Role of bibliometrics in scholarly communication

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Abstract:
The aims of the paper are, firstly, to provide an overview of the major developments of bibliometrics. Secondly, the paper will discuss features of two of the major citation databases, Scopus (Elsevier) and Web of Science (Thomson Reuters). Both vendors are focussing their product development in the areas of visual representation of the relationships of the cited papers. Thirdly, the paper will illustrate the opportunities for academic librarians to engage with their academic communities.

Introduction

Citation analysis and content analysis are commonly used bibliometric methods. Tracking citations and understanding their trends in context is a key to evaluating the impact and influence of research. Increasingly university administrators are using bibliometrics in quantitative research assessment exercises to determine academic output. While some academics fear that such applications threaten practice based research, governments world wide, are considering bibliometrics as process for determining quality of research outputs and, on the basis of the assessment results, will allocate research funding to universities.

At the end of 2007, the new federal Labor government fulfilled its election promise to abolish the Research Quality Framework (RQF) and replaced it with Excellence in Research for Australia (ERA). The initiative differs from the RQF in that it is administered by the Australian Research Council (ARC) rather than a federal government department.

The new Minister for Industry, Innovation, Science and Research, Kim Carr, described the RQF as ‘flawed’ because it ‘lacked transparency and did not reflect world’s best practice’ (2008). The minister also observed that under ERA, ‘metrics will be used as a measure in disciplines where they enjoy established confidence’, such as the physical and biological sciences. According to Webster (2009, p.10) “ERA is the world’s first research assessment exercise to use metrics to evaluate and, in the future, fund research in Australia”. Other countries like the UK, Singapore and Hong Kong are considering an increased use of metrics for their research assessments.

The current wide range of bibliometric studies opens new ways of understanding the scholarly communication process and the structure of science through citation relationships between journals, between scholars and between papers. Bibliometrics has changed in the sense of expanding the number of data sources that can be drawn on. Currently *Scopus* and *Google Scholar* are international bibliometric databases challenging those of Thomson Reuters. Bibliometrics has also changed by expanding the range of tasks investigated. Citation analysis, in conjunction with visualisation, also helps scholars understand the structure of individual fields, and is useful for evaluating emerging and rapidly developing research areas.

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Secondly, the paper will discuss features of two of the major citation databases, *Scopus* (Elsevier) and *Web of Science* (Thomson Reuters). Both vendors are focussing their product development in the areas of visual representation of the relationships of the cited papers.

Thirdly, the paper will illustrate the opportunities for academic librarians to engage with their academic communities.

Overview of the major developments in bibliometrics

Mainstream bibliometrics has evolved rather than undergone revolutionary change in response to the web and web-related developments. The core citation-based impact measures are still in place, but are now supplemented by a range of complementary techniques, such as visualisation (Thelwall, 2008). For the past half-century, the impact factor has been the most prominent of these citation metrics as a measure of the impact that individual articles have on the research community. The impact factor was originally intended as an objective measure of the ranking of a journal (Garfield, 1996), but it is now being applied to measure the productivity of scientists. The Impact factor is essentially a measure of the average number of citations that a journal's articles receive over the two calendar years following publication. Now it is more commonly used across all articles published by a journal to provide a measure of a journal's impact on the research community rather than the impact of an individual article. Medical journal editors and publishers (for instance, *Journal of the American Medical Association* and *PLOS Medicine*) use the impact factor as a means of attracting prospective authors to submit their work to these journals.

Journal Citation Reports provides quantifiable statistical data that offer a systematic, objective way to evaluate the world's leading journals (Thomson Reuters, 2009). The way it is customarily used is to examine the impact factors of the journals in which a scientist's articles have been published. The impact factor can be one measure of productivity, but other measures, such as awards and memberships, commercial applications, supervision of research students and grant income are other tangible measures of research impact. Even carefully constructed bibliometric indicators, which are reasonably robust because of aggregation over the publications of entire departments, need to be combined with other sources of evidence (e.g. funding, sources of esteem, peer review, narrative) in order to give solid evidence for major decisions, such as those involving funding (Thelwall, 2008).

