognizing Wikidata's value as a high-demand identifier hub, the PCC saw engagement with it as another opportunity for catalogers to implement identity management principles while also lowering the barrier for authority creation and maintenance, and commenced the PCC Wikidata Pilot in 2020.[6] Whereas participants for the first two pilots were drawn mostly from PCC institutions or partner communities, the Wikidata pilot was much larger and more diverse, with over seventy participating institutions that included several non-US and non-PCC organizations. At the time of this writing, over 52,000 Wikidata items had been created and over 162,000 Wikidata revisions had been made by pilot participants.[7] The PCC's current strategic plan seeks to further build on both of these pilot projects, calling for "broader PCC member participation in ISNI, Wikidata, and similar emerging Linked Data-based ventures, as activities that form a part of a holistic, reimagined standard cataloging workflow."[8]

Catalogers' Role in the Identifier Ecosystem

A common element of these PCC pilot projects was the ability of participants to determine their own goals and areas of concentration. Given the sizable proportion of academic library contributors, it is not surprising that several focused their efforts on working with the identifiers of their institutions' faculty and academic units.[9] In utilizing their identifier creation skills, catalogers play an essential role in strengthening their campus identifier ecosystem—the complex network of unique, persistent identifiers that exists in the scholarly communication universe—thereby providing crucial value to both scholars and their institutions. Faculty benefit from having a clear scholarly identity that is linked to a robust identifier profile. Rotenberg and Kushmerick note, "This ever-expanding universe of scholarship requires tools and services to enable proper attribution of contributions to the correct individual."[10] The proper attribution of scholarly output is critical to a faculty member's career and reputation and is essential to achieving tenure and promotion. Obtaining unique identifiers early in a researcher's career is especially important. As Smith-Yoshimura et al. state, "The earlier in the career an ID is used in association with a researcher's scholarly output, the less likely misattribution will occur—especially for common names—and the more likely the scholarly output associated with a researcher will be comprehensive and accurate."[11] Accurate attribution also assists universities in their efforts to track and report on faculty and graduate students' scholarly work, demonstrating institutional research productivity to governing bodies and enhancing the organization's academic reputation.

Cataloger intervention is essential to growing and maintaining the identifier ecosystem in a broader sphere, not just at the campus level. Three of the databases studied in this article are formed, some directly and others indirectly, by the labor of catalogers: LCNAF, VIAF, and ISNI. LCNAF is built and sustained solely by catalogers' authority control expertise and VIAF clusters are largely constructed by ingesting authority files from national libraries. VIAF was the base file used to populate ISNI's initial database, and PCC catalogers can now contribute directly to ISNI through the PCC's status as a registration agency. A growing number of catalogers have entered the vast community of Wikidata editors and are creating and enhancing items in the Wikidata repository. Moreover, although ORCID identifiers are self-claimed by faculty, catalogers can play the role of advocates or trainers on campus by raising awareness of the importance of unique author identifiers.[12] In addition to creating and promoting the use of identifiers, catalogers play an important role in connecting or embedding them as links to other identifiers in records they create and revise. This work advances the PCC's strategic action item: "URI-based linkages between data sources traditionally focused on by the PCC and other data sources where we want strategic connections."[13]

Literature Review

The value and use of unique author identifiers and the systems that promulgate them have been frequent topics in the library science literature for more than a decade. Articles on the impact that author identifiers have on the correct attribution of authorship and promotion and discovery of faculty scholarship abound. Also plentiful are articles examining the major identifier systems like ORCID,

ISNI, VIAF, and LCNAF, including how identifiers are minted and clustered, and the ways in which the systems interact with each other. A subgroup of this literature, discussed below, intersects with the foci of this article, namely the prevalence of various author identifiers among university faculty and the types of identifiers that are more common among faculty in particular academic disciplines. The discoveries of the prevalence and disciplinary distribution of faculty identifiers observed in previous research are briefly noted here but will be correlated in greater detail with the results of this study in the Results and Discussion section.

Panigabutra-Roberts conducted the only study thus far whose stated purpose was to analyze the prevalence of author identifiers among a set of faculty members, that of the American University in Cairo (AUC). In addition to investigating how fifty-five (out of a total of 491) randomly selected AUC faculty distributed and shared their creative work, she also examined how frequently their names were identified in LCNAF, VIAF, ISNI, Google Scholar, and ResearchGate. She counted the number of faculty members having each type of identifier, and her convenience sample included scholars from various disciplines, including arts, humanities, social science, science and engineering, business, and global studies. Panigabutra-Roberts concluded that researchers "tend to have scattered identities and publication profiles" and emphasized the challenge of maintaining and crosslinking multiple identities for researchers.[14]

Other authors have also noted the prevalence and disciplinary distribution of faculty identifiers as incidental observations, but not as the primary focus of their research. Separate articles by Mering and Downey in 2019 explored ways to implement identity management practices in the institutional repositories (IRs) of their respective universities. Mering addressed the challenge of consistently and accurately identifying contributors in the University of Nebraska-Lincoln's (UNL) IR and associating them with their scholarly works. Part of her study examined the prevalence of VIAF and ORCID identifiers for 114 tenured and pre-tenured faculty in four departments at UNL—food sciences, history, physics, and child, youth, and family studies—and noted some sharp contrasts among the disciplines, especially between history and physics.[15] Downey investigated the VIAF, LCNAF, and ORCID identifiers associated with a random sample of 290 unique name strings in Duke University's IR to identify a suitable source of author URIs. Her sample comprised mainly of Duke faculty whose specialties encompassed the humanities, social sciences, sciences, and medicine, and she discovered that although there was considerable disparity in the frequency of ORCID identifiers between faculty in applied sciences and those in the humanities and social sciences, the disciplinary distribution in the VIAF and LCNAF databases was much more even.[16] Sandberg and Jin explored methods of providing authority control for journal article authors by linking to external international authority databases, specifically VIAF, ISNI, ORCID, and Scopus. Their study concentrated only on music, library science, and computer science scholars, but they noted differences in the frequency of particular identifiers for faculty in certain fields.[17] Waugh, Tarver, and Phillips sought to develop and evaluate a workflow for establishing name authorities in the University of North Texas's electronic thesis and dissertation (ETD) collection. They recorded the frequency of VIAF and LCNAF identifiers in a random sample of 200 names in the ETD collection but did not take note of the disciplines.[18]

In addition to the studies that directly or indirectly considered the prevalence of author identifiers, two 2017 studies queried faculty members' awareness and use of their own unique identifiers. Tran and Lyon reported the survey findings of 300 Stonybrook University faculty respondents from a variety of disciplines, including the sciences and the arts and humanities. Of the identifiers studied— ORCID, Scopus, ResearcherID, arXivID, Google Scholar, and PubMed—ORCID had the highest level of awareness.[19] In another survey, the Primary Research Group asked faculty from 325 major research universities in the United States, the United Kingdom, Ireland, Canada, and Australia if they had ORCID and ISNI identifiers. The respondents represented a comprehensive array of subject areas and, unlike other studies in this review, the results were broken down by tenure status. However, the responses included large numbers of "No Answer" and indicated a lack of awareness of ORCID and ISNI identifiers.[20]

In summary, prior research has largely concentrated on either small groups of scholars, limited types of author identifiers, or contributors (sometimes non-faculty) to local storehouses of scholarship such as IRs and ETD collections. Furthermore, the studies examining the incidence of identifiers by academic discipline have looked at a limited number of subject areas and ignored academic rank.

