

## Data Management: Knowledge and skills required in research, scientific and technical organisations

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### Abstract:

*The purpose of this paper is to investigate the knowledge and skill requirements for people working in the data management space in universities and scientific research organisations. In order to do so 25 data professionals in universities and scientific research organisations were interviewed. The most common set of skills required were interpersonal skills and related personal characteristics, closely followed by data specific knowledge and skills, including broad understanding of data types, metadata, and legal and regulatory frameworks. Contextual knowledge, knowledge of appropriate information technologies and training and advocacy skills were also highly sought after. Few current data professionals had a data specific qualification, most had learned “on the job” and through targeted professional development such as workshops, webinars and in house training. This paper presents information specific to data professionals in context and will enable educators understand the professional context and therefore to more effectively plan appropriate forms of delivery.*

**Keywords:** Education & training, knowledge and skill requirements for curriculum development; professional development requirements reported by data management professionals

### Introduction

The professionals required to work in data science, data librarianship and data management are a “new breed” for whom the knowledge and skills requirements are just emerging (Davenport & Patil, 2012; Provost & Fawcett, 2013). Organisations need data librarians and managers to enable better use, management, curation, and preservation of data and to explore data reuse, aggregation and sharing. This need is evident in universities and research organisations as well as in business and government organisations (AGIMO, 2013; Corral, Kennan, & Afzal, 2013).

It is suggested that academic institutions are designing courses to address this shortage without fully understanding what the knowledge and skills requirements in different types of organisations are for data librarians, scientists, analysts or managers (Provost & Fawcett

2013). The research to be reported in this paper investigates specifically what data managers and librarians, and their supervisors and employers, see as the key knowledge and skills for new professionals coming into data practice in universities and other scientific and research organisations.

There is an increasingly vast literature that addresses evolving data management roles and the education and skills required to work in data management (c.f. Bailey 2016 <http://digital-scholarship.org/rdc/rdc.htm> ). The literature is complicated by related considerations of the education and training needs of researchers in addition to that of those such as data librarians or data managers potentially involved in curating and/or managing data created by others (Carlson, Johnston, Westra, & Nichols, 2013; Friedlander & Adler, 2006; Henty, 2008; Lyon & Brenner, 2015; Molloy & Snow, 2012; Pryor & Donnelly, 2009; Swan & Brown, 2008; Wood et al., 2010). The literature is further complicated in that data roles themselves are not clear. While there have been many attempts to classify them there is no agreement. (Cox & Pinfield, 2014) suggest that when the Digital Curation Centre's Lifecycle model is addressed, data management seems more related to archival and records management than librarianship, although they do map existing library roles to required data competencies. Swan and Brown (2008) suggest four main roles: Data Creator, Data Scientist, Data Manager and Data Librarian, each with discrete roles to play in the data lifecycle. Lyon and colleagues (Lyon & Brenner, 2015; Lyon, Mattern, Acker, & Langmead, 2015) propose slightly different families of data science roles and suggest their possible organisational locations.

Lewis (2010) suggests that the focus of data roles for library staff lies in developing the data literacy/data management skills of both graduate research students and undergraduates. Others suggest the foci of data librarians should include (among other things) advocacy and the training of data creators in research data management (Lyon & Brenner, 2015), adding metadata to data, and preparing data for curation (Li, Xiaozhe, Wenming, & Weining, 2013). Participants in a 2012 survey recognised knowledge and skills gaps in university libraries in data curation, information and communication technology, subject and/or disciplinary knowledge, research methods and processes (Corrall et al., 2013). While they may currently be skills gaps, Witt (2012) suggests that much of this work will just become part of regular library practice whereas others note there may be a continuing need for a series of specialists (Kim, Addom, & Stanton, 2011), although there may be some overlapping roles (and correspondingly knowledge and skills) (Lyon et al., 2015). In terms of translating roles from their job advertisement analyses into curricular recommendations, Kim et al. (2011) propose a list of top ten recommended courses which include: data curation, database design and management, project management, essentials of scientific research, overview of cyberinfrastructure, geographically distributed collaboration, web management and design, scripting or introductory programming, data mining and information systems.

While it is relatively common in the United States (Harris-Pierce & Quan Liu, 2012) for iSchools and LIS schools to increasingly offer courses on data curation/data management, it is less common in Australia, where, although there are courses in data science, they generally focus on the business and technological aspects of data, rather than the information or data management and curation aspects of data which are possibly more appropriate for data librarians.

