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"Striking Out on Your Own"—A Study of Research Information Management Problems on University Campuses

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Abstract

Here, we report on a qualitative study that examined research information management (RIM) ecosystems on research university campuses from the perspectives of research information (RI) managers and librarians. In the study, we identified 21 RIM services offered to researchers, ranging from discovering, storing, and sharing authored content to identifying expertise, recruiting faculty, and ensuring the diversity of committee assignments. In addition, we identified 15 types of RIM service provision and adoption problems, analyzed their activity structures, and connected them to strategies for their resolution. Finally, we report on skills that the study participants reported as being needed in their work. These findings can inform the development of best practice guides for RIM on university campuses. The study also advances the state of the art of RIM research by applying the typology of contradictions from activity theory to categorize the problems of RIM service provision and connect their resolution to theories and findings of prior studies in the literature. In this way, the research expands the theoretical base used to study RIM in general and RIM at research universities in particular.

"Striking Out on Your Own"—A Study of Research Information Management Problems on University Campuses

Research information (RI) has been a critical resource for many different workflows at research universities. Different units at universities (e.g., the office of research) have become increasingly interested in collecting and analyzing RI for reporting, accreditation, commercialization, expertise identification, and organizational reputation management. Those activities and interests have begun to overlap with the traditional interests and practices of RI managers and librarians in academic libraries. Academic libraries are expected to align their digital services with the broader organizational needs and priorities of research universities (Dempsey, 2014; Tenopir et al., 2012). Library and information science research and practice communities have engaged in considerable deliberation on the need for and uses of RI and data and how to manage it effectively (e.g., Bryant et al., 2017; NISO Altmetrics Initiative[1]; OCLC Research, Registering Researchers Task Force, 2014).

Academic libraries take different approaches to research information management (RIM). Some establish and operate stand-alone RIM systems (RIMSs), whereas others integrate additional RIM services into the existing institutional repository (IR) systems (Palmer, 2013). Indeed, evidence from practice suggests that adding more RIM services (e.g., research identity management) to an IR may increase researchers' interest in the IR (Dempsey, 2014; Tate, 2012).

Activity–service life cycles are dialectical and are developed through interactions among the users' dynamic needs, the contradictions and problems of the activity, and the solutions sought (Kaptelinin & Nardi, 2012). Misalignments between the users' RIM needs and practices and the available RIM services can be conceptualized as contradictions. To develop new, more innovative forms of RIM activities and RIM services, it is essential to identify the existing contradictions and problems, and how those problems have been addressed or mitigated. Studies have been conducted on researchers' use of RIM services, and their motivations and amotivations for engaging with those services (e.g., Stvilia et al., 2018b; Wu et al., 2017). The RIM literature also includes surveys of RIM service provision by academic libraries (e.g., Bryant et al., 2017). However, in-depth empirical investigations into the problems of RIM service provision and adoption in university RIM ecosystems that is grounded in a theory, and the solutions sought to address those problems are still lacking.

Problem Statement and Research Questions

The RIM ecosystem of a research university is complex. It may comprise the curation of multiple types of RI that are managed using different information systems operated by different units with different objectives and organizational cultures. In addition, with the increased ease of data collection, the amount and scale of RI grow to reach the level of "big data." Universities are building integrated infrastructures to enable big data-scale secure storage and analysis of RI. These institutions are seeking new opportunities and innovative ways to collect and leverage that information to enhance students' learning and experiences; increase the research productivity, reputation, and visibility of the faculty; optimize their administrative and reporting workflows; and commercialize their intellectual property. Furthermore, the federal government and funding agencies are expected to track and evaluate the impact and economic value of publicly funded research.[2] Following their traditional role as hubs of information on university campuses, academic libraries are eager to position themselves as hubs of RIM services, expertise, and training.

[1] https://www.niso.org/standards-committees/altmetrics.
[2] https://www.cbo.gov/publication/54089.

Complex information ecosystems have complex challenges and problems. A Systematic approach is needed to elicit RIM problems and devise interventions for their resolution. Although a number of studies have been conducted on RIM in academic libraries, in-depth, theory-guided investigations of challenges in RIM service provision on university campuses from RI managers' or librarians' perspectives are still lacking. In particular, there is a dearth of research on the problems of RIM service provision and adoption, the strategies RI managers and librarians use to address those problems, and the skills they need to be successful in their work. This study contributes to filling that gap.

In particular, we examined the following research questions in this study from the perspectives of RI managers and librarians:

- What are the main RIM services offered on university campuses?
- What are some of the problems in RIM service provision and researchers' adoption of those services?
- What are some of the skills RI managers and librarians need to possess to be successful in their work?

This research informs the development of best practice guides for RIM on university campuses. It also advances the state of the art of RIM research by applying the typology of contradictions from activity theory to analyze the structure of problems in RIM service provision and connect their resolution to theories and findings of prior studies in the literature. In that way, the work expands the theoretical base used to study RIM in general and RIM at research universities in particular.

Related Work

Research information management systems also referred as current research information systems can be defined as information systems that collect, organize, and provide access to the content or related metadata of researchers' activities, such as their affiliations, areas of expertise, publications, data sets, software, hardware, patents, grants, awards, service, teaching, and media reports (Bryant et al., 2017; Dempsey, 2014; Hey et al., 2009; Palmer, 2013; Stvilia et al., 2018b). Such systems can differ in scope, being global (e.g., ResearchGate, Google Scholar, Mendeley), national (e.g., NARCIS), statewide (e.g., Florida ExpertNet), disciplinary (e.g., DIRECT2Experts), or institutional (e.g., Scholars@TAMU). RIMSs and RIM services can support different activities and workflows, including, but not limited to, sharing, grouping, linking, aggregating, and retrieving scholarship; evaluating the research productivity and impact of individuals, groups, and institutions; identifying potential collaborators, mentors, expertise, and new technology; assessing the innovation potential of that technology; and evaluating the teaching and service of faculty (Stvilia et al., 2018b). Hence, in addition to supporting researchers' RIM needs, RIM services have many different users and stakeholder groups, which may include, but are not limited to, librarians, promotion and tenure committees, administrators, external evaluators, funding agencies, sponsored research and technology transfer offices, industry technology scouts, and the public. For example, innovation hubs and startup incubators use RI and RIM services to identify the needed expertise, potential project team members, and mentors (Stvilia & Gibradze, 2019). The U.S. National Science Foundation (NSF) is partnering with the U.S. National Institutes of Health to use Science Experts Network Curriculum Vitae (SciENcv) as an NSF-approved format in preparing the biographical sketch section of an NSF proposal.[3] This policy change is designed to reduce researchers' administrative burden by allowing them to create and re-create their biosketches easily. SciENcv pulls information from other systems, including MyNCBI, ORCID, and eRA commons. This change also points to the growing trend toward RI integration and reuse from different digital asset management systems and the need to support that integration.