Institutional Context

Founded in 1876, CU Boulder is classified as an R1 institution and is one of only thirty-five US public research institutions belonging to the Association of American Universities (AAU). Fall 2022 student enrollment was 36,430, and the campus has 1,300 tenured and tenure-track faculty.[21] CU Boulder offers courses in approximately 160 distinct fields of study and 235 degree programs across the baccalaureate, master's, doctoral, and professional levels. Its eleven colleges and schools encompass a full range of academic disciplines in the humanities; social sciences; physical and biological sciences; engineering and applied sciences; fine and performing arts; education; media, communication, and information; environmental design; business; and law. The size and disciplinary diversity of the CU Boulder campus thus allowed for a comprehensive examination of its faculty's identifier ecosystem. The University Libraries at CU Boulder has five library locations and houses the largest collection in the Rocky Mountain region, surpassing 15 million volumes. The primary cataloging unit within the University Libraries is the Resource Description Services (RDS) Team, which has been a long-standing contributor to all PCC programs. However, in recent years RDS has experienced several departures of key personnel and the current staff of thirteen FTE includes only three remaining PCC-trained catalogers, reduced from nine just three years ago.

Selection of Identifiers Studied

There are many identifier systems that could have been included in this study, but only five were selected: LCNAF, VIAF, ISNI, Wikidata, and ORCID. The rationale for focusing on these identifiers was based on both their utilization in current library linked data initiatives and the University Libraries' ability to bolster that utilization by actively contributing to and improving these databases. For

instance, LCNAF, VIAF, ISNI, and Wikidata identifiers are being used to enrich metadata in emerging linked data production systems like Share-VDE. This enrichment increases the discovery potential of library resources, facilitates information exchange, and enhances the authoritativeness of library data.[22] Similarly, the Linked Data for Production: Closing the Loop (LD4P3) grant aims to create a working model of a complete cycle for linked data creation, sharing, and reuse. As part of this project, Cornell University is experimenting with a process that uses linkages between LCNAF and Wikidata identifiers to add contextual information about authors and subjects to enhance discovery in their library catalog.[23]

Identifiers must be created before they can be used, and RDS catalogers have experience working with all identifier systems in this study. PCC-trained catalogers at CU Boulder usually have contributed several hundred NACO authority records to the LCNAF annually. NACO records created by RDS catalogers are ingested monthly into VIAF, where they are matched and clustered with authority files from more than forty national libraries, cultural agencies, and other organizations, and then assigned a VIAF identifier.

RDS catalogers have also engaged with the broader identifier ecosystem. A sample of 200 NACO records for CU Boulder faculty were enhanced with VIAF, ISNI, ORCID, and Wikidata identifiers as part of the PCC URIs in the MARC Pilot. Several team members also participated in the PCC ISNI Pilot, which afforded them the chance to experiment with identity management practices outside the traditional authority control realm. The ISNI database is populated from a diverse set of data sources, including libraries, rights management societies, researchers' databases, and the music industry. Consequently, its database includes artists, performers, inventors, visual creators, producers, publishers, and aggregators in addition to researchers and writers.[24] In partnership with CU Boulder's Office of Faculty Affairs (OFA), RDS staff created or modified ISNI records approximately for 250 faculty and twenty-five academic units in the College of Engineering and Applied Science. The purpose behind the team's participation was not only to provide new expertise to its catalogers, but also to assist OFA's efforts to harvest campus research productivity by building a more robust identifier environment for CU Boulder faculty.

CU Boulder catalogers next ventured further into the linked data sphere by participating in the PCC Wikidata Pilot in 2020. Wikidata is a knowledge base that contains the structured metadata that underpins all the various Wikimedia projects, the most familiar of which is Wikipedia.[25] CU Boulder's pilot project involved monographs by a group of women poets in its Women Poets of the Romantic Period and Santa Clara University's Stainforth Library of Women's Writing digital collections. This pilot became a convergence of all our catalogers' various identifier expertise, involving the creation or revision of NACO records, the attendant VIAF clusters, ISNI records, and Wikidata items, to which the other identifiers were added. Not only did this project provide an opportunity for our catalogers to build new linked data skills, but also to create a more robust bibliographic identity and Semantic Web presence that was sorely lacking for some of the women poets.[26]

ORCID identifiers, although not minted by CU Boulder catalogers, were included in the study because of their importance in campus efforts to harvest CU Boulder faculty's research productivity. The ORCID

registry allows scholars to self-claim identifiers by creating and maintaining a permanent, portable profile that can be linked to their scholarly works and grants.[27] In 2014 and again in 2016, CU Boulder proactively created ORCID identifiers for all current faculty and since then has strongly encouraged newer faculty to self-register, emphasizing the benefits of accurate attribution, increased researcher visibility, and enhanced academic reputation.[28] In fact, using ORCID to auto-claim publications has become an integral component of CU Boulder Elements (CUBE), which is used in the annual faculty reporting process to describe the contributions and scholarly impact of the CU Boulder campus faculty.

Interlinking Among Identifier Systems

Interlinks to related information among Semantic Web (SW) linked data datasets is a fundamental component of the SW and expands the knowledge of the relationship among resources within the datasets. Interlinks among identifier systems such as those in this study can be used to establish that an entity in one dataset is the same as an entity in another and therefore improve its discoverability.[29] Catalogers can therefore boost a person's SW profile by enriching their identifier records with links to other identifiers.

However, there are a considerable number of reciprocal links already embedded in LCNAF, VIAF, ISNI, and Wikidata identifiers and they are deposited there in a variety of ways. In the case of VIAF, an OCLC service, this occurs because it receives data periodically from the LCNAF, ISNI, and Wikidata databases. VIAF has two categories of membership—data contributors (agencies that formally join VIAF, including the Library of Congress (LC)) and data providers (selected data sources that are not VIAF contributor agencies, including ISNI and Wikidata).[30] VIAF receives all of LC's authority records in the LCNAF, as well as its MARC-formatted bibliographic records. The non-unique name authority records in the LCNAF are provided but are not loaded into VIAF.[31] VIAF also receives data from ISNI and Wikidata, although their data are used selectively because they are data providers, not contributors. As part of these processes, LCNAF, ISNI, and Wikidata identifiers are added to VIAF clusters. There is no set schedule for the data exchanges between VIAF and the ISNI, Wikidata, and LCNAF databases; VIAF relies on contributors notifying OCLC when updates are available.[32] Research by Bianchini, Bargioni, and Pellizzari di San Girolamo provides insight into how prevalent LCNAF, ISNI, and Wikidata identifiers are in VIAF personal name clusters. Thirty-eight percent of VIAF clusters contained an ISNI identifier and LCNAF and Wikidata identifiers were present in 33 percent and 10 percent respectively.[33]