While there is recognition of a skills gap, there is also discussion in the literature about whether formal training as part of an LIS, IT or other professional qualification or learning on the job or through continuing professional development is most appropriate (Corrall et al.,

2013; Cox & Pinfield, 2014; Cox, Verbaan, & Sen, 2014). Working in an institution that is considering offering a course in data management, in addition to understanding the literature on the topic, the author sought to understand directly from professionals working in the roles, what they felt the knowledge and skill requirements for current and future data professionals are. To develop that understanding the following questions were asked:

1. Where, and in what roles, are data librarians, managers and scientists likely to be employed;
2. What knowledge and skills are required of people working in data librarianship and management roles; and,
3. What are the educational and training requirements for data librarians and data managers?

## **Method**

In 2015 36 practicing data professionals and their employers or supervisors in Australia were interviewed from universities, scientific government and business organisations. The interviewees were located in libraries, research offices, information and/or data management departments and information technology (IT) units. It was evident after the first few interviews that data work is often conducted by teams of differently qualified professionals particularly in the larger organisations, and this is reflected in the literature (Sands et al 2014). Accordingly in some cases group interviews were conducted and in others one person, such as the originally contacted data librarian, spoke about their own role and the roles of their team members.

As the research progressed it also became evident that the knowledge and skills reported as required in business and government organisations were quite different and more aligned with what has become known as data science than data librarianship or management, so for this paper only the interviews from 25 participants from the scientific research organisations (SROs) and universities (mainly libraries) (ULs) are reported (see italicised participants in Appendix 1). Selection was based on participant availability and continued until content saturation was achieved. Individual interviews were often conducted via Skype. All group interviews were conducted face-to-face. The study was approved by the Ethics Committee of Charles Sturt University. Participation in the study was voluntary and all participants had the study explained to them.

Interviews were semi-structured, audio-recorded and transcribed using a professional service. Two types of coding were employed: initial coding to establish categories followed by more focused coding, for analytical depth. Every effort is made to present the viewpoint of participants.

## **Findings**

### **Where, and in what roles, are data librarians and managers likely to be employed?**

Participants reported that they and their fellow data professionals worked in the libraries and other information departments such as information technology (IT) and information management and research offices of universities and scientific organisations. The employment pattern differs across organisations. There was a huge range of job titles for those working in data roles. While many reported roles had the word data in the title

somewhere (Data Librarian, Data Manager, Data Specialist), occasionally the role was titled something more general like Eresearch Librarian , Eresearch Manager, even Project Officer (for examples see Appendix 1, column 1). In most of the universities and larger scientific organisations participants reported that it was not just data librarians and other data specialists who need to understand data, but most library staff, whether they are subject liaison, outreach, research or other librarians:

It's part of our library plan I believe, so strictly speaking we are all supposed to take an interest ... (UL)

Others, both in universities and in scientific research organisations, talked about the importance of data literacy not just for librarians working with researchers, but with the researchers themselves:

I really wonder if it should be more about trying to embed better information and data management skills in the curricula of other professions ... shouldn't there be some kind of information management and data management compulsory training for anyone that's going on to do any kind of advanced research in a university environment.(UL)

Finally several respondents mentioned that there is no one size fits all:

... the data librarian in another environment might be a completely different role altogether. When I go out and talk to people doing a data librarian role they're not doing any of what I'm doing. (UL)

The next section will look at what people say data librarians are actually doing and the knowledge and skills required to do the work.

### **What knowledge and skills are required of people working in data librarianship and management roles?**

Interestingly almost all the respondents indicated that major set of skills they required, or that they were looking for in librarians and others in the data field, were more generic than field specific and these could be labelled interpersonal skills and behavioural characteristics

... looking more at attributes than at concrete knowledge or skills because I want people who are flexible ... (UL)

#### **Interpersonal skills and behavioural characteristics**

The most commonly mentioned interpersonal skills were high level communication (including writing of documentation, use-cases and other technical writing), advocacy, negotiation, and capability building skills. In terms of personal characteristics, participants reflected that people working in the data space need to be comfortable with change, have a service philosophy, willingness to learn, discretion, “boundless curiosity” and be adaptable, assertive, and open to new experiences. The ability to network and use networks to learn and keep up to date were also frequently mentioned. Several participants also mentioned the importance of being confident enough to “know what you don't know” (SRO) and when it is time to call someone with different knowledge or skills in.