There have been examples of integration of RI managed by different units on campus into a single, university-wide RIMS. These integration efforts can reduce the cost of RIM to researchers and give research administrators

[3] https://www.nsf.gov/bfa/dias/policy/biosketch.jsp.

mechanisms for more effective planning and strategizing (Dvořák et al., 2019; Klausen et al., 2017). Furthermore, adding research data management functionalities to a RIMS can further increase its value to researchers by providing them with a single interface to manage both their research data and information (Jetten et al., 2019). However, to make the integration of a information infrastructure successful, the integration of its technical components must be accompanied by a successful integration and alignment of its social components and structures (Star & Ruhleder, 1999). The scholarly communication and research data management teams must work together to make the integration of research data management in a RIMS successful (Fina & Proven, 2017).

Our earlier study of researchers' uses of RIMSs found that most researchers used RIMSs to find and access authored content and evaluate that content and the researchers. Fewer used RIMSs to share their research or identify potential collaborators and experts (Stvilia et al., 2018b). In addition, the use of RIMSs varied by researcher seniority and discipline. Assistant professors and postdocs used RIMSs to share their research content more often than did full professors and students. Different disciplines also have different models of scholarly communication and evaluation (e.g., book based vs. article based; Wilsdon et al., 2015) that can affect their uses of RIM services. For instance, humanities scholars may rely on RIMSs for evaluating research and scholarship less than researchers from other disciplines (Stvilia et al., 2018b).

Different kinds of problems and barriers can arise on the path of RIM service provision and adoption. These may be related to, but not limited to, insufficient resources, researcher amotivations, and RI and service quality. Researchers may perceive RIM services as not being useful to their reputations and careers, too costly to use, or a poor match with the research and scholarly communication cultures of their disciplines (Melscheimer et al., 2017; Stvilia et al., 2018b). Researchers may also believe that their use of RIM services will be hindered by privacy concerns and the risks of misuse or misinterpretation of their data (Cragin et al., 2010; Gruzd et al., 2012). Researchers may dislike relinquishing control over their RI to the university, and fear that the university could misuse their RI and evaluate their research productivity and impact without taking into account differences in the scholarly communication cultures of different disciplines (Melscheimer et al., 2017). In general, the technology adoption literature suggests that the level of information system adoption may be affected by its perceived usefulness, cost of use, and effectiveness relative to alternatives (Venkatesh et al., 2003).

Another critical component of service design and implementation is identifying and acquiring the skills and competencies needed to provide that service. Little investigation of RIM-specific skills has been undertaken in the library and information science literature. Researchers, however, have examined the skills needed to curate research data. Although research data curation differs from RIM, with research universities taking a comprehensive approach to managing their faculty's scholarship, these two processes have begun to overlap. Research data sets and software are essential types of scholarship, and universities are interested in tracking and measuring their impact by using RIM services (Lyon, 2012). An earlier study of IRs at 13 large research universities in the United States identified 11 skills needed by research data curation staff (Lee & Stvilia, 2017). These skills included an understanding of data curation, the ability to handle the complexity and diversity of data, knowledge of research practices, collection management skills, software skills, technology skills, metadata skills, an understanding of disciplinary workflows, needs assessment skills, communication skills, and teamwork skills. Another study (Cox et al., 2019) surveyed 209 libraries around the world, including 23 libraries in the United States, and found the following areas of skill gaps: data curation skills; knowledge of a variety of research methods; data description and documentation; legal, policy, and advisory skills; technical and IT skills; an understanding of research integrity; knowledge of reproducibility and transparency principles; knowledge of the research life cycle; and subject or disciplinary knowledge. One recent study investigated data curators' skills by interviewing 26 librarians, including 5 librarians in the United States (Tammaro et al., 2019). The researchers identified four categories of skills: communication, data management, data description and documentation, and data publishing. The previous research provides useful insights into the skills needed to curate research data. However, a need still exists to

examine the skills necessary to identify, integrate, manage, and provide access to multiple types of RI from disparate systems in research universities' RIM ecosystems.

Design

The study design was guided by activity theory (Engeström, 1990; Leontiev, 1978). Research information management work at research universities can be conceptualized as networks of activity systems, their components, and the mediating factors of the activities' immediate contexts. These networks occur not only in libraries but also in other units of research universities. Hence, it is essential to examine emergent relationships between the RIM work in university libraries and other units, as well as how they shape the RIM ecosystems of research universities. The unit of analysis of this study was a RIM activity. An activity is the fundamental building block of work, and activity theory captures the basic structure of an activity system and the mechanisms of its transformation. The latter includes, but is not limited to, the mediating artifacts, the context, and the contradictions of the activity system. Consequently, the conceptual models of activity theory can help identify possible interventions to resolve the contradictions (Kaptelinin & Nardi, 2012; Kuutti, 1991). In this study, we used semistructured interviews to collect data. To recruit the study participants, we searched the web domains of universities categorized as Doctoral Universities with Highest Research Activity in the Carnegie Classification of Institutions of Higher Education for the use of RIMSs. In addition, we used our professional networks and a snowball sampling approach to identify potential participants. Before participants were interviewed, they were given a consent form approved by the Human Subjects Committee of Florida State University (FSU HSC Number 00000031). The form contained information about the project, including information about potential risks associated with participation in the data collection. Fifteen participants were interviewed in November and December 2019 by two authors using the Zoom teleconferencing software. The 14 participants who finished interviews were mailed an honorarium in the form of a $30 Amazon gift card. One additional participant finished the interview but declined to accept the honorarium. The average length of the interviews was 37 minutes. The content of the transcribed interview recordings was analyzed for both a priori themes defined by the research questions for the study and themes that emerged from the data. Next, we compared our individual lists of codes, aggregated them, and mapped them. To enhance the reliability of the content analysis, we used the coding schema that resulted from the first round of content analysis to recode two interviews (i.e., ~10% of the data). We discussed and resolved the code assignments on which we disagreed, updated the coding schema, and then recoded the complete data set.

Results and Discussion

RIM Services

Nine of the study participants were female and six were male, representing 15 universities. Fourteen participants had master's degrees and one had a doctoral degree. The disciplines in which they received their degrees ranged from library and information science, English, and sociology to chemistry, physics, and mathematics. Most of the participants were employed in university libraries. One RI manager worked for the Office of the Provost and the other for the Office of Research. Different universities used different RIMS software. Elsevier Pure and Symplectic Elements were the systems most frequently referenced by participants, followed by the VIVO web client. Participants also mentioned the use of Interfolio's Faculty180 and Academic Analytics. Two participants stated that they used homegrown RIMSs.