In the case of ISNI, there are no comprehensive data exchanges between it and the VIAF, LCNAF, and Wikidata databases, although these identifiers are often embedded in ISNI records. Some of this interlinking is the result of past exchanges. ISNI used VIAF data as its base cross-domain file for populating the initial ISNI database, and until 2016 there was an identifier linkage process. However, this process was discontinued around 2016 when the VIAF clustering process was judged to be too volatile for it to be used as a reliable feed into ISNI. Nevertheless, ISNI still selectively uses VIAF data for correction and enrichment, and it adds appropriate VIAF identifiers to its records. There was a one-time multimillion record load of data from LCNAF into ISNI around April of 2021, but that exercise has

not been repeated since.[34] The initial ISNI database also included loads from non-library partners like ProQuest, which contributed millions of identities from its portfolio of databases.[35]

LCNAF records contain links to VIAF, ISNI, and Wikidata sources. The one-to-one relationship between the LCNAF and VIAF (with a few exceptions for undifferentiated names) enables a search between the two systems that populates the LCNAF record with the VIAF identifier. Links in LCNAF records to ISNI identifiers are only present because they were inserted into the NACO record by individual catalogers.[36] The Library of Congress (LC) recently announced a collaborative creation "with the Cornell University Library of a Wikidata bot (LccnBot) to facilitate creating connections between the LCNAF and Wikidata. The bot adds the LC control number (LCCN) from a name authority to Wikidata when the authority record contains a Wikidata identifier in the MARC 024 or 670 fields. This eliminates the need to return to the Wikidata item to add the LC identifier after a name authority record has been created. . . . The bot runs weekday mornings to ensure timely updates to Wikidata."[37]

Wikidata is still very far from having a structured workflow to ingest data from other data sources. Wikidata items can house many identifiers from other identifier systems, but they are only input through the voluntary work of Wikidata users. When examining Wikidata items, Bianchini, Bargioni, and Pellizzari di San Girolamo found a notable connection with VIAF; almost 25 percent of the items included a VIAF ID. Furthermore, they noted that almost all Wikidata items that include a VIAF identifier also have at least one VIAF source ID (e.g., LCNAF or ISNI). VIAF IDs are automatically sorted as the first external identifier in Wikidata items, but there is no automatic reciprocity between VIAF and Wikidata, i.e., when one system gets a link to the other, the latter system does not automatically get a link to the former.[38]

The ORCID system is the one least connected with the other four. Its closest connection is with ISNI, which has reserved a block of its IDs for ORCID's use. In spite of there being a tool, ISN2ORCID, that allows ORCID registrants to import their ISNI information into their ORCID profile, it is unclear how frequently this is done or how prevalent ISNI identifiers are in ORCID records. ORCID identifiers are also present in LCNAF records and Wikidata items, but only because individual contributors have input them. ORCID is not a participant in VIAF.

Academic Disciplinary Aspects of Identifier Systems

Previous research has indicated that authors from certain academic disciplines or those who mainly publish in certain types of publications are better represented in some identifier systems than others. For instance, the VIAF and LCNAF databases are built from library authority files and primarily represent authors of monographs.[39] This means that faculty in the arts, humanities, and social sciences, fields in which books have great reputational value, will have more representation in VIAF and the LCNAF than scholars in other disciplines.[40] Even though they are close cousins, there are also some disciplinary distinctions between VIAF and the LCNAF. Engineering faculty, for instance, are not well-represented in the LCNAF but have a greater presence in VIAF because it includes more conference proceedings.[41]

The monograph-centric nature of both LCNAF and VIAF, however, can omit authors who chiefly produce journal articles. Therefore, in disciplines like engineering, the hard sciences, and law, where journal articles are a highly valued vehicle for disseminating scholarship, some prominent researchers will not have authority records in VIAF and the LCNAF.[42] The disciplinary gap left by authority hubs like VIAF and LCNAF is filled in part by identifier registries such as the ISNI and ORCID databases. Like VIAF and LCNAF, the ISNI database includes book and conference paper authors, but it also aggregates identities of journal article authors from data providers like ProQuest and Scholar Universe. Furthermore, it creates identifiers for artists, producers, and performers, thereby including faculty whose scholarship is non-textual.[43] ORCID also encourages the registration of scholars who publish journal articles, papers, datasets, and software.[44] Although ORCID does not store data about the types of publications included in it, it is possible that journal articles are the predominant type. This would explain Dasler et al.'s observation that the representation of ORCID identifiers within the natural, health, and applied sciences is higher than in fields of the arts, humanities, economics, and social sciences.[45] It would also validate Webster's suggestion that the ORCID database has a potential bias against scholarship within the humanities, which is generally published as monographs rather than journal articles.[46]

Research Design and Methods

Faculty data for Academic Year (AY) 2019/2020 obtained from CU Boulder's OFA included 2,201 persons. The dataset contained names, academic ranks, academic appointments to colleges and schools, and links to the faculty member's online campus profile. CU Boulder has numerous academic ranks, and faculty members were assigned to one of six categories: tenured and tenure-track, non-tenure track, administrative, research, clinical, and other. For faculty with multiple ranks, their CU Boulder faculty profile was consulted to determine their primary job duties and they were assigned to the most relevant rank. Some academic ranks include several classes of faculty titles. The tenure and tenure-track category includes professors of all levels (i.e., assistant, associate, full, distinguished professors, and emeritus/emerita professors). The non-tenure track category contains all instructors, teaching professors, scholars-in-residence, and artists-in-residence. Chairs, faculty directors, deans, chancellors, and provosts were assigned to the administrative faculty group. Clinical instructors and clinical professors made up the clinical faculty category, and the research group contained faculty listed as research professors. The "other" category comprised a mix of other (sometimes temporary) ranks, including lecturers, adjoint/adjunct professors, attendant professors, and visiting professors.

Academic appointment information received from the OFA was used to assign faculty members to one of the units in the university's eleven colleges or schools. Some faculty members held appointments in multiple colleges or schools, but for the purposes of this study, each faculty member was assigned to only one unit based upon the primary appointment designated in the OFA data. Given the size and structure of the College of Arts and Sciences, its faculty were further subdivided by academic division (Arts and Humanities, Natural Sciences, and Social Sciences) and then again by department.

The final step was compiling a list of all existing LCNAF, VIAF, ISNI, ORCID, and Wikidata identifiers for every CU Boulder University faculty member. Columns for each of the four identifiers were added to the faculty dataset spreadsheet received from OFA and, during August and September 2021, every faculty member was manually searched in each database and identifiers were recorded in the appropriate column. Because Neubert's research demonstrated Wikidata's potential as an identifier hub, the presence of LCNAF, VIAF, ISNI, and ORCID identifiers in faculty Wikidata items was also recorded in separate columns.[47] It was often necessary to consult the published works listed in the person's profile page or curriculum vitae to match the person with the proper identifier correctly. Linkages between the identifier systems (e.g., the inclusion of an LCNAF identifier in a Wikidata item or the presence of a Wikidata identifier in a VIAF record) also aided the reconciliation process. Instances of duplicate identifiers were also recorded; although duplication was rare, it was most prevalent for Wikidata and ISNI identifiers. Because the Wikidata and ISNI systems have mechanisms for resolving duplicates, deduplication was done whenever possible.