## **Contextual knowledge**

Almost all participants, in one way or another, mentioned the importance of contextual knowledge about the research environment of the university or scientific organisation, and related funding agency policies, research measures and research evaluation activities. In addition to organisational context, the importance of understanding or being open to discipline specific research life cycles and cultures, processes, ethics, disciplinary research methods and scholarly communication mores (e.g. attribution, publishing preferences and citation), intellectual property and licencing laws and policies, access norms, and cultural sensitivities. Particularly the librarians and other staff in the scientific research organisations felt that domain scientific knowledge was either a prerequisite or something useful that should be learned on the job and several of the universities also mentioned that subject speciality in specific areas would be encouraged.

## **Data specific knowledge and skills**

The second most frequently mentioned requirement was knowledge, or willingness to learn, about knowledge, in the data domain and related data skills. This came through particularly in scientific organisations which emphasised the need to understand the variety of data from flat textual, to relational, numerical, instrument generated data, archival and cultural heritage data. Frequently mentioned was data that may be used in multiple contexts and therefore need to flow from one organisation or organisational unit to another or be active for long periods and/or constantly updated (for example meteorological, historical, oceanographic, geoscientific and other “really big data sets”). Several sites mentioned learning analytics and student data as research data and a couple mentioned physical data such as cassettes, other tapes, papers, photographs, bark paintings, “frozen fish bits”, images, and text as data that needed to be dealt with by their data librarians and other data staff.

In addition to understanding and learning how to manage different data types, also mentioned were a need for knowledge, and the related skills to facilitate data sharing, linked data, the data management lifecycle, data management processes such as quality control, data processing, data management planning, and an ability to understand and support data storage requests. Data professionals should also be aware of the legal and regulatory frameworks relevant to data and those specifically mentioned were ethics and consent, copyright and creative commons issues. In the ULs and SROs there was some mention of the need for data analysis knowledge, mainly as an emerging need in universities although in the SROs it was mentioned as a specialised need, particularly as a specialised role assisting scientists when data from two or more sources were to be merged and analysed. Data mining as a useful skill was only mentioned by one participant.

Interestingly only two UL’s specifically mentioned the phrase “data curation” as important, although more did mention the importance of understanding of the data lifecycle and individual aspects of data curation such as data archiving, provenance, the importance of data as ongoing records, digitisation of analogue data, and digital preservation. It is probably little mentioned because at the present time curation is “rare because of costs” (UL) and also because of costs respondents felt they “can’t make many assurances” (UL) about preservation although they “would like to do more”(UL). It seems that at the moment to focus is more on description and storage and the time for curation, including preservation is yet to emerge:

“the time for that hasn’t emerged” (UL)

“... curatorial leadership. It’s absent presently and it’s a real gap.”(SRO)

Almost every participant mentioned the importance of knowledge about, and skill in applying metadata using terms such as advanced metadata, metadata standards, metadata mapping, cataloguing, structured information, ontologies, and metadata harvesting. While specific (and different) metadata standards and schemas were mentioned in almost every interview and frequently, (for example Dublin Core, Darwin Core, RDF, DIF, ANZLIC , RIF-CS) most participants emphasised that knowledge about the purpose and use of metadata and a willingness to accept and learn the different standards and schemas applicable in different contexts was appropriate,

While one of the purposes of metadata is to provide access to the data or information described, knowledge and skills about enabling access in other ways were also frequently mentioned by participants. For example the importance of knowledge about “discovery (how people look for information)” was mentioned in both SROs and ULs, as was more technical access knowledge and skills such as knowledge about the user experience, web interfaces, and Graphical User Interfaces (GUIs). The dynamic nature of data was frequently mentioned in the access context so understanding of Digital Object Identifiers (DOIs), back up, version control and naming conventions were also listed as important.

### **Information technology**

Many issues related to access in are in the information technology (IT) realm, for example, web interfaces and GUI. Other important IT knowledge and skills were raised. Most participants however said that while IT skills were important, it was more important to have *just enough* of an understanding of IT, to be able to 1) bridge the perceived communication gap between IT departments and researchers, and 2) understand the IT options and make informed decisions rather than to be able to actually “do” IT. For example, one participant (Scientific Data Coordinator) had overseen the development of the data centre website in his organisation, but not actually done the website development. In the words of one participant IT knowledge and skills are “not strictly necessary, but it helps” (SRO). Specific useful IT knowledge and skills mentioned were XML, database structure and design, APIs, user centred design, natural language processing tools, sensor networks, and the internet of things. Programming was also frequently mentioned, but different languages in different contexts and, again, the importance of being “programming savvy” (SRO) was stressed rather than the requirement to be an actual programmer. Examples of useful programs though were mentioned and included Python (SRO, UL), SQL (SRO) Java (UL). Useful systems and tools for data professionals to be across included web services (SO); open journal systems (ULs); open formats (ULs), collaborative tools, visualisation tools, and analysis tools (ULs, and SROs). Less frequently mentioned were infrastructure, software development, machine coding, software coding, technical and use-case writing and database development and management skills.