The first research question was designed to elicit the RIM services offered on the respondents' university campuses. Participants identified 21 different services (see Table 1). The most frequently chosen services were traditional services, such as finding, obtaining, archiving, and sharing authored content and maintaining research identity profiles. The least frequently identified services included finding mentors and evaluating researchers. In addition to selecting from

the predefined set of RIM services provided to them during the interviews, participants mentioned other RIM services available on their campuses. These included providing training in RIM, helping researchers obtain and integrate author identifiers, and examining researchers' output at other institutions for scouting and recruitment. One participant mentioned using their institutional RIMS to manage faculty services and to ensure the equity and diversity of faculty committee assignments. In addition to human users, RIMSs and IRs supply RI to other information systems, such as departmental websites and content management systems.

Table 1

RIM Services

Item	Answer	%	No.
1	Find papers	93.3	14
2	Obtain papers	80.0	12
3	Share authored content	80.0	12
4	Archive authored content	80.0	12
5	Add or modify information for one's own research identity profile	80.0	12
6	Provide information for other researchers' identity profiles (e.g., disambiguate identities, endorse for expertise, determine authorship)	73.3	11
7	Obtain or generate citations	66.7	10
8	Monitor specific researchers' projects and publications	60.0	9
9	Evaluate papers on impact (including a researcher's own papers)	60.0	9
10	Identify potential collaborators	53.3	8
11	Generate evaluation documents (e.g., a CV, annual evaluation report)	46.7	7
12	Identify experts	46.7	7
13	Answer questions	40.0	6
14	Monitor the literature in general	33.3	5
15	Identify mentors	26.7	4
16	Evaluate researchers	26.7	4
17	Ask questions	13.3	2
18	Other (Please specify)		
	Provide training in RIM	13.3	2
	Obtain and integrate researcher identifiers	6.7	1
	Scout and recruit researchers at other institutions	6.7	1
	Ensure the equity and diversity of faculty committee assignments	6.7	1

A comparison of the set of services identified in this study with the set of researchers' uses of RIMSs identified in an earlier related study (Stvilia et al., 2018b) showed that most (73%) of the RIMS uses reported by researchers in the previous study were supported by institutional RIMSs on university campuses, although there were some differences. Institutional RIMSs did not support finding external evaluators and reviewers, finding job opportunities, getting feedback on papers, recruiting students, and raising personal profiles in research communities. On the other hand, RI managers and librarians identified RIM services that were not included in the researchers' list of uses of RIMSs. These included providing training, obtaining and integrating researcher identifiers, scouting and recruiting researchers at other institutions, and ensuring the equity and diversity of faculty committee assignments.

An analysis of the differences between the two studies suggested that most of these differences may stem from differences in the scope of the RIMSs and the priorities of researchers and their institutions. Researchers are not limited to using university RIMSs and RIM services. They may use global RIMSs, such as Google Scholar or ResearchGate. Furthermore, many universities still do not manage the RI and authored content of their student researchers. In addition, the local scopes of institutional RIMSs may make those systems less suitable venues for some researchers seeking to achieve global recognition in their research communities and to complete research activities that involve researchers, information, or authored content from outside their institutions. Likewise, universities strive to have complete and

accurate records of their faculty's activities to support internal organizational workflows, report to external evaluators and accrediting bodies, and comply with state and federal laws. Researchers, however, might not perceive those activities as their priorities.

One of the most widely provided RIM services was the curation of research identity profiles. In this study, we asked participants to specify what types of information and metadata those profiles comprised. Not surprisingly, most of the participants stated that they collected metadata about publications, data sets, and awards, followed by expertise and creative activities. The least selected types were mentorship, equipment, and consulting. Participants also mentioned that faculty identity profiles included information about honors and fellowships received, offices held, community activities, news articles, and faculty course evaluations (see Table 2). We also asked about the types of scholarship and research content curated on campuses. Participants identified scholarly publications, preprints, data sets, software, audio, video, posters, gray literature, and other publication types.

A comparison of these findings with the findings of a prior study of research identity profiles in a global RIMS, ResearchGate, by Lee et al. (2020) showed that institutional RIMSs collect metadata for a broader set of researcher activities. Institutional RIMSs also have a broader coverage of scholarship types because they are expected to represent all departments on the campus, not just the departments that have article-based scholarly communication cultures. For example, metadata on creative and performance arts scholarships were found only in institutional RIMSs. Likewise, institutional RIM services captured information on mentorship and faculty course evaluations that represented the priority activities of teaching-focused faculty.

Table 2

Types of Information or Metadata Included in RIMS Profiles

Item	Answer	%	No.
1	Publication	93.3	14
2	Data set	73.3	11
3	Award or grant	73.3	11
4	Expertise	60.0	9
5	Creative and performance arts scholarship (e.g., painting, drawing, sketching, dance performance, writing [literature], filmmaking, and musical composition)	60.0	9
6	Patent	46.7	7
7	Software	46.7	7
8	Service	40.0	6
9	Course information	40.0	6
10	Mentorship	33.3	5
11	Equipment	33.3	5
12	Consulting	26.7	4
13	Other (Please specify)		
	Honors and fellowships	6.7	1
	Offices held and community activities	6.7	1
	News articles	6.7	1
	Faculty course evaluations	6.7	1

Problems

A research university's RIM ecosystem may comprise multiple activities that generate, maintain, and use RIM services, and multiple kinds of problems or contradictions may be associated with those activities. In general, activities are dynamic and evolve in time and space (Kaptelinin & Nardi, 2012). Activity theory conceptualizes changes in activity systems as a dynamic interaction of the contradictions present in the activities and the resolutions sought for those contradictions. In this section, we describe problems reported by the study participants and classify those problems by using the contradiction typology of activity theory. In particular, we used Engeström's four-level typology of activity system contradictions (Kaptelinin & Nardi, 2012) to understand the activity structure of problems found in the interview data and their relationships with potential solutions and intervention strategies.

First-Level Contradictions

Activity theory defines first-level contradictions as the problems inherent in individual components of an activity system. Our analysis identified first-level contradictions for three activity system components: tools, objects, and actions (see Figure 1).

Having too many RIMSs available on campus could hamper researchers' engagement in RIM. This scenario could increase both the cost of decision making regarding what RIMS to adopt and the cost of learning and using the software. Multiple factors could lead to the proliferation of RIMSs on campus. Different departments on campus might have different types of faculty with diverse research, teaching, and service assignments, as well as different types of research project components (e.g., equipment), life cycles, outcomes, collaboration, and scholarly communication patterns. Consequently, they might have different RIM needs, activities, norms, and policies, and therefore different needs for RIMS functionalities. They might have different RIM cultures. Likewise, different RIMS software might have different strengths and different sets of features that were tailored to the workflows of a specific type of university unit (e.g., the office of research, the office of faculty development, libraries). One type of RIMS software might focus on supporting faculty's annual evaluation and tenure and promotion workflows, whereas another type of software might provide more robust support for publication tracking and ingesting publication metadata.

