Making Research Count:
Analyzing Canadian Academic Publishing Cultures

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HIGHER EDUCATION STRATEGY ASSOCIATES

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Introduction

The use of bibliometrics as a way of measuring research output is now entering its sixth decade. Ever since the Science Citation Index appeared in 1961 (the Social Sciences Index followed in 1966), it has been possible to answer questions such as "who publishes more articles" and "whose articles are being cited more often?" With additional analysis and more advanced databases, it is possible to aggregate up from individual academics to departments or institutions, to answer the question "which groups of scholars have greater research output?" It is precisely this kind of data which has fed the recent explosion of university rankings, and in particular international rankings such as the Shanghai Jiao Tong *Academic Ranking of World Universities*.

As use of bibliometrics has become more widespread, its critics have become more vocal. The criticisms of bibliometrics fall into four main categories:

- Bibliometrics don't measure the full range of scholarly activity and are therefore an inadequate way to measure scholarly performance. In particular, they do not measure teaching ability.
- Bibliometrics can be misleading; some metrics have multiple interpretations (i.e., a high citation count may reflect widespread criticism); more comprehensive metrics are often not very intuitive and hence not easy for users to understand.
- Citation databases used in bibliometric calculations contain various biases that may affect the result (such as under representation of non-English journals).
- The potential for bias in bibliometric comparisons is poorly understood and rarely controlled. For example, bibliometric comparisons usually fail to account for the differences among disciplines in scholarly *publication cultures*. Bibliometric comparisons that do not control for these differences are biased when the groups being compared are from disciplines with different publication cultures.

These criticisms reflect structural limitations of bibliometric measures which, for the most part, can be addressed by changing the ways bibliometrics are both calculated and used. The first criticism reflects a common concern that faculty should not be judged solely by their publication record. Indeed, bibliometric measures only assess one component of academic activity, and should be used accordingly – either in conjunction with other measures (such as expert peer review[1]), or explicitly as a measure of research output *only.* This issue is beyond the scope of this paper.

[1] For a discussion of how expert peer review can benefit when complemented by bibliometric analysis, see Aksnes D. W. and Taxt R. E. 2004. "Evaluation Correlation" *Research Evaluation,* 13(1), p. 33-41. The authors conclude that both measures are strongest when used in tandem – using bibliometric measures to identify possible problems with peer-review processes, and vice-versa.

The next three criticisms are essentially technical problems that can be addressed. In this document, we propose a new way of comparing research output among groups of scholars that addresses these objections to bibliometrics, especially the concern that bibliometrics can be biased by field of study. In Part I, we describe the objections to bibliometrics and the methods we use to address them. In Part II, we use a new method to estimate differences in publication cultures across disciplines at Canadian universities, and identify the top scoring institution and researcher within each discipline. We finish in Part III by demonstrating how this approach can be applied to Canadian scholars.

Part I: Making Bibliometrics Work

In part I, we look at three specific questions. First, we examine the question of how to display bibliometric information on both scholarly productivity and impact in an efficient and understandable manner. Second, we discuss considerations regarding the use of different bibliometric databases. And third, we look at how to conduct bibliometric analysis in a manner which properly takes account of disciplinary differences in publication cultures, or, to put it in the current jargon, to "discipline-normalize" bibliometric data.

i) Choosing a simple bibliometric indicator

The increasing importance of publication records to hiring, quality assurance, and accountability processes have brought a range of bibliometric measures into broad use over the past decade. At the same time, the practical challenges to this type of analysis have faded as large citation databases have reduced the costs of collecting source data.

Publication counts (a rough measure of productivity) and citation counts (a rough measure of impact) are perhaps the most common bibliometric measures in use. They are both simple to calculate and easy to understand, and their popularity stems in no small measure from this simplicity. But these measures carry drawbacks. Publication is no guarantee of impact; some academics may publish extensively while garnering few citations. Citation counts, on the other hand, may come disproportionately from one or two papers that were highly influential (or worse, which are widely criticized), and thus may not signify the presence of a sizable body of impactful work.