Over the years, many issues about the use of impact factors have surfaced. The numbers of citations to articles during the two years after publication varies considerably across different subject fields. Medicine and science have higher citation rates than arts and social sciences, such as history or education, where more citations go to books than journals. In computing and engineering, conference proceedings are cited rather than journal articles. Impact factors cannot be used to compare journals from different subject areas; what the impact factor indicates is the relative ranking of a particular title within a defined subject category. Original research and review articles are citable but editorials, letters, news items, and meeting abstracts are usually not included in article counts because they are not generally cited. Journals published in non-English languages or using non-Roman alphabets may be less accessible to researchers worldwide, which can influence their citation patterns. This should be taken into account in any comparative journal citation analysis.

A range of other measures have been developed which complement the impact factor; one gives weighting to the citation source (Eigenfactor), and the other measure (*h*-index) was developed as a way to evaluate authors.

Eigenfactor metrics

While the impact factor has been prominent as one way of measuring journals, it does not measure the quality or influence of a paper. Eigenvector centrality, developed by sociologist Philip Bonacich in 1972, quantifies an individual's status in communication networks. This development is used for Google's PageRank algorithm; examining citation networks and is a basis of Eigenfactor™ Score and Article Influence™ Score.

The Eigenfactor TM score of a journal is based on calculation of the percentage of the time that the model researcher visits that journal in her walk through the library (West, 2009, p.7). The measure is a way of rating the importance of a journal. Journals are rated according to the number of incoming citations, with citations from highly-ranked journals weighted to make a larger contribution to the Eigenfactor than those journals with lower rankings. The Eigenfactor™ score is intended to give a measure of how likely a journal is to be used. With the impact factor calculation, a citation from *Nature* is not given any more weight than a citation from a second-tier review journal. In the mathematics field, recent citations are rare and bibliographies are not extensive, yet a citation is given the same value as a citation in the field of immunology where lengthy bibliographies and recent citations are the norm.

The Article Influence™ Score measures the influence, per article, of a given journal. Unlike the impact factor, Article Influence™ Score adjusts for differences in citation patterns between disciplines. In a paper by West (2009), the researchers provide an example of the power of Article Influence™ Score for the economics discipline. Journal rankings for Economics do not rank very highly. Yet, using the article Influence™Score, 31 Economics journals are ranked in the top 400 journals.

As a result of the development of Eigenfactor metrics, publishers, such as EBSCO and Thomson Reuters are utilising the advancements in their product development and are promoting the new forms of metrics as a point of differentiation in their marketing campaigns. For example, one product newly released by EBSCO promotes the journal content on the basis that the database includes journals that are in the top 25 Eigenfactor ratings.

The *h*-index

The *h*-index was developed in 2005 by J.E.Hirsch as a way to enhance the evaluation of an author. A high *h*-index indicates that a scientist has published a considerable body of highly cited work. It is a metric that is easily calculated (as long as citation data can be obtained.) Papers can be listed in order of most cited to least cited. The *h*-index is the point where the number of papers matches the number of citations. In one study, the *h*-index was one of the measures used to identify the top 100 researchers in the field of Alzheimer's disease (Sorenson, 2009). The *h*-index is considered a reasonably robust indicator of a scientist's productivity as it provides an overview of an author's citation and publication patterns over time and helps to put the author's career into context. *H*-indexes can be calculated over particular time periods or can be calculated for the entire span of a researcher's career. The date range limitation could be useful in comparing two authors; one may be an experienced researcher whose active publication is not recent, and the other researcher may be in the early stages of a career, newer on the scene but with a more recent volume of work. Limiting the time periods in the calculation of the *h*-index may provide a different perspective for the assessment of the two researchers.