In addition to local, institutional RIM services, researchers' attention and time could be sought by external RIMSs with global, statewide, and regional scopes (e.g., ResearchGate, Google Scholar). This could lead researchers to face a challenging decision-making problem. They might need to identify the most optimal way of managing their research information and reputation in the face of this abundance of RIM services and requests for their attention and time. With this multiplicity of RIMSs, the added value of participation in one additional RIMS might become smaller. At the same time, the amount of resources (i.e., time) the researcher was left with to maintain one extra RIMS profile could become scarcer and therefore more expensive. An increase in the choice of RIMSs might also increase a researcher's anxiety (Schwartz, 2004). Some researchers might opt not to have any RIMS presence instead of having incomplete or outdated profiles spread across the web:

> "They would rather maintain none of them than [be] forced to choose which ones or try maintaining all of them." (S2)

A straightforward resolution to this contradiction identified by the study participants would be to provide a single, centralized interface to the RIM services that hid the differences and complexities of working with multiple individual systems. The interface could use author or researcher identifiers to integrate and reuse RI from different RIMS and publisher databases (Dvořák et al., 2019; Klausen et al., 2017). Research information managers could map researchers' campus IDs to external IDs, such as ORCID. However, different publishers and aggregators might use different identifier systems. Hence, this approach would require aggregating researchers' identifiers and resolving them with researchers' actual identities, necessitating their contribution.

Another first-level contradiction was associated with not knowing the optimal division of labor for a particular RIM activity. For any collaborative activity to be successful, the division of labor of the activity must align with the competencies and motivations of its subjects or participants. Finding the right balance between the researcher's contribution to the RIM work and the RI manager's mediation of it could be challenging:

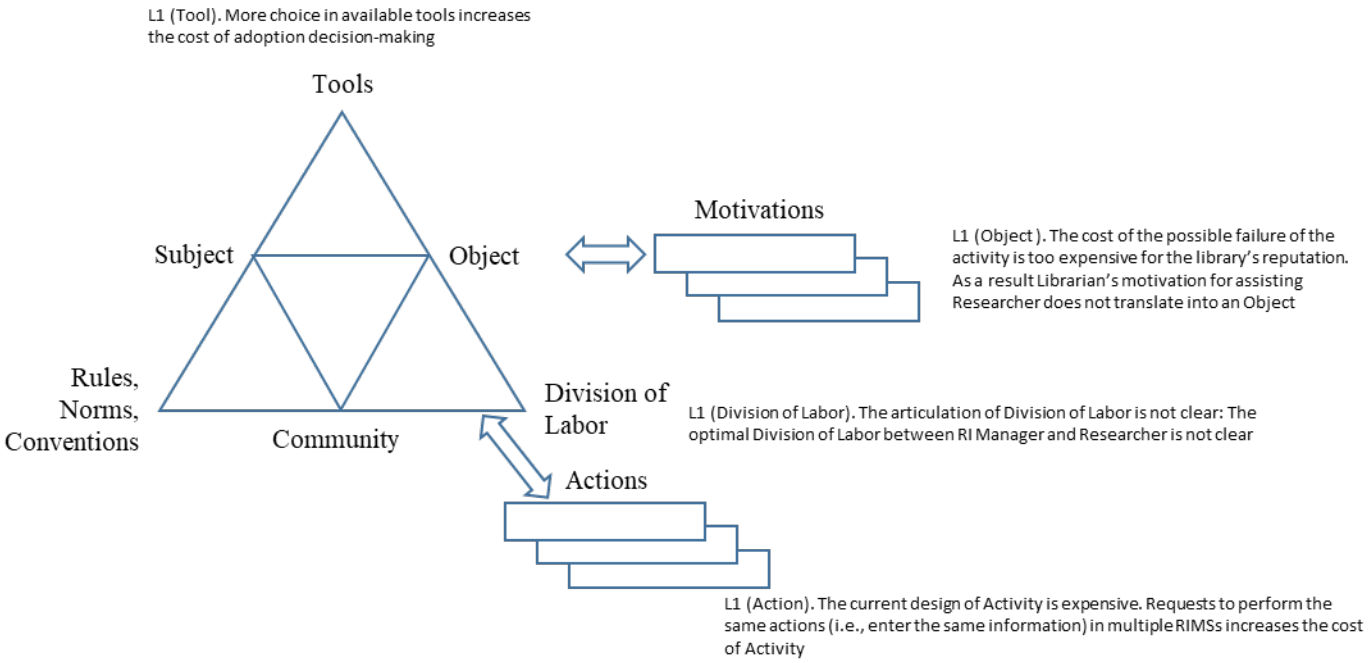
> "And then figuring out the right balance of what the library can do versus what the researcher can do . . . That's definitely a challenge." (S11)

Furthermore, researchers' characteristics might change over time. The literature shows that research seniority and discipline can serve as proxy indicators of researchers' willingness to participate in RIMSs (Stvilia et al., 2018b). Hence, RI managers and librarians might use researchers' career trajectories to predict changes in their motivations for RIM and align the division of labor for RIM activities accordingly. In addition, having RIM activity workflows with a less rigid design and allowing more flexibility in how the work was divided (e.g., allowing researchers to maintain and customize their profiles in RIMS) could provide space for a more dynamic, self-organized division of labor. Researchers would be able to choose the RIM tasks that matched their motivations, priorities, and skills. Communicating effectively with researchers about the library's RIM expertise and services and how RI managers could help, identifying what unique knowledge and contribution only the researcher could make to a particular RIM activity and why (i.e., what the researcher's motivations would be for contributing to the RIM), and finally designing a RIM workflow that was grounded in that knowledge could mitigate this problem.

The last first-level contradiction found in the study was associated with tension among motivations that shaped the object of a RIM activity. In particular, one participant spoke about the danger of not being able to complete a RIM service or project promised to a user. The object of an activity is shaped by the interplay among multiple motivations (Kaptelinin, 2005). Furthermore, to achieve the object of the activity, the subject(s) should be able to complete the actions for that activity by using the available tools. When determining the scope of a RIM project, RIM managers could be affected by the conflicting motivations of being helpful to researchers and safeguarding the reputation of their department or library from the potential failure of a project. With the continually evolving RIM needs of researchers and mandates handed down from federal and state agencies, determining the optimal scope of their services was a continuous balancing act for RIM managers and librarians. Regularly assessing stakeholders' RIM needs and the staff and technology requirements to meet those needs could help RIM managers design services that were not only aligned with those needs but also scoped to the levels of the existing resources to minimize the odds of service failures.

Figure 1

First-Level Contradictions



Second-Level Contradictions

Second level contradictions are problems or tensions between the components of an activity system. We identified the highest number of second-level contradictions as being associated with the subject and tools of an activity (see Figure 2).

For some newly hired researchers, the RIM services at their current institutions could be less effective than the ones they had used at their previous institutions (see Figure 2). This, in turn, might negatively affect their willingness to adopt and use the RIM services at their current institutions. Even if an institution was not immediately able to offer the level of RIM services researchers were accustomed to at their previous institutions, by identifying and working with those researchers, the RI manager could recognize problems in their current RIM services and mobilize political support to address those problems and improve the services.