Results and Discussion

Table 1 shows the breakdown of the 2,201 faculty members by rank. Tenured or tenure-track faculty comprise the largest group (63.3 percent), followed at a considerable distance by non-tenure track faculty (25.7 percent) and administrative, research, clinical, and other faculty (collectively 11 percent). Full professors constitute the largest single cohort of all faculty (n = 612, 27.8 percent), and the overall numbers indicate that most CU Boulder faculty are seasoned researchers in the mature stages of their careers.

Table 1. CU Boulder faculty by academic rank

Academic Rank	Total Population (N = 2,201) n (%)
Tenured/Tenure-Track	1,394 (63.3)
Professor	612 (27.8)
Associate Professor	407 (18.5)
Assistant Professor	375 (17)
Non-Tenure Track	566 (25.7)
Instructor/Senior Instructor/Teaching Professor	511 (23.2)
Artist/Scholar in Residence	55 (2.5)
Administrative Faculty	105 (4.8)
Research Faculty	71 (3.2)
Clinical Faculty	15 (0.7)
Other Faculty	50 (2.3)

Table 2 shows the distribution of the 2,025 faculty members (92 percent of total faculty) who held an academic appointment in at least one of CU Boulder's academic units. The College of Arts and Sciences (COAS) was home to the greatest number of faculty (n = 1,040, 51.4 percent), followed by the College of Engineering & Applied Science (CEAS) (n = 375, 18.5 percent). COAS's Natural Sciences division contained the most faculty of any single academic unit (n = 560, 27.7 percent) and combined with CEAS comprised over 45 percent of the total faculty, revealing the campus's strong focus on science. In addition, the substantial number of faculty in such diverse areas as the arts, humanities, social sciences, business, media, music, law, and education demonstrates the comprehensiveness of the university's academic profile.

Table 2. CU Boulder faculty by academic unit

| Academic Unit	Total Population (N = 2,025) n (%)
College of Arts and Sciences	1,040 (51.4)
Natural Sciences	560 (27.7)
Arts & Humanities	289 (14.3)
Social Sciences	191 (9.4)
College of Engineering & Applied Science	375 (18.5)
Business School	151 (7.5)
College of Media, Communication and Information	99 (4.9)
College of Music	85 (4.2)
Law School	72 (3.6)
School of Education	69 (3.4)
University Libraries	54 (2.7)
Program for Writing and Rhetoric	43 (2.1)
Program in Environmental Design	29 (1.4)
Graduate School	6 (0.3)
Continuing Education and Professional Studies	2 (0.1)

The analysis of the collected data examined three broad areas regarding CU Boulder faculty identifiers: the current state of CU Boulder's identifier ecosystem, including the total number of each identifier, further dissected by academic rank and discipline; the robustness of faculty identifier profiles; and the extent to which Wikidata is serving as an identifier hub for faculty. This section will explain the results in each area and compare them to findings in related studies when appropriate.

Overall Prevalence of Identifiers at CU Boulder

Figure 1 shows the number of each identifier for all CU Boulder faculty. The most prevalent faculty identifier was the ORCID at 82 percent. ORCID's primacy in the CU Boulder identifier ecosystem was expected given the university's promotion of ORCID registration among its faculty. Given the large number of faculty in engineering, natural sciences, art, music, and law—whose scholarly work is prone to take the form of journal articles, exhibitions,

Figure 1. Prevalence of identifiers among CU Boulder faculty (*N* = 2,201)

and performances—it is not surprising that the cross-domain ISNI is the second-most common identifier (54 percent). Furthermore, the smaller yet still substantial number of faculty in monograph-centric disciplines like the arts, humanities, and social sciences accounts for the position of VIAF (46 percent) and LCNAF (40 percent) in this order. One might not expect such a large gap between the closely related VIAF and LCNAF systems, but it is likely accounted for by the former's inclusion of conference proceedings, making it therefore more likely to include some of CU Boulder's engineering and science scholars that are excluded from the LCNAF. Despite Wikidata's relatively recent emergence as an identifier system, it was only slightly behind the much more established LCNAF database at 39 percent. This might be explained by Wikidata's broader community of contributors, which extends well beyond the realm of librarians, as well as the utilization of bots—computer programs that can create and revise Wikidata items without direct human intervention.

When comparing these findings to other multidisciplinary identifier analyses, it is useful to note that previous studies were much more limited in terms of both the number of faculty and the academic disciplines represented in them. Nevertheless, an examination is offered for the sake of interest. ORCID identifiers for CU Boulder faculty existed at a much higher rate than those found in studies by Mering (43 percent), the Primary Research Group (35 percent of US faculty), and Downey (19 percent).[48] The prevalence of ISNI identifiers among CU Boulder faculty also shows a much higher percentage than that discovered by Panigabutra-Roberts (38 percent) or reported by respondents to the Primary Research Group's survey (2 percent). A large number of participants in the latter study, however, did not answer the ISNI question, indicating that they may not have known if they had one.[49] On the other hand, the percentage of CU Boulder faculty with VIAF identifiers is below that found by Panigabutra-Roberts (56 percent) and Mering (52 percent), although it is higher than the one found by Downey (23 percent).[50] The percentage of CU Boulder faculty with an LCNAF record was similarly middling when compared to other studies. It is lower than that reported by Ilik (almost half of Texas A&M University faculty) and Panigabutra-Roberts (46 percent) but larger than that found by Waugh, Tarver, and Phillips
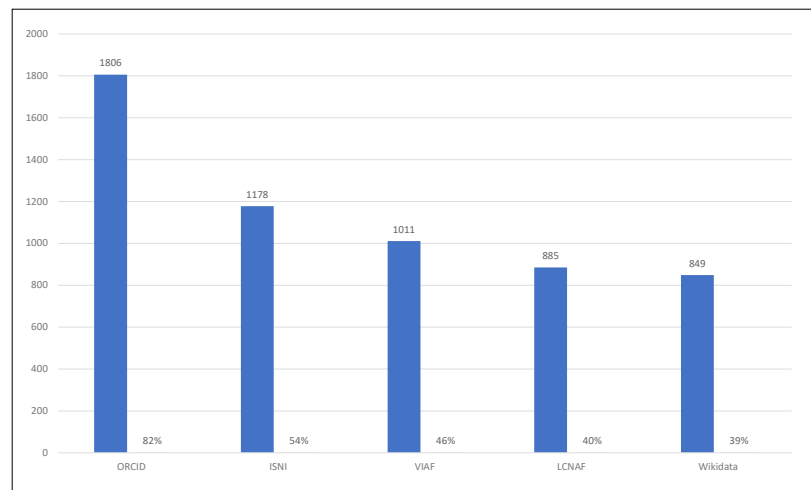
(26 percent) and Downey (14 percent).[51] Given the disparities between sample sizes of faculty and disciplines, it is difficult to draw any firm conclusions from these comparisons.