Both *Scopus* and *Web of Science* have features which automatically calculate the *h*-index of authors. In *Scopus*, the *h*-index is available for all authors in *Scopus* Users can view an author's *h*-index either by selecting the Scopus Citation Tracker on the author search results page or by viewing the author details page. In *Web of Science*, the *h*-index of an author is automatically calculated by choosing the Create Citation Report link on the Results page.

Bibliometrics and institutional rankings

One application of citation counts and impact factors is the ranking of world universities. For example, the Higher Education Evaluation and Accreditation Council of Taiwan (HEEACT) measures the publication performance of the world's top 500 universities.

Performance measures for the HEEACT rankings comprise eight indicators to assess a university's overall scientific paper performance and three criteria: research productivity (20 per cent), research impact (30 per cent) and research excellence (50 per cent). The indicators chosen to measure research impact were the number of citations from the past eleven years, the number of citations in the last two years and the average citations over the last eleven years. The aim was to include both short-term and longer-term indicators of impact. The indicators that were chosen to examine research excellence were the *h*-index calculated from the last two years, the number of highly cited papers using data from *Essential Science Indicators* and the number of articles in high impact journals in the current year, using *Journal Citation Reports* data <http://ranking.heeact.edu.tw/en-us/2009/>.
The authors of the HEEACT rankings claim the emphasis on current research makes it fairer than some traditional indicators, such as a university's reputation or the number of Nobel Laureates, which tend to favour long established universities or universities in developed countries <http://blogs.unimelb.edu.au/musse/?p=2553 >. Using a combination of indicators, the project uses the results to compare the research performance of universities throughout the world. The Australian universities that feature in the rankings are Melbourne, Sydney, Queensland, Australian National University, University of New South Wales and Monash. The top ten are North American universities.

Bibliometric products

The emergence of bibliometrics as a scientific field was triggered (in the 1960s) by the development of the Institute for Scientific Information (ISI) *Science Citation Index* (SCI) by Eugene Garfield, and later expanding to produce the *Social Sciences Citation Index* (SSCI) and the *Arts and Humanities Citation Index* (AHCI). The products were developed with the desire to support scientific literature searching. The SCI was created as a database of the references made by authors, to earlier articles, in their articles published in the top scientific journals, originally focusing on general science and genetics. The underlying idea, still highly relevant today, is that if a scientist reads an article, then s/he would benefit from knowing which articles cited it, since they may cover a similar topic and might update or correct the original article (Thelwall, 2008). As of 2006, there are other sources of such data, such as *Scopus* and *Google Scholar*.

Scopus is a database of abstracts and citations for scholarly journal articles. It indexes 18,000 peer-reviewed journals in the scientific, technical, medical and social sciences (including arts and humanities) fields. It is owned by Elsevier and is provided on the Web for subscribers. Searches in *Scopus* incorporate searches of scientific web pages through Scirus, another Elsevier product, as well as patent databases. *Scopus* also offers author profiles which cover affiliations, number of publications and their bibliographic data, references and details on the number of citations each published document has received. It has alerting features that allow anyone who registers to track changes to a profile. By using Scopus Author Preview anyone is able to search for an author, with affiliation name as a limiter, verify the author's identification and set-up an automatic RSS feed or e-mail alerts to the author's homepage.
<http://info.scopus.com/detail/facts/>.

Scopus has gaps in coverage of its journals. One example is *Journal of the American Medical Association* (Listed in Journal Citation Reports as having the second highest impact factor in the Medicine, General and Internal category) with coverage for the following years: 1909, 1925, from 1928 to 1929, from 1935 to 1938, 1942, from 1945 to 1946, from 1949 to 1951, 1953, 1955, from 1958 to present.

Web of Science includes over 16,000 titles
<http://thomsonreuters.com/content/PDF/scientific/Web_of_Science_factsheet.pdf >.