Hirsh developed the H-index as an alternative to traditional bibliometric measures. The H-index is a single bibliometric indicator that combines measures of productivity and impact into one. Hirsch argued that this combination reflects the impact of a publication on the corresponding scientific community (Hirsch, 2005; see also Hirsch, 2007). The enormous popular interest and scholarly attention that this metric has received since 2005 is a testament to the appeal of an easily-derived compound bibliometric, and to the growing importance of the H-index to bibliometric analysis.

Understanding the H-index

The Hirsch-index, commonly abbreviated as the H-index, was proposed by Jorge E. Hirch (a physicist at UCSD) in 2005 as a compound metric based on a single author's citations and publications. A researcher's H-index is the largest possible number *n* for which *n* of the researcher's publications have been cited at least *n* times. The table below provides examples using four researchers, showing the number of citations of their four most-cited papers, and the corresponding H-index. The average citations per paper is also included, to demonstrate how the H-index differs. In this example, Scholar C has a single highly-cited paper, and four papers with not more than one citation. Because the H-index limits the contribution of individual papers with many citations, as well as papers with low citation counts, this scholar has a low overall H-index despite an average number of citations per paper that is the same as the other three.

Table 1: H-index calculation examples

	Scholar A	**Scholar B**	**Scholar C**	**Scholar D**
Citations for most-cited article	3	5	14	8
Citations for second most-cited article	3	5	1	3
Citations for third most-cited article	3	5	0	2
Citations for fourth most-cited article	3	0	0	1
Citations for fifth most-cited article	3	0	0	1
Average citations per paper	**3**	**3**	**3**	**3**
H-index	**3**	**3**	**1**	**2**

The popularity of the H-index is driven by the advantages it has over other bibliometric calculations:

- It considers both productivity and impact.
- It is not influenced by a small number of very successful articles, which may not be representative of a researcher's career output. The H-index similarly discounts the value of papers that are not influential.
- The H-index is simpler and easier to understand than many other compound bibliometric metrics.

While the H-index has many advantages, some factors are not included. Some of these include the age of the scholar, the time since publication of individual articles, the quality and impact of the journals in which they were published, the number of authors, whether the scholar in question was the first author, whether the citations viewed the article positively or negatively, and whether the publication was a book, monograph, or other publication type. Because these factors can be a source of bias, researchers have attempted to control for many of these factors by constructing variations on the H-index.[2]

Many of these sources of bias do not matter when comparing academic departments within a discipline (the basic unit of analysis used in this paper). For instance, type of publication differs greatly across disciplines, but is rather homogeneous within a discipline, so is not a source of bias when comparing within a discipline. While factors such as age do affect publication productivity and impact, controlling for age does not necessarily add value when comparing across departments. It can be argued that a department with older scholars deserves the value added by the publication records of its senior faculty. Hence, the research we are reporting here has opted not to account for age.

ii) Choosing an appropriate database

Every system of bibliometrics requires a database from which to draw information. The problem is that while many databases are extensive, no database can ever be truly comprehensive. Database managers have to make editorial judgements about which publications will and will not be included in the database. A comparison of the world's two largest databases of peer-reviewed journals, Elsevier's Scopus and Thomson-Reuters's Web of Science, reveals that the former contains a much larger number of journals than the latter, but the difference is to a certain extent the result of a decision to include more lower-impact (i.e., less-frequently cited) publications.

Decisions about what to include have the potential to generate biases. For instance, publication databases tend to favour English-language publications, though Thomson Reuters has recently been active in adding Mandarin and Lusophone journals in order to court the Chinese and Brazilian markets. There are also biases which arise from differences across disciplines (other than publication culture). For example, the strong hierarchy of journals that is observed in medicine or biology is not as pronounced in many other disciplines. So limiting the journals that are included in the database will be more of an issue for some disciplines than for others generate additional discipline-specific biases.

Over the past few years, Google Scholar has approached this problem with an alternative to traditional indexing. Instead of archiving journals, it archives individual papers instead, which are identified and indexed automatically. Google Scholar's broad scope and inclusiveness give it several advantages over Scopus and Web of Science; notably, that it also has much better coverage in humanities and social sciences than other databases.[3] Because it is not limited to peer-reviewed publications, it is useful for fields such as economics and political science where some researchers' best work can be for think-tanks

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[2] Many of these are discussed in S. Alonso, F.J. Cabrerizo, E. Herrera-Viedma, F. Herrera. 2009. "H-index: A Review Focused in its Variants, Computation and Standardization for Different Scientific Fields" *Journal of Informetrics* 3(4): 273-289. An online addendum listing and describing variant H-indices is maintained by the authors at http://sci2s.ugr.es/hindex/.