To cooperate with RI managers and librarians and participate in curating their RI, researchers needed to be sufficiently motivated. Our analysis identified several second-level contradictions representing tensions between a researcher's motivation and other components of the activity, such as the division of labor and actions. At present, no index databases similar to Scopus are available for research data sets and software. Hence, RI managers could not automatically harvest data set and software metadata. Data sets and software need proper documentation to enable their discovery and reuse and to evaluate their impact. In addition, unless a particular publication was published with an open access license, the IR might need the author's cooperation to provide the most advanced version of the publication permissible by the publisher. Often, even a small cost, such as filling out an online submission form, could be a barrier to that cooperation. One participant revealed that, on average, only 10% of the researchers they had contacted cooperated with the request:

> "I had a conversation with faculty where they were very excited about the repository and really want to deposit, but they just don't have the time to sit down and fill out the form." (S10)

Universities could offer researchers fully mediated RIM services in which the researchers would not be asked for and would not be expected to contribute to the management of their RI. However, as discussed above, these fully mediated RIM services are not error free and might still require researchers' participation to identify and address errors. In addition, a mediated model of a RIM activity might conflict with the researchers' intrinsic motivations, such as self-efficacy or receiving instant gratification. Some researchers might want to be involved in curating their research and scholarly record to ensure that those records represent their scholarly activities accurately and completely. If researchers could not achieve instant gratification by being able to make changes to their RI and having those changes rendered immediately in the RIMS, they might be disincentivized from engaging in the RIMS (Stvilia et al., 2008, 2018a). To mitigate this problem, some universities might offer an "opting out" mechanism for faculty who want to manage their RI themselves. Others might try to find a middle ground and provide partially mediated RIM services. For instance, one participant revealed that they set up initial RIMS profiles for faculty, integrated those with scholarship activity tracking and awareness services by using ORCID identifiers and index databases, and then handed the profiles over to faculty or their proxies in the department for further maintenance.

To integrate multiple RI and data streams from multiple sources, as well as different RIM services offered on campus, RI managers and librarians often used author or research identifiers. If a researcher did not have an author ID for a particular publication index database, RI managers could claim one for the researcher. They might need the researcher's permission for and engagement in disambiguating and integrating those identifiers. Researchers' cooperation, however, might be determined by the interaction between different motivations and amotivations (Kaptelinin, 2005; Stvilia et al., 2018b). Some of those amotivations might be researchers' concerns about the privacy and cost of maintaining their research identity information (Gruzd et al., 2012; Melscheimer et al., 2017; Stvilia et al., 2018b). Researchers' motivations and amotivations, along with the rest of the activity structure, are dynamic and can change over time as researchers' careers evolve (Stvilia et al., 2018a). Hence, it is essential that RI managers consider the dynamics of those relationships and craft their interventions accordingly. In particular, they could craft their emails to researchers in a way that enhanced the researchers' motivations and decreased their amotivations to participate in RIM (Stvilia et al., 2019):

> "We have a little bulleted list about the benefits for researchers of making their work available. So we are talking about a global reach and impact. We are talking about preservation, we talk about citation counts. Yeah. Those are the three main ones that we emphasize." (S13)

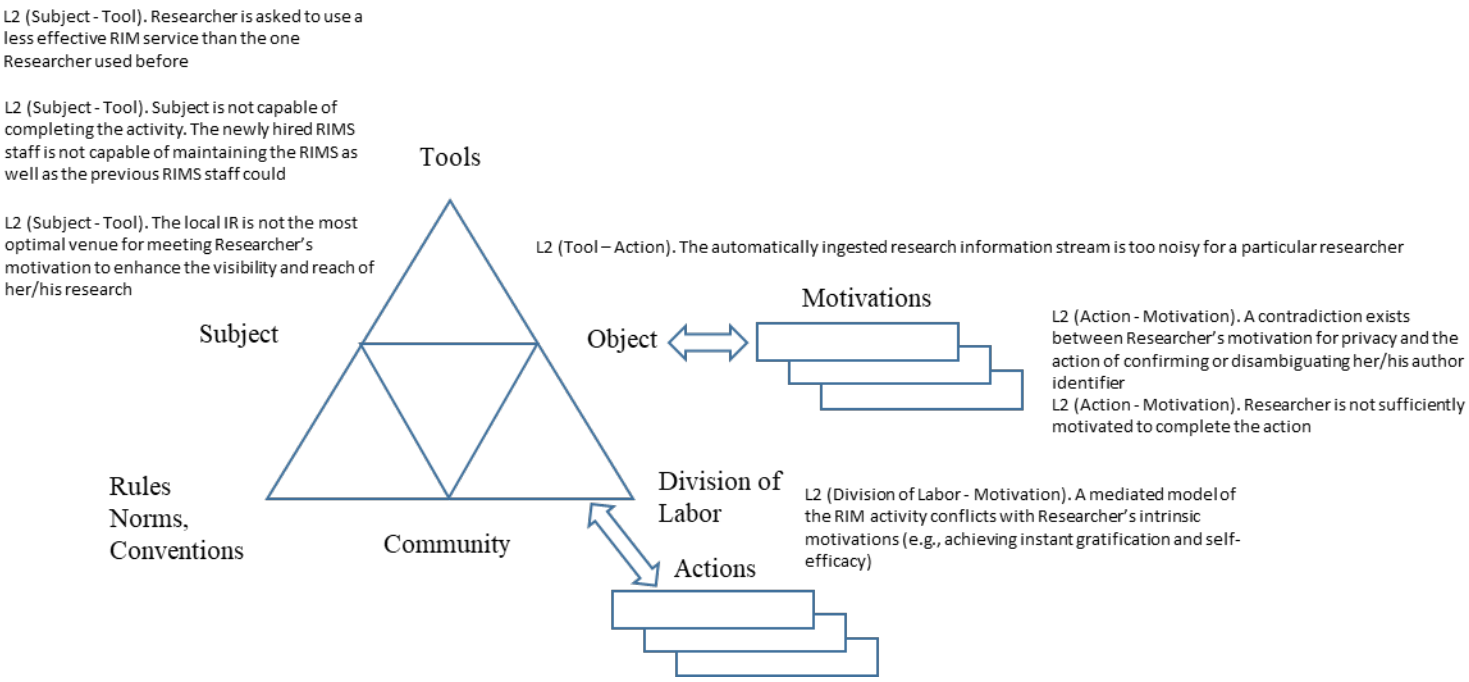
Participants indicated that they found personalized emails to be more effective. In addition, prior outreach and the faculty member's recognition of the RI manager's name made the intervention email more successful:

> "I think people often will respond to those [personalized] emails. And it'll be people that I've met with them before, I've guest lectured in their class. And they'll be like, "Hi X. Is this what you're looking for?" So I think that helps with our response rate." (S5)

Another strategy participants used to resolve the motivation-related contradictions was to make RIMS use a part of required institutional workflows, thus making researchers' participation in the curation of their RI required de facto. Finally, providing complete life cycle support for RI and data could help engage researchers early with the institution's RIM services and educate them about the importance of managing and providing access to RI. It could help tip the structure of researchers' motivations and amotivations in favor of contributing to the RIM. Researchers could internalize the importance of providing access to their RI and engage in its curation without mandates or other extrinsic incentives (Ryan & Deci, 2000).