For many disciplines, *Web of Science* has limited coverage, although from 2009 the product will have expanded coverage with the addition of the Century of Social Sciences content which institutions can purchase. Anthropology, Communication Economics and Management, Education, Geography, History and Philosophy of the Social Sciences, Law, Political Science, Psychiatry, Psychology, Public Health, and Social Issues and Sociology will have additional titles added.
<http://isiwebofknowledge.com/products_tools/backfiles/coss/>

Comparison of author and publication coverage in Web of Science and Scopus

Research output as listed by *Scopus* and *Web of Science*: (University of Melbourne)
A search of *Web of Science* using the advanced search feature and search string OG=univ Melbourne retrieves 69, 884 results (search conducted 25/8/2009). The publication years span 1900 to 2009. A search of *Scopus* using the affiliation search retrieves 59,662 results (search conducted 25/8/2009). Publication years span 1886-

2009. Analysing the results by year indicates that coverage for the papers produced by University of Melbourne researchers is very similar (from data taken over a 10-year period).

The table below lists the top 5 authors, comparing the results obtained using *Web of Science* and *Scopus* data.

Table 1 University of Melbourne researchers in order of research output

Web of Science	Number of papers	Scopus	Number of papers
Masters CL	454	Masters CL	327
Hopper JL	399	Hopper JL	304
Martin TJ	390	Clark GM	304
McGorry PD	349	Gasser RB	258
Burrows GD	319	Taylor HR	252

With the calculation of the *h*-index for Masters, *Web of Science* had 454 papers with an *h*-index of 66 (i.e 66 papers had been cited 66 times or more). The *Scopus* data for the same author used 321 papers and the *h*-index was 58 (i.e 58 papers had been cited 58 times or more). *Scopus* does not have complete citation information for articles published before 1996. Google Scholar Universal Gadget calculates 801 papers and an *h*-index of 82 for this author.

In both *Scopus* and *Web of Science*, records are included from 1989-2009. In *Scopus,* 4 papers are listed as being published in *Nature* and 1 paper in *Science*; in *Web of Science*, 6 papers are listed from *Nature* and 3 from *Science*. Coverage of *Nature* in *Web of Science* and *Scopus* varies. *Scopus* records for the journal *Nature* go back to 1869; *Web of Science* records go back to 1902. In 2008, *Scopus* listed 2345 records from *Nature*, compared to *Web of Science* with 2118 records.

The table below lists total number of research publications produced each year by the University of Melbourne (the total output figure includes book chapters, journal articles and conference proceedings.) The *Web of Science* column lists papers produced by University of Melbourne researchers which have been included in *Web of Science*. The *Scopus* column lists papers which have been produced by University of Melbourne researchers which have been included in the *Scopus* database.

Of the total research output, over half of the papers are included in *Scopus* or *Web of Science* in the last 6 years.

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Table 2
University of Melbourne publications 1999 – 2008:
a comparative view *Web of Science* and *Scopus*

Year	***Web of Science***	***Scopus***	**Total output**
2009	*3211 (as at August 2009)*	*3163 (as at August 2009)*	*(not yet listed)*
2008	4873	5,029	8024
2007	4456	4,643	7557
2006	4121	4,292	7470
2005	3703	3,781	7329
2004	3386	3,412	6404
2003	3017	2,853	6144
2002	2773	2,565	5520
2001	2584	2,200	5114
2000	2429	2,124	5905
1999	2185	2,115	6242

Source:
<http://www.research.unimelb.edu.au/performance/documents/WV_Section06_Publications_2008.xls>

Incorporation of visualisation

One powerful tool is the citation map feature that is provided by *Web of Science*. By selecting a paper, a citation map can be created, then edited to highlight authors, countries, institutions or subject categories of cited and citing papers. This visual representation highlights the impact that the paper has had worldwide providing a powerful tool for researchers.