[3] Harzing, Ann-Wil. 2012. "A preliminary test of Google Scholar as a source for citation data: A longitudinal study of Nobel Prize winners" *Scientometrics* (forthcoming).

and public agencies which typically fall outside the range of citation databases, or in disciplines where conference papers play an important role in the academic process, as is the case in computer science. Google scholar can also capture books and other monographs that are more typical scholarly outputs than journal articles in some disciplines, such as English.

Lastly, because Google Scholar can be freely accessed, and because extracting and analyzing Google Scholar data can be automated, researchers can perform basic bibliometric analyses at relatively low cost – as has been done by the software tool *Publish or Perish*,[4] as well as by numerous researchers working in academic environments.

While Google Scholar has advantages that make it an attractive choice, there are three very common criticisms of Google Scholar that need to be acknowledged.

First, due to the format in which Google Scholar allows users to enter name searches, it can be difficult to distinguish between authors with similar or identical names. This presents a problem of false attribution that increases H-index scores wherever common names are being analyzed. This is a serious hurdle for automated bibliometric analysis, as it requires a manual review process before data can be used. Second, Google Scholar is often criticised for inaccuracies in publication metadata, including author, year of publication, and other fields (although this has improved dramatically in recent years).[5]

Both of these problems can be addressed in a straightforward, if time-consuming, manner through manual review and correction of Google Scholar outputs. By this method, false attribution due to similarity of names can be avoided and alternative spellings can be included (Google Scholar automatically parses alternative name spellings and abbreviations). Similarly, metadata errors can be identified and corrected.

The third criticism points to issues with Google Scholar's coverage. First, that Google Scholar includes data on publication *types* that are excluded by other popular databases (primarily patents and conference proceedings). Second, that some of the included publications are not peer-reviewed. And third, that the coverage is sufficiently different from the more established databases that its use would lead one to substantially different conclusions about an individual's publication record.

The issue of inclusion differences can be addressed with a combination of automated screening and manual review. While non-peer reviewed publications could be similarly screened, this research has included publications such as conference proceeding and work done for agencies such as the World Bank (in economics), the Truth and Reconciliation Commission (in history and Aboriginal studies), and the Institute for Research on Public Policy (political science). The rational for this choice is that non-peer

[4] *Publish or Perish* is a free software tool that can be used to automatically retrieve publication data from Google Scholar and produce basic bibliometric indicators.

[5] One of the most vocal critics of Google Scholar and the metadata errors it contains, Péter Jacsó, recently catalogued many of the changes, noting the improvement in metadata (but noting the need for more work to be done). See Péter Jacsó. 2012. "Google Scholar Author Citation Tracker: is it too little, too late?" *Online Information Review* 36(1): 126 – 141. See also Péter Jacsó. 2010. "Metadata mega mess in Google Scholar" *Online Information Review* 34(1): 175 – 191.

reviewed work can have scholarly impact, insofar as it is cited by other researchers (and therefore has a potential impact on the H-index of a given researcher). This is one of the advantages of using the H-index as a metric of reference for this study, as this measure ensures that publications with no impact are not reflected in scores. This is especially relevant because differences in inclusion weaken comparisons across discipline – unless those differences have been normalized.

A number of scholars have compared existing citation databases, such as Thomson Reuters's Web of Science, Elsevier's Scopus and Google Scholar. In 2010 Massimo Franchescet published a detailed literature review of studies that had compared indicators calculated by different citation databases, as well as a correlation test of results from Google Scholar, Web of Science and Scopus.[6] He found four examples that specifically focus on the H-index. These four papers found that the correlation between H-indexes produced by different databases was high or moderate, and in most cases, that Google Scholar produced higher H-index scores, which implies that it was able to capture a larger number of publications and citations than either of the other two databases. Specifically, Franceschet noted the following:

- Saad (2006) found a correlation of 0.82 between H-index scores of productive consumer scholars calculated using Google Scholar and Web of Knowledge.[7]
- Meho and Rogers (2008) found a correlation of 0.96 for human-computer interaction scholars, when comparing H-index rankings of Google Scholar with the union of Web of Knowledge and Scopus (both databases combined).[8]
- Sanderson found "moderate" correlations of 0.51 and 0.69 between the H-index scores of information science scholars calculated with Google Scholar and Web of Science, and Google Scholar and Scopus, respectively.[9]
- The fourth paper (Bar-Ilan, 2008) found differences across a very small sample (40 scholars) of Israeli scholars from mixed disciplines, but did not perform statistical analysis.[10]
- Franceschet conducted a fifth study among computer science scholars, finding that Google Scholar generated higher H-index scores, but that these were correlated to those calculated

[6] Franceschet, M. 2010. "A comparison of bibliometric indicators for computer science scholars and journals on web of science and Google Scholar." *Scientometrics,* 83(1): 243-258. See especially pages 249-250.

[7] Saad, G. 2006. "Exploring the H-Index at the author and journal levels using bibliometric data of productive consumer scholars and business-related journals respectively." *Scientometrics,* 69(1): 117-120.

[8] Meho L. I. and Rogers, Y. 2008. "Citation counting, citation ranking, and H-Index of human-computer interaction researchers: a comparison between Scopus and Web of Science." *Journal of the American Society for Information Science and Technology,* 59(11): 1711-1726.

[9] Sanderson, M. 2008. "Revisiting h measured of US LIS academics." *Journal of the American Society for Information Science and Technology,* 59(7): 317-330.

[10] Bar Ilan. 2008. "Which H-Index? A comparison of WoS, Scopus, and Google Scholar." *Scientometrics,* 74(2): 257-271.

using Web of Science. Franceschet found a Spearman correlation of 0.84 between H-indexes calculated using Google Scholar and H-indexes calculated using Web of Science.[11]

Two conclusions stand out from this review. The first is that the degree of correlation between results in Google Scholar and other databases differs somewhat from one field to another. This is to be expected, as it is well-known that the coverage of Scopus and World of Science can vary from one field to another. More broadly, though, the degree of correlation suggests no prima facie reason why one would not consider Google Scholar a reasonable indicator of scholarly output.

In sum, there are a number of databases that could be used to derive H-index data. Scopus and Web of Science have the benefit of being easy to use and having wide currency. Google Scholar has the benefit of wider coverage (which has some distinct advantages in certain disciplines), and greater ease of use when using automated calculation processes.

iii) Accounting for differences in disciplinary publication cultures

Possibly the most important weakness of bibliometric analysis comes when attempts are made to compare scholars across disciplines without taking into account the dramatic differences in publication cultures. Scholars in different disciplines tend to produce research at different rates. They also cite other papers at different frequencies, co-author papers with differing numbers of other scholars, collaborate at different levels and publish in books, monographs, and journals at different rates. For example, only the most productive scholars in the humanities publish on a monthly basis, rarely with more than one or two authors. In other disciplines (e.g., biological sciences) however, this level of productivity and multiple authors is quite common. This affects most of the basic inputs of common bibliometric measures, including the number of articles published in peer-reviewed journals, the citation rate of published articles and the number of authors per paper.

These differences in publication cultures can pose challenges when comparing the performance of scholars across different disciplines. This point has been discussed by many authors, dating back at least to Braun and Schubert's 1986 article "*Relative Indicators and Relational Charts for Comparative Assessment of Publication Output and Citation Impact*."[12] Braun and Schubert note that the inability to compare publication productivity and impact across disciplines due to the differences in publication and citation cultures is *"one of the most frequently claimed caveats"*[13] in the use of publication and citation measures.

By extension, this criticism applies to attempts to compare groups of scholars when they do not take into account differences in publication culture between disciplines. For example, the Academic Ranking

[11] Franceschet, 2010. See Pages 256-258.

[12] Braun, T., and Schubert, A. 1986. "Relative indicators and relational charts for comparative assessment of publication output and citation impact" *Scientometrics* 9(5-6): 281.

[13] Ibid., 281.

of World Universities (also known as the Shanghai Ranking), which uses counts of highly cited papers, publication counts and per-capita academic performance for 70% of their ranking, does not account for differences in publication culture. The insensitivity to discipline-based publication cultures is a major weakness of this ranking, and others using similar inputs.