Figure 2

Second-Level Contradictions



Third- and Fourth-Level Contradictions

Third-level contradictions are problems or tensions between the current form of an activity system and a new, desired form of that activity system with a revised and/or more advanced object and outcome. Fourth-level contradictions are problems between activity systems that contribute to the generation of a joint outcome (Foot, 2014; Kaptelinin & Nardi, 2012). The two third-level contradictions identified in the study were linked to a conflict between the existing culturally established norms, divisions of labor, role expectations of a research process, and RIM and the new forms of those activities that libraries or universities promoted (see Figure 3).

Data are an essential research output (Tenopir et al., 2020). To collect and manage RI for data, however, the data first need to be curated and shared. Although mechanisms are available for tracking the use and impact of research data (e.g., datacite.org; data papers of Newman & Corke, 2009), curating and sharing data might not be the norm of a particular discipline's research culture. In many disciplines, no culturally approved or widely used processes are available for researchers to receive credit for sharing data sets generated by their research projects. The curation of research data and software and managing the related RI not only adds to the cost of the research process, but could also require a behavioral change on the part of researchers, as noted by one of the participants, by having researchers include these tasks as a part of their research project planning.

Furthermore, researchers might not perceive librarians or RI managers as potential contributors to a research process or RIM beyond their current culturally stereotypical roles, such as curators of books and other traditional library items. This prevents librarians and RIM managers from playing more active, visible roles in research projects and RIM, including assisting researchers with curating their data and RI. As one librarian participant observed, providing successful outreach and dissolving those stereotypes remained the biggest challenges:

> "I think that it's kind of cultural or a way that people understand the library. I feel like more broadly we have to really be able to convince researchers that the library can help them with research data and research software and we have a set of services that'll really make their lives easier." (S11)

This type of problem could be mitigated by using the same strategies discussed above. Research information managers might strive to interact with researchers as early and often as possible and better align data curation and RIM with the life cycles of their research projects, educate researchers about the benefits of data curation and RIM, and introduce them to related services and resources available on campus. These could counterbalance some of the perceived costs of managing RI for data and the resistance to that behavioral or cultural change. In particular, these could help researchers enculturate data curation and the RIM objectives, perceive RI managers and librarians as potential collaborators in achieving those objectives, and become engaged in those activities with fewer mandates or other extrinsic motivations (Ryan & Deci, 2000).

Participants indicated that they targeted interventions at some of the most active and malleable user groups on campus: postdocs and graduate students. Often faculty themselves might not participate in the library's programming events but instead would send their graduate students and postdocs to learn RIM skills. Frequently, they were the ones responsible for day-to-day RI and data management for the faculty member's laboratories and research projects. Graduate students and postdocs could serve as useful "word of mouth" conduits and help librarians and RI managers promote their RIM services. Stvilia et al. (2019) showed that postdocs, assistant professors, and graduate students could be more intrinsically motivated to participate in RIMSs than senior faculty. The participants in this study revealed that in their outreach efforts, they also targeted influential members of the faculty, such as members of national academies, as early adopters, who then used their influence to bring others on board.

Another third-level contradiction was associated with a new personalized form of a RIM activity that was more expensive than the existing one, which was preventing its adoption. Although this problem was due to a lack of resources, it pointed to a long-standing problem that library and university information systems face. These systems were compared with their commercial alternatives, such as Google Scholar and ResearchGate, which have more resources and can therefore provide more personalized and user-friendly RIM services. One approach that libraries have taken to mitigate this problem is to integrate those global commercial RIMSs into local information systems, whether it is a library catalog, RIMS, or IR. This approach could provide researchers with a one-stop location for their RIM needs.

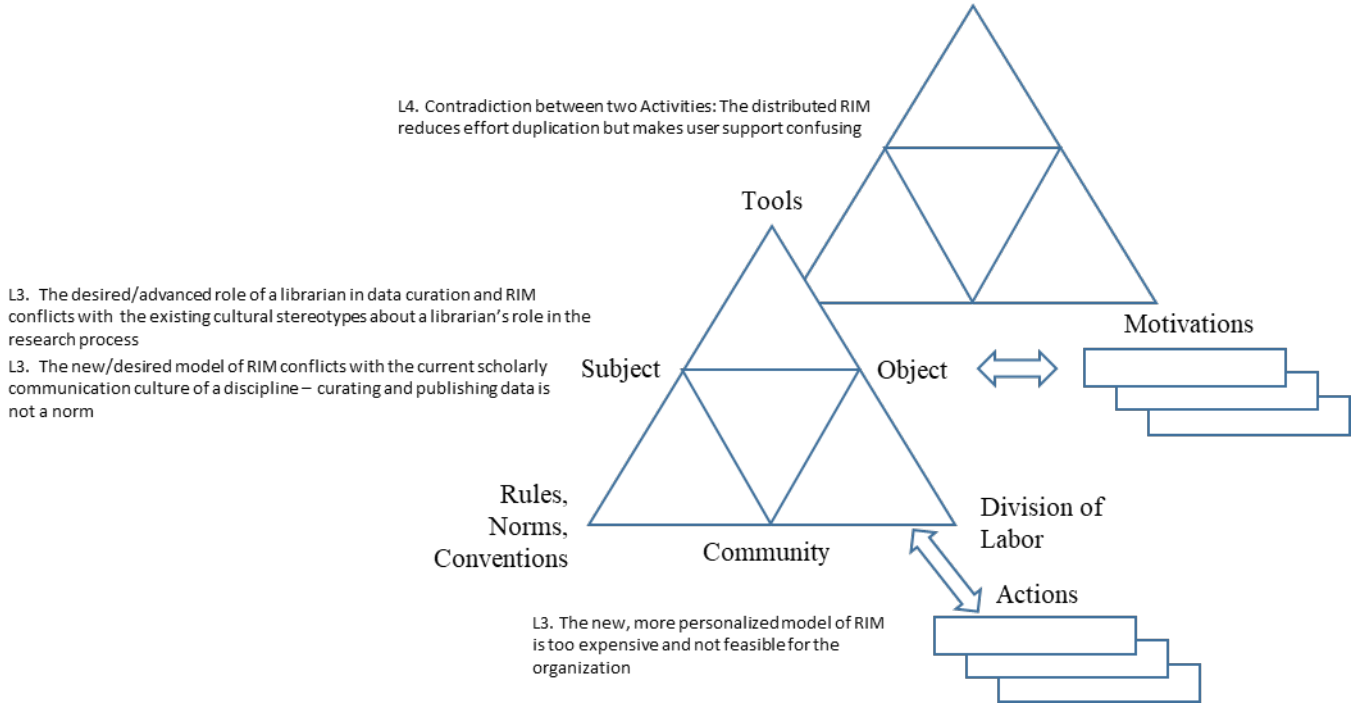
In this study, we also identified one fourth-level contradiction. A distributed, integrated model of RIM might reduce effort duplication in RI collection and sharing but could make it difficult for researchers to identify and obtain user support. If the integration of RI on campus is seamless and functioning well, the distributed nature of the RIM infrastructure, work, and access to RI might be invisible (Star & Ruhleder, 1996; Star & Strauss, 1999). As a consequence, some users could develop inaccurate mental models for those components of the RIM. Specifically, when a distributed model for providing mediated RIM services is available, different units, people, and systems could be responsible for providing and maintaining different kinds of RI. That capability could be hidden to the user. Furthermore, a RIMS might not control how its information and content are used by other systems on campus, such as departmental websites. Hence, it could be confusing and difficult for researchers to identify who to contact if they needed help with updating their RI or inquiring how their RI had been used.