Elsevier has entered the visualisation market with a web-based tool, SciVal Spotlight. The new product, launched in June 2009, promises to produce customized maps that provide graphical views of an institution's performance over time and across scientific fields, focusing on specific topical areas. According to the media release (2009), SciVal offers institutions a unique multidisciplinary perspective of research performance to evaluate, establish and execute more informed research strategies.

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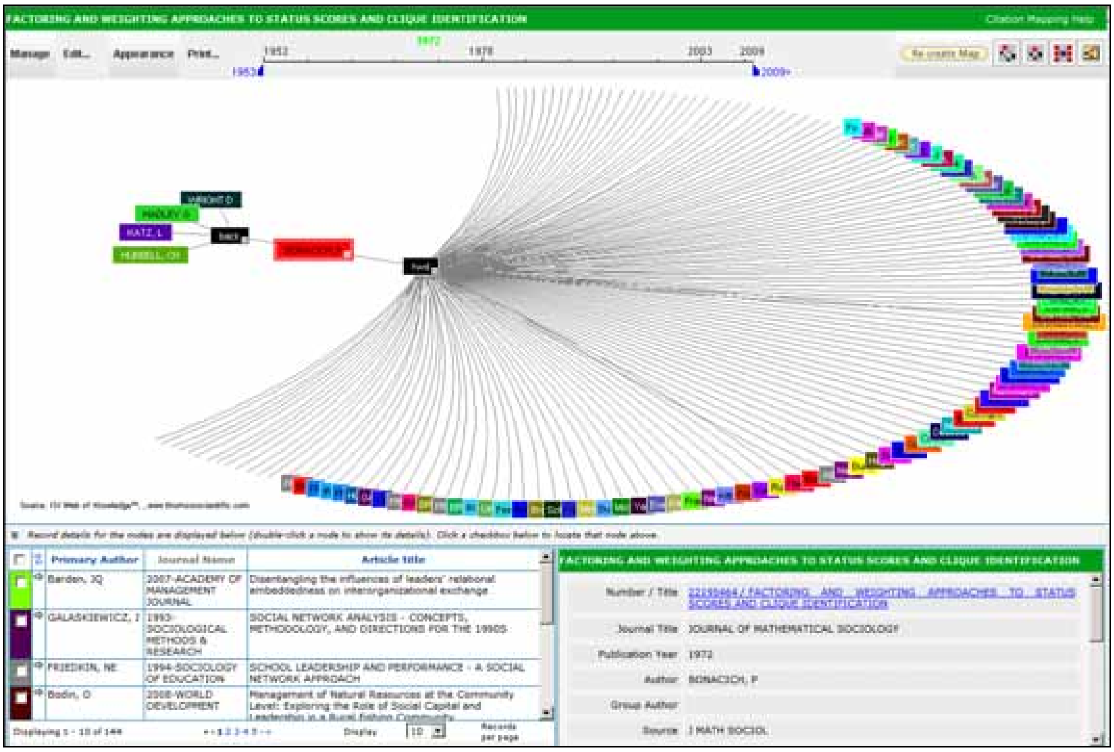
Illustration 1: An example of a visualisation map of citations provided by *Web of Science*



Google Scholar

Google Scholar <http://scholar.google.com> attempts broad coverage of web content. Google Scholar indexes print and electronic journals, conference proceedings, books, theses, dissertations, preprints, abstracts, and technical reports available from major academic publishers, distributors, aggregators, professional societies, government agencies, and preprint/reprint repositories at universities, as well as those available across the web. Annual Reviews, arXiv.org, Association for Computing Machinery (ACM), BioOne, Cambridge Scientific Abstracts (CSA), CSIRO Publishing, Duke University Press, Emerald, HighWire Press, Ingenta, Institute of Electrical and Electronics Engineers (IEEE), Nature Publishing Group, PubMed, Sage, ScienceDirect, Springer, Taylor & Francis, University of Chicago Press, and Wiley Interscience are content sources searched by Google Scholar. Lack of detail about what content is actually searched is a weakness. Some publishers do not allow it to crawl their journals. Elsevier journals were not included before mid-2007, when Elsevier began to make most of its ScienceDirect content available to Google Scholar and Google's web search. It is not known how frequently the content is updated. It is therefore impossible to know how current or exhaustive searches are in Google Scholar. Using it for bibliometric or scientometric purposes is problematic. There are no explanations on how citation rates are calculated. Google Scholar has been criticised (Jacso, 2008) for inflating its citation counts. Highly cited papers are listed at the top of the search results but search results are not able to be sorted by citation counts.