The higher order IT management related knowledge and skills of information architecture and information governance were only raised by two SROs, and yet these were raised frequently by business and government organisations and will be addressed in a later paper. However other management knowledge and skills requirements were frequently mentioned especially project management, but also stakeholder and relationship management, and change management. One academic librarian specifically mentioned the need to understand and create policy. Mentioned by fewer participants, but still important were strategic planning, internal consulting, business analysis, and stakeholder requirements gathering.

## **Training and advocacy**

Related to communication skills, is the important work of data professionals, particularly in the ULs, but also in the larger SRO, to put together workshops and presentations around legal and regulatory frameworks, copyright and creative commons, service availability, policy (both organisational and external), processes (such as version control, back up, naming conventions), and storage, and to provide data literacy workshops to higher degree by research students and early career researchers.

## **Teamwork**

While participants generally were talking about knowledge and skills that might be useful to all data professionals in their organisations, most also recognised that not all these knowledge and skills might currently reside in the one person or role, particularly in the larger organisations. Instead teams of people provide data support and they may reside in the library, in IT, or another part of the organisation.

You tend to bring together teams of different specialists (SRO)

The teams might consist of metadata, data/information management, IT, analysis, storage, and other specialists who work as a data support team to bring their organisations a wide variety of data services.

## **What are the educational and training requirements for data librarians and data managers?**

With regard to the education and training of those currently working in a data professional role, or for whom data was a part of their role, most in the universities were librarians, some with prior qualifications in IT, and several had IT only backgrounds. These people had learned, largely “on the job” data specific knowledge and skills. In three of the SROs the data professionals had scientific backgrounds (PhDs, although one said that for data work a bachelors should be sufficient) and had learned their data and information management knowledge and skills also “on the job”. The most common ways of learning on the job were directly from colleagues, “learning by doing”, and through formal professional development such as webinars, conferences and workshops.

Well I think I’m a common example in the research data management space of a hybrid. We have hybrid professionals ... who ... bring absolutely everything together that you’ve acquired sometimes through education and sometimes through experience – sometimes by taking a leap of faith or watching other people do it. (SRO)

When asked to look towards the future and speculate about what might be the ideal educational and training requirements for data professionals, there was a wide range of responses. Most commonly mentioned were either “librarians with more”, where in some cases the “more” included data specific skills and in other cases IT education or training. Many of the respondents in the SROs felt it was still important for data professionals to have the relevant scientific qualification (usually a PhD) backed up with formal data education or training. It was also recognised that in some cases there was a need for formal external courses, for example, in project management, data analysis, XML and other IT, whereas there was also a place for internal training on internal systems, policies and procedures. While some participants felt that short or mini courses were “the way to go” others felt that either a

specialisation in an LIS masters or a graduate certificate open more broadly would be appropriate.

“Yeah, and so, I guess, you know, if I had to summarise all that in one sentence it’s, basically that a narrow focus on librarianship would prepare you less for this than a more generic kind of qualification that covered aspects of archives and knowledge management type stuff, as well, because it’s definitely bits from all of those that are really useful.” (UL)

## **Conclusion**

The interviewees worked mainly in libraries, data centres, and information technology departments. The importance of team work and knowledge and skill sharing was constantly emphasised. The reported roles had a range of titles and included knowledge and skills which Swan and Sheridan (2008) suggested fall within both the Data Manager and Data Librarian roles, and within all three more specialist roles (Data Librarian, Data Archivist and Data Steward) suggested by Lyon et al (2015), reflecting role ambiguity. This is perhaps because of the nature of the work in the organisations in which participants worked, although these previous authors also acknowledge overlap between roles. SROs were more likely to require scientific domain knowledge and qualifications, but all reported the importance of specialist data knowledge and of contextual knowledge about research and organisational environments as key. The emphasis of practicing professionals on interpersonal skills and behavioural characteristics is interesting from an educator’s point of view. While some attributes reported within the communications skills category such as technical writing can be taught and the importance of advocacy, negotiation and capability building can be emphasised and practiced, and indeed are part of many existing LIS programs (Lyon et al., 2015; Pryor & Donnelly, 2009), others such as willingness to learn, discretion, curiosity, and adaptability are more likely to reside in individual personalities although may be encouraged by education, and further enquiry is warranted to investigate how these attributes may be built into appropriate educational programs. The required knowledge and skills reported by the data professionals in this study generally reflect those reported in the literature, with a lesser emphasis on data curation, which is however, noted as a future requirement. This may reflect a difference in the organisational context in Australia, as Harris-Pierce & Liu (2012) noted data curation as a mainstay of data courses in the United States. Some data specific knowledge and skills reported here can be incorporated into existing LIS curricula and others will need new subjects to be written. Discussion on these aspects, and at what level, with what approach (e.g. continuing professional development or graduate courses), and to whom courses will be pitched will take place in future papers. In addition further work needs to be done to analyse data roles in business and government organisations, to find commonalities and differences.