A distributed RIM infrastructure implies distributed labor, and the complexity of RIM workflows must be matched with the complexity of user support (Ashby, 1962). One of the participants described a distributed user support model his institution had implemented to support RIM service adoption and use. The model consisted of multiple roles, such as data administrators who did proxy data entry for the faculty and liaisons who helped the faculty establish their

RIMS profiles and bring them to the level at which the faculty could maintain and manage their profiles independently. Additional layers of support were available, including librarians, a university-level RIMS implementation and coordination group, and a vendor-operated help desk. It is vital that the articulation of the distributed user support work be clear and communicated to researchers so they know who to approach when they need assistance with a particular RIM task.

Figure 3

Third- and Fourth-Level Contradictions



Skills

To meet the challenges related to RIM service provision and adoption discussed in the previous section, RI managers and librarians need to have the relevant skills and competencies. Participants identified several skills and types of knowledge they considered important in their work.

Needs Assessment, Design, and Communication Skills

The study participants emphasized the importance of user needs assessment and requirements identification skills. Research information managers and librarians should be able to identify stakeholder groups for RIM services, their tasks, and their needs and motivations for using those services:

> "You're working with these data providers on campus, the organizational groups, and a lot of it is trying to understand what are their needs, what are their wants from both the system, but also other players in the space. Both internal and external, and trying to find solutions that will be amiable to all involved. So a lot of it is also that, help me help you." (S4)

In addition to the ability to identify users' needs and the functional requirements for RIM services, RI managers

should also have design skills. They should be able to convert user research findings into RIMS design solutions that are useful and usable:

> "Our faculty don't have a lot of patience for systems that are not well designed. . . . They want things to be right, they want things to be good. And that's how we should design all our systems in my opinion." (S9)

Communication skills are critical for successful outreach. Research information managers should be able to communicate effectively with the stakeholders. Strong interpersonal and communication skills and patience are essential for working on teams, working with user groups, identifying their needs, and facilitating RIM service adoption:

> "There's definitely some so-called soft skills that are really required. In that you have to have a thick skin and to be able to communicate effectively and positively with a wide variety of stakeholders because you're going to be talking up and down the entire university ecosystem. You may find yourself presenting in front of the University Senate or talking to provosts or deans, and you may find yourself talking to graduate students, undergraduates, and kind of trying to adjust your message for these different stakeholders; it's really important." (S3)

One participant stated that RI managers had to have a "sales mentality" and persuasion skills and have to be able to connect effectively to the different contexts and motivations of their user groups. Another participant in an administrative position noted that RI managers should be able to be extroverted at work to serve their users successfully.

Knowledge of the RIM Ecosystem and Domain-Specific Research and Scholarly Communication Cultures

To identify the needs and functional requirements for RIM services successfully, RI managers ought to have a good understanding of the RIM ecosystem, including the infrastructure and RI streams available locally on campus and externally from various publishers as well as state and federal agencies. They need to know who owns a particular RI stream, how it is used, and what technologies are used to manage it:

> "Competencies, and just knowledge, and [an] understanding of the complexity of these things, that the data comes from different sources, [are important]. You have to understand those venues or those mechanisms. Understanding how does Scopus work to get Scopus IDs. Understanding all these different disparate systems, our services, and how they play into the system. And they also, I think, have to be good at seeing the bigger picture. Especially when you start talking about campus data sources, you never know how good, or bad, your institutional data is structured until you try to put it in something else." (S4)

In addition to their knowledge of the campus RIM ecosystem in general, participants reflected on the importance of being familiar with domain-specific research and scholarly communication processes, as well as the models of intellectual property rights management. The knowledge of domain-specific promotion and tenure, reputation management processes, and related evaluation models and metrics was also identified as necessary. According to participants, RI managers and librarians need to be familiar with various metrics of scholarly productivity and impact to help faculty manage their scholarly and research reputations. These might include a good understanding of both traditional and alternative metrics of scholarly communication and research activities.

Technical and Quality Assurance Skills

Some RI managers' immediate job responsibilities might consist mostly of administrative tasks and outreach and might not include the development and upkeep of the technical side of a RIMS. Still, they might need to have a basic knowledge of the technical side of RIM workflows. That knowledge could help them communicate effectively about stakeholders' needs and design recommendations with their system developers.

In addition, participants noted that RI managers and librarians, who were involved in the day-to-day management

of a RIMS, data entry, and aggregation, would benefit from the knowledge of API (application programming interface) programming and Python coding. They could use those skills to automate information harvesting and ingestion in the RIMS, as well as access to and analysis of that information. Some participants also noted that the knowledge of markup languages, relational databases, SQL (structured query language), and visualization software and the ability to write data transformation and processing scripts was helpful.

Another related skill participants mentioned as useful was the knowledge of and experience with working with open source RIM software. Many RIMSs and IRs use open source platforms, such as VIVO and DSpace. Knowledge of these platforms and other types of open source RIM software could enable RIM managers to develop and maintain homegrown RIM services.

Quality management is an essential component of any management process, whether in industrial manufacturing or higher education. Information quality problems are ubiquitous, and quality assurance is not free. Participants noted that the ability to work with imperfect information, design and deploy quality assurance mechanisms, and determine what was sufficient and sustainable information quality for a particular RIM activity were important competencies. In addition, participants commented that RI managers had to be able to listen to the stakeholders and be understanding of their frustrations with quality problems the RIM services might have.