A Google Scholar Universal Gadget <http://code.google.com/p/citations-gadget/> can be installed which enables researchers to search for the total number of citations authors have received. Total citation counts, total number of cited publications and the *h*-index are calculated, but there is no authority control for authors' names.

Scholarly databases, citation data and evaluations

Many more data sources for citation information are now available for researchers. For example, Business Source Premier (on the EBSCOhost platform) includes cited references and number of times the paper has been cited (from documents included in the database). PsycInfo, published by the American Psychological Association includes cited references and the number of times an article has been cited. Published by Biomed Central, Faculty of 1,000 Biology provides researchers with papers that have been evaluated by over 2000 leading scientists. Experts provide a ranking system; to name two examples, there is a current top ten list and a hidden jewels list, which covers papers that are highly ranked but may have been published in less obvious journals. The papers are classified according to a number of categories: new finding, controversial findings, technical advance, refutation, interesting hypothesis and important confirmation. CINAHL on EBSCOhost, ScienceDirect, Scifinder Scholar, MathSciNet and Sociological Abstracts on the CSA platform are other products which trace citations to papers.

ISI Highlycited.com

Access to ISIHighlycited.com is from the Web of Knowledge platform. This product gives researchers a tool to identify the most cited and influential scientific authors for the period 1981-1999.

Profiles include awards, research list of publications, research and funding grants, memberships, honours and awards. One hundred and twelve authors from Australia have been identified as highly cited researchers, nine of whom are from the University of Melbourne. These nine are from the fields of pharmacology, physics, biology and biochemistry, neuroscience, geosciences, engineering and plant and animal science.

Essential Science Indicators

Essential Science Indicators is an analytical tool which provides data for ranking scientists, institutions, countries, and journals. Essential Science Indicators also lists research areas, called Research Fronts, with topics reflecting research intensive and breakthrough areas of current science. It provides total citation counts and citations per papers (influence and impact measures). Data is sourced from Thomson Reuters indexed journal articles only and does not include books or book chapters. Highly cited papers are chosen from the most recent 10 years of data, and “hot papers” focus on very recent papers (from the past 2 years) that show an unusual rate of citation in the current period. Data is updated every two to four months.

Librarians responding to the research environment

The ERA initiative has created opportunities for librarians to really engage with their academic colleagues. For university library administrators, the ERA initiative is an opportunity to plan and recast service models, refocus collections and develop staff skills to support research needs of their academic communities. The research evaluation process provides a perfect opportunity for librarians to reconnect with the academic community by demonstrating expertise which can support other areas such as information literacy programs for graduate students. Metrics continue to be used for grant applications, academic promotion, recruitment, research assessment (school, research centre, whole university) as well as used for decisions about where to publish. With ARC grant applications, researchers are required to nominate their ten career-best publications and to outline why each one is best. Librarians need to understand the uses that are being made of bibliometrics and to ensure that professional development for library staff is provided.

In this highly competitive research environment, library staff are providing a range of levels of support. Traditionally, librarians have focused on hands-on searching instruction, through workshops, assistance at reference desks or responding to requests from academics and research students. The University of New South Wales Library has taken a different approach with its restructure to create the Research Impact Measurement Service (RIMS). In this initiative, library staff produce ‘Research Impact Statements’ and more specialised ‘Grant Application Statements’ for academic staff. The service has seven staff, with fifty percent of their time spent on creating citation reports for researchers. Monthly bibliometric reports that measure the impact of publications, researchers and departments of the University are supplied (Drummond 2009). The service was developed in response to supporting university provide research output measurements as outlined in the Federal Government’s research framework, the ERA initiative.