Prevalence of Identifiers by Academic Rank

No prior studies have examined the incidence of author identifiers in connection with academic rank and that was a primary objective of this study. Table 3 shows the results. Tenured or tenure-track faculty account for the largest percentage across all types of identifiers. This should not be surprising given the fact that this group has the highest expectations for research productivity on campus. Full professors are the largest subgroup across all identifier types. This is probably because faculty in more mature stages of their careers will have a more robust scholarly profile and will therefore have accrued many research identifiers. This hypothesis also holds true at the associate professor versus assistant professor ranks for all identifiers except Wikidata. It breaks down, however, when comparing assistant professors with non-tenure track faculty. Despite having lower expectations for research productivity, the latter group outpaces the former in all identifiers except Wikidata. The reason for this may be accounted for by the fact that assistant professors are in the early phase of their careers and are still forming a substantial research footprint, whereas non-tenure track faculty may be more seasoned academics and have had time to accumulate a body of scholarly work.

Table 3. Incidence of CU Boulder faculty identifiers by academic rank.

Academic Rank	ORCID ($n = 1,806$) n (%)	ISNI ($n = 1,178$) n (%)	VIAF ($n = 1,011$) n (%)	LCNAF ($n = 885$) n (%)	Wikidata ($n = 849$) n (%)
Tenured/Tenure Track	1,314 (73)	927 (79)	812 (80)	705 (80)	712 (84)
Professor	598 (33)	524 (44)	452 (45)	412 (47)	387 (46)
Associate Professor	393 (22)	291 (25)	247 (24)	221 (25)	158 (19)
Assistant Professor	323 (18)	112 (10)	113 (11)	72 (8)	157 (19)
Non Tenure Track	375 (21)	166 (14)	121 (12)	111 (13)	62 (7)
Other Faculty	117 (6)	85 (7)	78 (8)	69 (8)	75 (9)

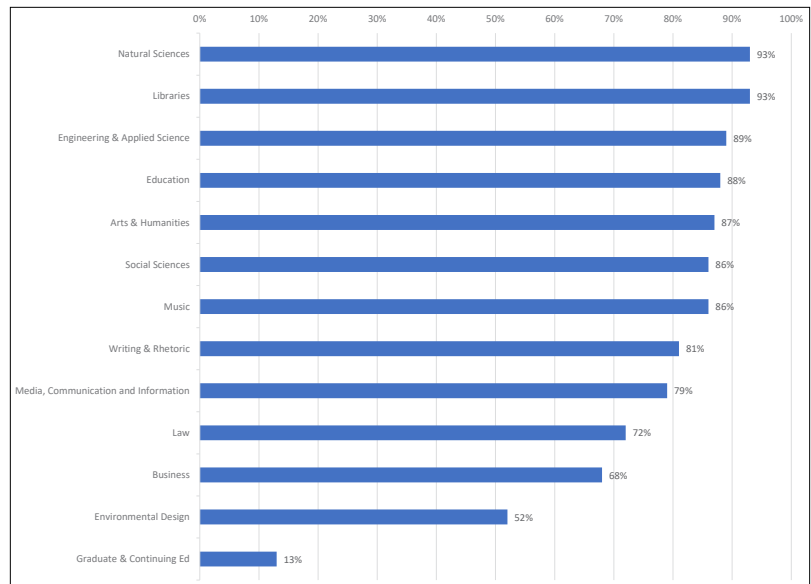## Prevalence of Identifiers by Academic Discipline

Given the previous examination of the disciplinary aspects of identifier systems, some hypotheses were drawn about the types of identifiers that CU Boulder faculty in certain academic disciplines were most likely to have. It was assumed that a higher percentage of faculty in monograph-centric areas like the arts, humanities, and social sciences would have LCNAF and VIAF identifiers than those in other fields. It was also expected that CU Boulder scholars in engineering, the hard sciences, and law, fields in which journal articles are the predominant publication type, would be better represented in the ISNI database than in the LCNAF and VIAF.[52]

These hypotheses were largely borne out in the findings of this study. Figures 2 through 6 show the percentage of faculty within an academic unit having each type of identifier. Considering ORCID's
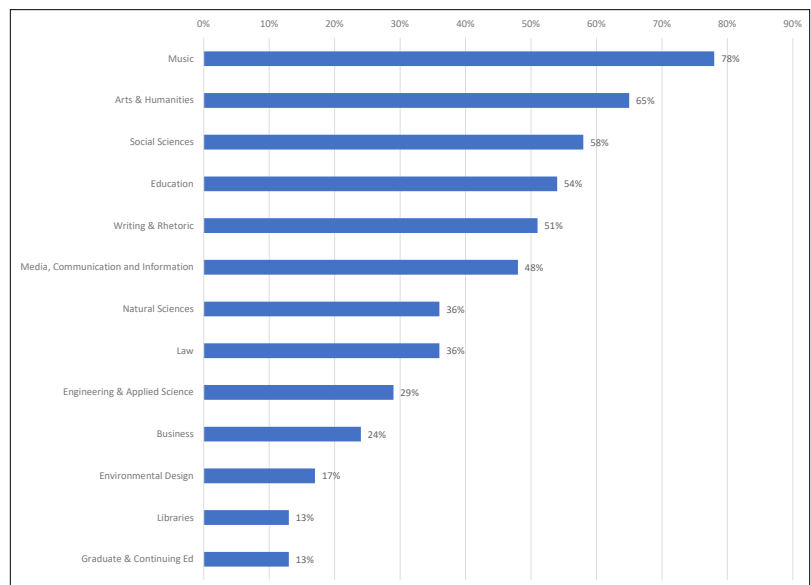
prevalence among all CU Boulder faculty, the results shown in figure 2 indicate that the campus's promotional efforts have been quite effective in most academic departments. An intriguing discovery was that music faculty were the best-represented group of CU Boulder scholars among all identifier systems, having the highest percentage of LCNAF, VIAF, and ISNI identifiers and in the top half of Wikidata. Although this was an understandable outcome in the case of the more cross-disciplinary ISNI, it was a rather surprising finding for the LCNAF and VIAF given their reputation for being monograph-centric databases. This phenomenon might be attributed to the industriousness of NACO music catalogers, but a deeper analysis of NACO and VIAF records is needed to detect a cause.

Less surprising is the high incidence of LCNAF, VIAF, and ISNI identifiers among arts, humanities, and social science scholars. As noted, faculty in these areas deem monographs an important indicator of research quality, although many also publish journal articles.[53] This aligns with observations in Panigabutra-Roberts' study, which also found that humanities and social

Figure 2. Percentage of faculty with ORCID IDs within CU Boulder academic units

Figure 3. Percentage of faculty with LCNAF IDs within CU Boulder academic units

sciences are better represented in the LCNAF and VIAF than the sciences and engineering.[54] Faculty in the field of education also landed in the upper tier of all identifiers.