## **Acknowledgements**

The author acknowledges with thanks the time and effort contributed to the study by the participants and Dr Jessie Lymn for her comments on the draft.

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## Appendix 1 - Interviewees (those in italics reported in this paper)

	<b>Role</b>	<b>Organisation</b>
1	<i>Data Specialist– research data management capacity building role</i>	<i>Eresearch Support Organisation (individual interview)</i>
2	<i>Scientific Data Coordinator</i>	<i>Scientific Research Organisation 1 (individual interview)</i>
3	<i>Project Officer</i>	<i>Scientific Research Organisation 2 (individual interview)</i>
4	<i>Head of Resources Division, Information Management team</i>	<i>Scientific Research Organisation 3 (group interview)</i>
5	<i>Researcher and Data Specialist</i>	<i>Scientific Research Organisation 3 and University (group interview)</i>
6	<i>Director Science Data Platforms ad Strategy</i>	<i>Scientific Research Organisation 3 (group interview)</i>
7	<i>Senior Data Strategist/Data Scientist</i>	<i>Scientific Research Organisation 3 (group interview)</i>
8	<i>Manager Information Services</i>	<i>Scientific Research Organisation 4 (group interview)</i>
9	<i>Data Librarian</i>	<i>Scientific Research Organisation 4 (group interview)</i>
10	<i>Data Librarian</i>	<i>Scientific Research Organisation 4 (group interview)</i>
11	<i>Information Specialist</i>	<i>Scientific Research Organisation 4 (group interview)</i>
12	<i>Director Digital Library Services</i>	<i>University Library 1 (individual interview)</i>
13	<i>Project Officer Library Repository Service</i>	<i>University Library 1 (group interview)</i>
14	<i>Technical Lead, Library Repository Service</i>	<i>University Library 1 (group interview)</i>
15	<i>Manager Data Quality</i>	<i>University Library 1 (group interview)</i>
16	<i>Library Repository Manager</i>	<i>University Library 1 (group interview)</i>
17	<i>Manager, Research Reporting</i>	<i>University Library 1 (group interview)</i>
18	<i>Manager, Content and Discovery (previously Data Librarian)</i>	<i>University Library 2 (individual interview)</i>
19	<i>Archivist</i>	<i>University Library 3 &amp; IT service (group interview)</i>
20	<i>eResearch Manager</i>	<i>University Library 3 &amp; IT service (group interview)</i>
21	<i>eResearch Analyst</i>	<i>University Library 3 &amp; IT service (group interview)</i>
22	<i>eResearch Contractor</i>	<i>University Library 3 &amp; IT service (group interview)</i>
23	<i>Information Service Librarian</i>	<i>University Library 3 &amp; IT service (group interview)</i>
24	<i>Data Librarian</i>	<i>University Library 3 &amp; IT service (individual interview)</i>
25	<i>Data Librarian</i>	<i>University Library 4 (previous role) and ANDS (current role)(Individual interview)</i>
26	<i>Data Architect</i>	<i>Bank 1 (individual interview)</i>
27	<i>Business Analysis Manager</i>	<i>Bank 1 (individual interview)</i>
28	<i>Workload Performance Engineer</i>	<i>Bank 2 (group interview)</i>
29	<i>Programmer</i>	<i>Bank 2 (group interview)</i>
30	<i>Principal Analyst</i>	<i>Utility company (individual interview)</i>
31	<i>Manager Digital Archives</i>	<i>State Records authority (individual interview)</i>
32	<i>Manager, Knowledge and Information management</i>	<i>Government authority (group interview)</i>
33	<i>Assistant Director General</i>	<i>National Archive (group interview)</i>
34	<i>Director, Information</i>	<i>Government Department (group interview)</i>
35	<i>Director Information Management</i>	<i>Government Department (group interview)</i>
36	<i>Big data statistical researcher, health sciences</i>	<i>University (individual interview)</i>