Being a Self-Starter and an Innovator; Staying Proactive

One participant contended that RI managers had to be innovative and self-starters to be successful in their work. They often had to invent with little or no guidance from RIM data workflows and solutions:

> "What's the word for this? Entrepreneurial spirit or attitude? Being a self-starter because, in a lot of cases, it's new territory. . . . And it is quite often the case I think for RIM librarians that no one else at their institution really knows much about RIMS. . . . You're just entrusted to figure it out. And you don't get a whole lot of direction on how exactly to do that in a lot of cases. So having that entrepreneurial spirit and being able to strike out on your own and break new ground and try new things I think is really important as well." (S13)

Participants also noted that RI managers needed to stay on top of the RIM conversations to enhance the reputation of and goodwill toward their services and themselves on campus. They had to stay informed about new RIM technologies, proactively seeking opportunities to assist people with their RIM needs, build bridges between RIM services and user groups, and make themselves useful.

Comparison with the Skills of Data Curators

In this study, we categorized the identified skills into four categories: user skills, technical skills, domain knowledge, and innovation skills. The user skills category comprised user requirements identification and design skills, communication skills, and persuasion skills. The technical skills category included familiarity with the technical aspects of RIM workflows, data manipulation and coding skills, and quality assurance skills. The domain knowledge category covered knowledge of the RIM ecosystem on campus and knowledge of domain-specific research and scholarly communication cultures. The innovation category included innovation skills and the ability to stay proactive and make oneself useful for RIM-related projects on campus (see Table 3).

To the best of our knowledge, no prior study has focused on RI managers' skills. Hence, we compared the skills of RI managers and librarians identified in this study with the set of skills needed for closely related work. In particular, we compared the findings of this study with the skills needed by research data curation staff reported in two prior studies (Lee & Stvilia, 2017; Tammaro et al., 2019). The comparison revealed some differences and some similarities (see Table

3). The user skills category could be mapped onto the interpersonal and communication skills categories of the prior studies. Similarly, all three studies identified technical skills as important. The knowledge of domain-specific research and scholarly communication cultures in the domain knowledge category comprised the metadata skills identified by Lee and Stvilia (2017). Likewise, we made a connection between the data manipulation and quality assurance skills identified in this study and the ability to handle data complexity and diversity from the 2017 study, although there were some differences.

Research information management is more distributed than research data curation on university campuses. As research information and data are collected, curated, and shared by different units on campus, not just by libraries, RIMS managers and librarians are expected to be knowledgeable of that broader institutional RIM ecosystem. The list of skills identified in the present study also includes knowledge of the promotion and tenure evaluation processes and the research impact evaluation metrics and platforms. As expected, these competencies were not reported in prior studies. Furthermore, the skills of being a self-starter and an innovator and the ability to stay proactive and useful did not have matches in the studies by Lee and Stvilia (2017) and Tammaro et al. (2019). New technologies offer new opportunities for large-scale automated identification, collection, aggregation, and analysis of researcher activity information from different sources. Innovation skills become critical for recognizing and using those opportunities to ideate and implement new, innovative RIM services for different stakeholder groups on university campuses. On the other hand, the study by Tammaro et al. (2019) included teaching skills, which were not emphasized by the participants of the present study.

This comparison of RIM managers and data curators' skills points to the close and complementary relationship between RIM and data curation activities. It echoes the prior calls to apply a comprehensive, aggregated approach to curating and showcasing faculty scholarship and tracking its impact (Jetten et al., 2019; Lyon, 2012). The comparison of skill sets also indicates that academic libraries may be better prepared to serve as the focal points of such efforts than any other units on university campuses.

Table 3

Comparison of the Skills of Institutional RIMS Managers with the Skills of Research Data Curators

Institutional RIMS managers' and librarians' skills	Research data curators' skills (Lee & Stvilia, 2017)	Research data curators' skills (Tammaro et al., 2019)
User skills (soft skills) • Needs assessment and design skills • Communication skills • Collaboration skills • Persuasion skills	Interpersonal skills • Ability to communicate and collaborate • Needs assessment skills	Communication skills • Ability to work effectively with scholars with different needs and levels of experience • *Teaching and presentation skills* • Ability to design and deliver effective presentations • Ability to prepare learning and informational materials • Communication and interpersonal skills • Ability to develop collaborative relationships • Ability to establish trust with the researchers in a changing field
Technical and quality assurance skills • Familiarity with the technical side of RIMSs • Data manipulation skills • Quality assurance skills • Ability to work with imperfect data • Metadata skills	Technical skills • Software and technology skills	Data management skills • Data formats and file-naming conventions • Data cleaning and verification • Data conversion
Domain knowledge • Knowledge of RIM ecosystems on campus • Knowledge of domain-specific research and publication life cycles • *Knowledge of promotion and tenure evaluation processes* • *Knowledge of research impact evaluation metrics and platforms* • Knowledge of copyright policies	Metadata skills • Knowledge of data curation life cycles (e.g., documentation, preservation) and research practices • Knowledge of the subject area, including its metadata schemes or vocabularies and collection management	Data description and documentation • Metadata creation using standardized schemas and vocabularies • Data linking
Innovation skills • *Be self-starters and innovators* • *Be proactive and make oneself useful to RIM projects on campus*	Interpretative skills • Ability to handle data complexity and diversity	Data deposit and publishing • Ingest into repository systems • Assign identifiers • Data citation • *Data anonymization* • *Data security*

Conclusion

In this study, we examined RIM ecosystems on research university campuses from the perspectives of RI managers and librarians. Participants identified 21 RIM services offered to researchers. The most frequently identified services included discovering, storing, and sharing authored content and maintaining research identity profiles. The less frequently offered services were the uses of RIMS for recruiting faculty and ensuring the equity and diversity of committee assignments. We also identified 15 types of RIM service provision and adoption problems, strategies for resolving those problems, and the skills RI managers and librarians needed in their RIM work. The problem types were classified into four categories according to the typology of activity system contradictions in activity theory. The categorization of activity problems helped provide a better understanding of the structure and contexts of those problems and helped connect them with potential solutions. The results of this research can inform RIM practitioners about how to predict and resolve similar problems in their work. Furthermore, the findings of this study can inform the development of best practice guides for RIM on university campuses. They also advance the state of the art of RIM research by applying the typology of contradictions from activity theory to categorize the problems of RIM service provision and adoption and connect their resolution to theories in the literature and the findings of prior studies. In this way, these results expand the theoretical base used to study RIM in general and RIM at research universities in particular. Finally, the findings of this research inform LIS education and professional development programs for academic librarians in the areas of research information and data management.

The research has limitations. It represents only providers' (i.e., RI managers' and librarians') perspectives on RIM service provision and adoption. Furthermore, the small size of the study sample and its qualitative nature limit the generalizability of the study findings. Finally, the study represents the context of RIM at research intensive universities in the United States. Hence, its findings may not be directly applicable to RIM on university campuses in other parts of the world.

A future study investigating researchers' perspectives on the usefulness and usability of university RIM services and barriers to their adoption will complement the present study. In addition, a future related study will examine the use of research information and data by other stakeholder groups, such as startup incubators and innovation centers, to support the needs of student innovators and entrepreneurs. In particular, the future study will examine what RIM services are offered to those stakeholder groups and how the services are used.

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