Also expected was the predominance of ISNI and Wikidata identifiers among engineering and applied science and natural sciences scholars over VIAF and LCNAF. Faculty in engineering and applied science were near the top in ISNI and Wikidata but were in the lower half of LCNAF and VIAF, which validates the previously discussed assertion that these databases tend to exclude authors who produce chiefly journal articles. It must be noted that the prevalence of ISNI identifiers among engineering and
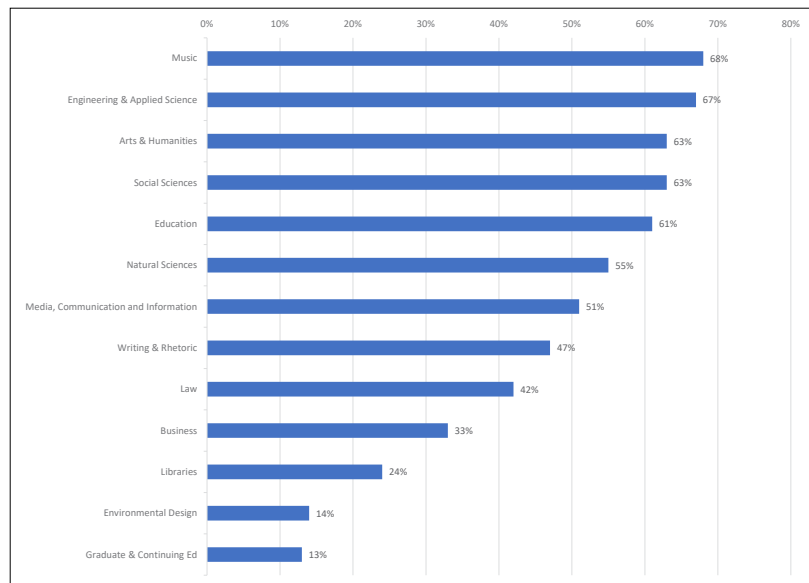
applied science faculty was influenced by CU Boulder's participation in the PCC ISNI Pilot, in which local efforts focused on College of Engineering and Applied Science faculty, but only partly so since catalogers found that one-half already had ISNI records before their intervention. Faculty in the natural sciences had the highest percentage of Wikidata items but were near the middle of the pack for all other identifiers. Likewise, scholars in fields like writing and rhetoric and media, communication, and information tended to be in the middle range for all types of identifiers. Law, business, and library faculty were in the lower tier for all identifiers; further investigation is needed to determine why.

Figure 4. Percentage of faculty with VIAF IDs within CU Boulder academic units

Although identities in the LCNAF, VIAF, ISNI, and ORCID databases are mostly created from sources within the publishing universe, Wikidata items can be created by anyone and can describe any kind of entity. One might hypothesize, therefore, that the disciplinary divisions found in the other identifier systems would be absent in Wikidata. The data collected in this study does not support that hypothesis. Figure 6 shows a substantial disparity

Figure 5. Percentage of faculty with ISNI IDs within CU Boulder academic units

between natural sciences and engineering and applied science faculty and those in other disciplines. They hold the predominant places in Wikidata, in contrast to their lower percentages for most of the other identifiers. Conversely, academic disciplines like the arts, humanities, social sciences, and music, whose faculty had high percentages of LCNAFs, VIAFs, and ISNIs, lagged in Wikidata. Although an explanation is not readily apparent, it is possible that a closer examination of the types of contributors or bots in the Wikidata items' revision history might reveal a more concentrated effort in the Wikidata community to identify science scholars than other types. Business and law faculty continued to have a relatively low incidence of Wikidata, as they did with the other identifiers. It must be noted that,
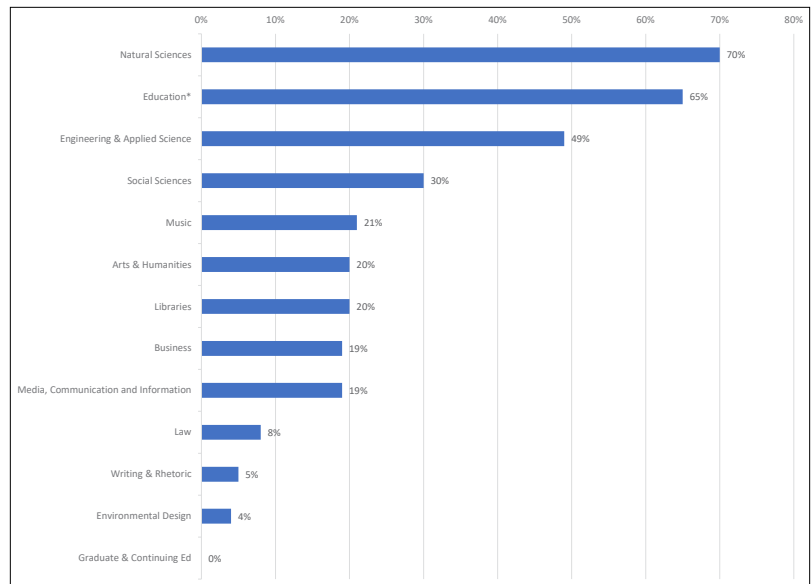
although education faculty had the second highest percentage of Wikidata identifiers in this study, this is not an organic outcome due to the intervention of CU Boulder catalogers, who focused on CU Boulder education faculty while experimenting with creating and revising Wikidata items.

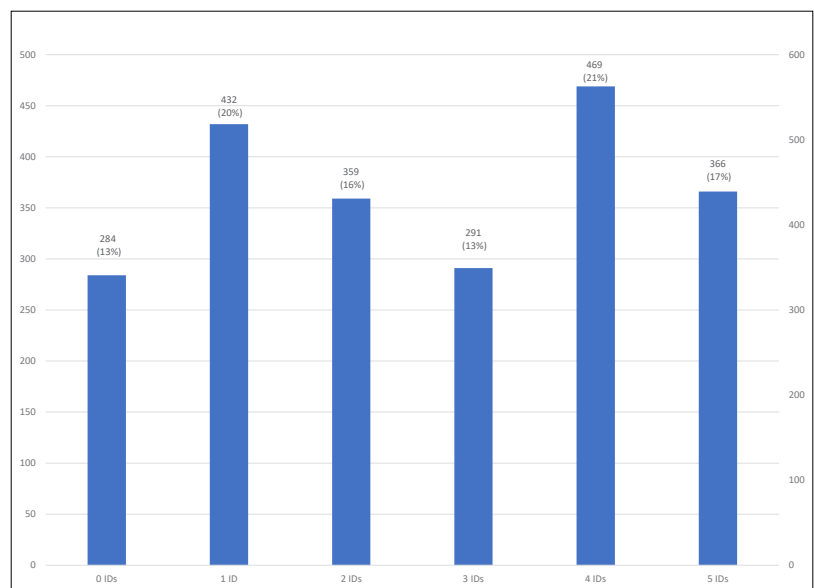## Multiplicity of Identifiers and Linkages among Identifier Systems

French and Fagan's 2019 article on the visibility of faculty researchers suggested that the presence of multiple research profiles increased the web discoverability of faculty and their publications.[55] Therefore, in addition to investigating the prevalence of individual identifiers, this study also examined how many CU Boulder faculty had multiple identifiers and what the most common identifier combinations were. Figure 7 shows the number of author identifiers per faculty. Although one-third have zero or one, slightly more than half have three or more and over one-third have four or five, demonstrating that most CU Boulder faculty have extensive identifier profiles.