At the University of Melbourne, the ERA initiative provided the impetus for librarians to forge links with academics chairing the evaluation clusters. The trials of the two clusters, particularly the Humanities and Creative Arts cluster, required library staff support. The involvement ranged from data entry and digitising to reporting on the library holdings of the ranked A+ and A journals. The experience of working with the University’s Research Office and meeting with academic staff involved in selecting material for peer review provided invaluable insights into the process of analysing research outputs and impacts. The ERA exercise also led to the development of a training program to inform liaison librarians and to extend their knowledge about the evaluative applications. Discipline Librarians at University of Melbourne conducted a number of forums for liaison librarians where various measures (impact factor, h-index, Eigenfactor) were explored to promote greater understanding of the bibliometric tools. Reading lists were compiled and added to the Learning Management System community site. The presentations focussed on the differences between disciplines and highlighted some of the key issues of the current debates. Since the training sessions, liaison librarians have applied their learning by creating tailored bibliometric support sites on the Learning Management System for their Schools.

University of Melbourne library staff have also provided workshops on citation databases for research and higher degree students. Training workshops for supervisors have been included as part of a broader information literacy program. In addition, liaison librarians have provided assistance with grant applications. Library staff have focused on hands-on searching instruction, through workshops, individual consultations, as well as offering assistance at reference desks. An emerging area of support that Discipline librarians at the University of Melbourne have become involved is checking researchers' lists of publications and citations on Web of Science, Scopus and Google Scholar to verify the h-index calculation. Formerly librarians were not sought out to work on such projects and it is clear that increasingly, library staff will be required to participate in studies of the reliability of Journal Impact Factors, *h*-index and other indicators of quality, especially in areas of emerging or interdisciplinary research.

Victoria University has undertaken a range of activities to provide support for academic staff. Library staff in a research consultant role have developed, advertised and delivered 'Research Quality' or 'Citation Tracking' workshops, timed to critical dates such as when grant applications or academic promotions applications are due. Sessions at different campuses were undertaken. Two elements emerge as key factors for success: collaboration with the University Research Office, and targetted communication to market the sessions.

Librarians have extended their reach to their academic communities by adding research support information to their institution's websites. Such support varies from notification of forthcoming seminars on citation workshops, information on basic searching techniques to substantial websites which cover information on metrics, database product features and information about the ERA initiative.

The University of Queensland Library's "Research output and impact" <http://www.library.uq.edu.au/research/roi.html> is a well designed website. The site provides practical information on citation counts, features of various tools such as creating citation maps, definitions, bibliometric analyses and notifications of forthcoming metrics conferences and workshops.

The University of South Australia Library research support webpage includes information about ERA and links to measuring journal quality, being cited and research leaders <http://www.library.unisa.edu.au/research/eraresources/peers_leaders.asp>.

Deakin and RMIT library staff are developing research support strategy frameworks. Liaison librarians at RMIT provide individual support and citation tracking is covered briefly in postgraduate sessions for Engineering and Science. Library staff noted that it was important to provide separate training sessions for academic staff rather than offering sessions for both staff and graduate students.

A greater issue in relation to research support is that of sustainability. While the University of New South Wales RIMS service has elevated the library's profile, is the model equitable? If liaison librarians are to take on the responsibility to corroborate citation data from multiple sources and provide accurate data, decisions need to be taken about work priorities – what is left off in order for the bibliometric support to be provided. The question remains whether the level of information provided is adequate for the types of evaluative applications that currently confront the academic community. While ERA provides opportunities for greater collaboration with academics, there are implications for how libraries prioritise and orient their services to the research community.

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