Figure 8 shows the number and percentages of the various combinations of LCNAF, VIAF, ISNI, and Wikidata

Figure 6. Percentage of faculty with Wikidata items within CU Boulder academic units

Figure 7. Multiplicity of identifiers among CU Boulder faculty

identifiers. ORCID identifiers were excluded from this comparison since the ORCID database has limited interactions with the other databases. Given the previously discussed data sharing among VIAF, ISNI, and LCNAF, it is not surprising that 54 percent of CU Boulder faculty possessed all those identifiers. Figure 9 shows that the ISNI identifier appears in the most combinations (93 percent), followed by VIAF (85 percent), LCNAF (77 percent), and Wikidata (55 percent), mirroring the overall prevalence among CU Boulder faculty of each identifier. This ranking also aligns with the findings of Bianchini, Bargioni, and Pellizzari di San Girolamo regarding embedded identifiers in VIAF clusters.

Is Wikidata Operating as an Identifier Hub?

Wikidata's interoperability, combined with its richer entity descriptions and community-centered approach to eliciting contributions, has led some authors to posit that it may be a better solution for recording authority data than other identifier systems.[56] Indeed, Wikidata has been touted as an identifier linking hub because of its ability to house a multitude of other authorities, and thus ameliorate the challenges posed by scattered and divided identities recognized by Panigabutra-Roberts.[57] Perhaps more optimistically, it has even been proposed as the universal identifier.[58]

During the data collection portion of this project, LCNAF, VIAF, ISNI, and ORCID identifiers found in Wikidata items for CU Boulder faculty were recorded. Figure 10 shows the results. Fifty-six percent of CU Boulder faculty Wikidata items contained a link to just one other identifier, almost 20 percent had none, and only 25 percent had more than one. Figure 11 shows

Figure 8. Combinations of identifiers among CU Boulder faculty
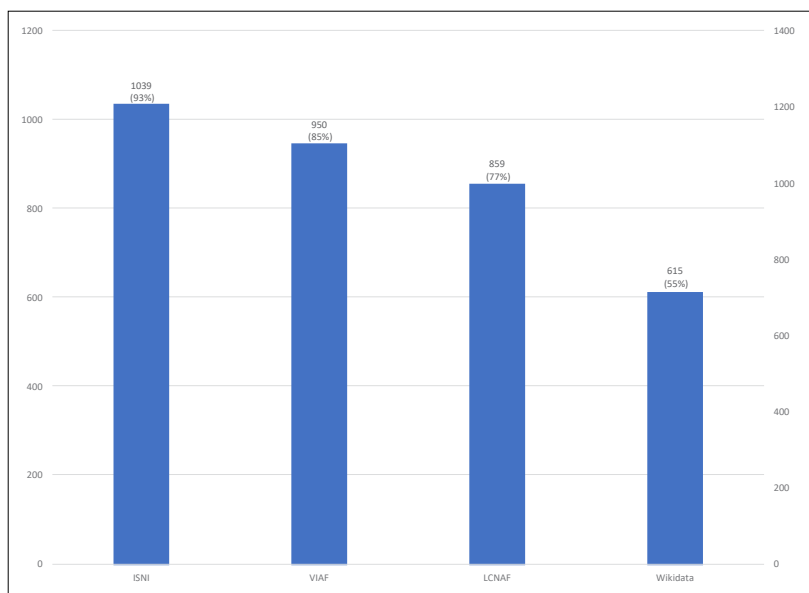
Figure 9. Frequency with which identifiers appear in combinations among CU Boulder faculty

the prevalence of each identifier within Wikidata items. ORCID identifiers had the highest frequency at almost 70 percent; this might again be explained by the work of bots mining ORCID's database and adding identifiers to Wikidata. VIAF, LCNAF, and ISNI identifiers, on the other hand, were present in a relatively small percent of Wikidata items. These findings indicate that, despite Wikidata's potential as a clearinghouse for author identifiers, much work yet remains for this promise to be realized.

Conclusion: Focusing CU Boulder Libraries' Identifier Efforts

Through their participation in the PCC and its recent pilot projects, RDS catalogers have embraced the PCC's strategic action item of "participation in ISNI, Wikidata and similar emerging Linked Data-based ventures."[59] However, one of this article's primary aims was to inform decisions about whether to
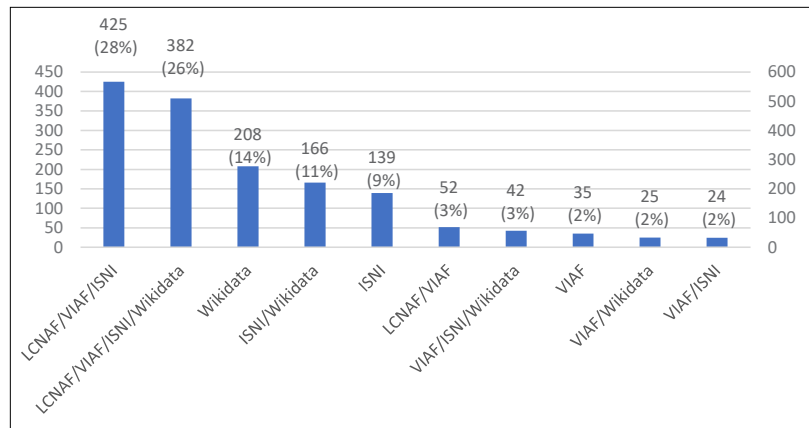
continue this work and, if so, where CU Boulder should concentrate its identifier creation efforts. Several strategies could be pursued. One option is to create, enhance, and connect identifiers in multiple databases. This decision would ensure a robust identifier profile for all CU Boulder faculty members. But although RDS has the requisite skills and authorizations to accomplish this, it must also consider its capacity to achieve it. Staff departures have diminished the team's ability to sustain the same amount of cataloging and identity management activity as before. There are plans to train more RDS catalogers to create NACO and ISNI identifiers, but only in limited numbers because preparing catalogers to perform that work is very labor-intensive in terms of instruction and review, especially with fewer experienced PCC-trained catalogers on hand to assist.
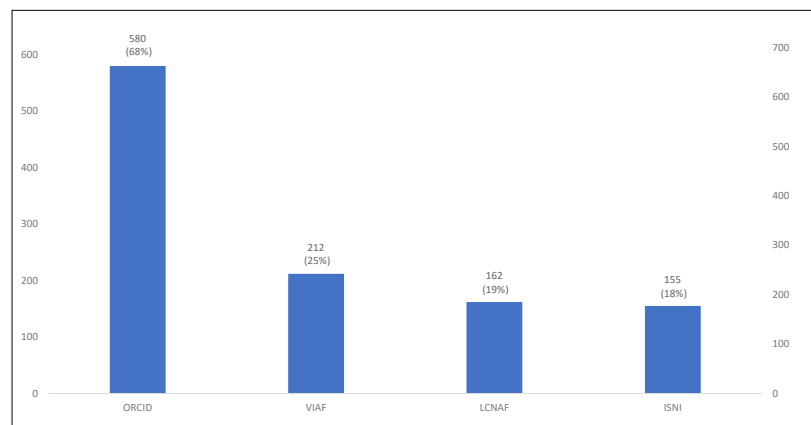
In light of limited staff resources, another approach might be to focus efforts on only one or two identifiers.

Figure 10. Numbers of identifiers in CU Boulder faculty Wikidata items

Figure 11. Prevalence of specific identifiers in CU Boulder faculty Wikidata items

The data in figure 1 shows that Wikidata items and NACO authority records have the lowest incidence among CU Boulder faculty, and RDS could concentrate on bolstering those numbers to the greatest extent possible. Wikidata items are the most attractive choice because they are the least prevalent and do not require the same rigorous training as NACO records, allowing all RDS catalogers to contribute. In addition to Wikidata, RDS could continue to do a modicum of NACO authority records to maintain its PCC participation and abandon ISNI work, depending on ISNI registration agencies to create identifiers for a portion of CU Boulder faculty.

After weighing the choices and balancing capability and capacity, RDS intends to implement a plan involving Wikidata, ISNI, ORCID, and NACO identifiers, but with different levels of team involvement for each. The determining factor in pursuing a comprehensive approach was the demonstrated value in the professional literature to both the CU Boulder campus and its scholars of providing faculty with a strong scholarly profile that includes a multiplicity of author identifiers, which currently does not exist for every CU Boulder faculty member. As figure 7 shows, a third of CU Boulder's faculty have no or

only one identifier and only 18 percent have more than two, so the scholarly publishing process cannot be relied on to automatically generate robust identifier profiles for all researchers. There is ample opportunity for RDS catalogers to improve that situation, especially through the creation of Wikidata items and ISNI records. As noted in the literature review, faculty often lack awareness of their own identifiers and are unlikely to advocate for themselves, so it falls to catalogers to assume that work and advocate through action. Furthermore, in alignment with the observations in figures 3-6, Downey's study suggested that no single data source includes a "critical mass" of scholars from all academic disciplines, highlighting the impracticality of relying on a single identifier system and reinforcing the need for catalogers to create multiple types of identifiers.[60] Working in multiple systems also gives RDS catalogers the ability to interlink identifiers in each system, thereby acting as both creators and cross-pollinators and fulfilling the PCC's goal of more engagement with linked data.

The team's Wikidata project will be the most inclusive since it will involve all RDS catalogers and encompass all CU Boulder faculty. Using the data compiled for this study, catalogers will create new Wikidata items for faculty and enhance existing ones, including statements on academic discipline, affiliation with CU Boulder, and other information found on their public-facing profiles, as well as adding LCNAF, VIAF, ISNI, and ORCID identifiers when available. This part of the plan is the easiest to implement on a broad scale since Wikidata's low training barrier permits all staff to be quickly trained. It concentrates the most effort on the least prevalent identifier and is an additional step in turning Wikidata into an identifier hub, given that 75 percent of current CU Boulder faculty Wikidata items include either no or one link to another identifier in this study. This project also offers hands-on linked data experience for CU Boulder catalogers and gives them exposure to a wider range of identifiers than they normally encounter in their cataloging work. The assignment, however, is not without challenges, foremost of which is designing a template of data for new Wikidata items that is robust yet practical, allowing catalogers to create fulsome descriptions while still completing the project in a reasonable timeframe. Furthermore, for staff accustomed to following rigorous cataloging rules and working in a rather siloed environment, Wikidata's lack of best practices and an open policy of community editing might be a source of frustration and cause them to feel that other contributors might compromise the quality of their work. However, once RDS catalogers attain a sufficient level of familiarity and comfort with Wikidata, the team might do as other libraries have done and progress to creating Wikidata items for our faculty's publications and linking them to the individual's Wikidata item to further boost their scholarly profiles.[61]

By contrast, the team's continuing NACO efforts will be much more restrictive than those for Wikidata in that not all RDS catalogers will take part, nor will a NACO authority record be created for every CU Boulder faculty member. In addition to being foundational to the University Libraries' continued participation in the PCC, NACO work enriches the overall identifier ecosystem in several ways. NACO records are ingested into VIAF, and RDS catalogers can also create linkages to other identifier systems within records by using the MARC 024 field. Using automated tools like the Authority Toolkit can reduce the manual effort needed. Even considering these benefits, though, NACO work by itself will never be a sufficient solution to enhancing all faculty members' identifier profiles. The labor intensity of

both the training and the performance of the actual work precludes most cataloging departments from creating NACO records for all campus faculty. This obstacle is compounded by the need to base NACO descriptions on "literary warrant" and how an entity represents itself in resources.[62] As previously discussed, this privileges monograph authors, since the information is relatively easy to find in the normal course of cataloging work, but disadvantages journal article writers because much extra effort would be needed to scour journal indexes and find representation. However, RDS plans to conduct NACO training for several new catalogers, after which the team may be able to proactively target CU Boulder scholars in disciplines that tend to have a fairly low incidence of NACO records, such as those in law and business.

The RDS Team's resumption of its ISNI work will strike a balance between its capability and capacity. In its first steps, this will involve fewer catalogers and target only CU Boulder faculty in academic disciplines that have lower rates of ISNIs. ISNI work, although still time-consuming, does not carry the same requirements as NACO. There is no need to create a unique, preferred form of name text string, nor do all assertions in an ISNI record need to be justified by external sources, enabling both PCC and non-PCC trained staff to participate. Eventually, every RDS cataloger can be trained for ISNI work, making it then feasible to create or enhance ISNI records for all CU Boulder faculty and provide an additional identifier for almost half of CU Boulder's faculty. RDS catalogers can also integrate ORCID identifiers into the ISNI records they work with. As more catalogers are trained in ISNI, RDS can implement a phased plan that focuses first on faculty in academic disciplines with lower rates of ISNIs and then progresses to those with higher rates. This approach takes advantage of efficiencies inherent in the scholarly publishing process, since ISNI assignation may be done for faculty publishing in journal-centric fields by ISNI's journal aggregator data providers like ProQuest and Scholar Universe and thus reduce the workload for RDS.

All libraries are able to contribute to the broader identifier ecosystem in some fashion, although substantial obstacles exist for certain identifier systems. NACO participation has a high barrier for entry in terms of training and ongoing review. The need to establish a unique authorized heading based on a preferred form of name as well as the obligation to provide external references for all assertions made in the record make creating NACO records a very labor-intensive process. It is therefore not surprising that less than 10 percent of the library community participates in the NACO program.[63] Although ISNI training is less stringent, involvement is restricted because participation is predicated on institutional membership in the PCC. Wikidata, on the other hand, has a very low barrier to participate and no formal training and review requirements to meet, so catalogers of all stripes can create Wikidata items for campus faculty or other constituencies and embed other identifiers in them, thereby bolstering faculty scholarly profiles, augmenting their Web presence, and enriching the overall identifier ecosystem.

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