This problem is not insoluble. As Braun and Schubert said, "*a reliable way to overcome this problem seems to be the assessment of each single paper against its own standards, thus building some kind of relative indicators of performance or impact*."[14] This type of *field normalization* can be achieved either by only making comparisons within a single discipline, or by accurately measuring publication culture and then comparing each researcher against the standards of their own discipline. While many contemporary scholars have discussed this issue and created field-normalised metrics within small communities of researchers,[15] a comprehensive database of field-normalized or discipline-normalized bibliometric indicators has not been available prior to this publication.

Summary

In Part I, we looked specifically at three basic objections to bibliometrics. The first, that they should not be used as a sole judge of scholarly value – is not a criticism of bibliometrics per se, but a criticism of using bibliometrics out of context. The second, that citation databases contain biases, can be approached by using one of a number of different comprehensive databases (Web of Science, Scopus or Google Scholar), provided the limitations of different lenses on the universe of scholarly publication have been measured and are well understood. The third and final objection – the difficulty in accounting for cross-disciplinary differences in publication cultures – can be dealt with by restricting comparisons to within a given field of study, or by comparing metrics to disciplinary norms.

The third objection, the need to account for cross-disciplinary difference in publication cultures, is the focus of Part II.

[14] Ibid., 281.

[15] A recent example of an attempt to create field-normalized citation counts among Norwegian researchers may be found in Ahlgren, P., Colliander, C., and Persson, O. 2012. "Field normalized citation rates, field normalized journal impact and Norwegian weights for allocation of university research funds" *Scientometrics* 91(1): 1-14.

Part II – Determining Disciplinary Norms

To determine disciplinary publication norms that can be used for discipline-normalization, we began by constructing a complete roster of academic staff at Canadian Universities, using institution and department websites. We then derived an H-index score for each academic by feeding each name into a program that uses Google Scholar to derive an H-index value. We also employed a number of quality-control techniques (including manual review) to reduce the number of false positives, correct metadata problems, and ensure that only desired publication types were included. Finally, with H-index scores for each individual scholar, disciplinary averages were constructed from the national data. Below, we explain this process and the results in more detail.

Creating a national roster of academics - Criteria for inclusion

The first step was to generate a roster of academics who would be included in calculation of the norms. The first criterion for inclusion in the database was institutional: 71 universities were included, covering the vast majority of university academics in Canada. A number of small universities were excluded, especially in Quebec, due difficulty building accurate staff lists (and especially, differentiating between adjunct and regular faculty) for those institutions. For the same reason, Laval University was not included in this analysis. A full list of institutions is included in this document as Appendix A.

The second criterion for inclusion was disciplinary. Non-academic disciplines (i.e., those that deliver programs of a primarily vocational nature, and which are mainly located in the newer universities in British Columbia) were excluded. So, too, was medicine due to the difficulty in distinguishing between academic and clinical faculty on institutional websites. Apart from these, all academic staff at the 71 universities were included.

Faculty members were included in a department if they were listed on that department's website at the time of collection (Summer 2011). Inclusion was limited to active academic staff in positions that *potentially* involve both a research and teaching role within the department in question. Position titles of those who were included consisted of:

- Professors
- Assistant professors
- Lecturers
- Instructors
- Deans/associate deans
- Chairs/associate chairs

Note that lecturers, instructors and chairs were included only at institutions where these positions could *potentially* involve both a research and teaching role. For example, instructors at some institutions lack a research role (and should therefore be excluded), while this term is used at some institutions to describe academic faculty at an early stage of their career and so in these cases were included. Staff in the following positions were not included:

- Administrative assistants
- Sessional lecturers
- Post doctorates
- Emeriti
- Adjunct professors
- Graduate students
- Visiting professors

Data Cleaning

Automated data collection processes risk producing large numbers of false positives. This is due to a limited ability of these processes to distinguish between different authors sharing the same name, and sometimes working in the same discipline. Authors with very common names can have bibliometric scores that are dramatically inflated as publications by similarly named authors are falsely attributed. Some publications appear more than once in Google Scholar's list of results, duplicating their citation counts or splitting citations for a single paper between two entries. For some types of searches, these problems can cause serious issues for automated data collection process.

In order to avoid these kinds of issues, the Google Scholar results were manually reviewed by HESA staff, to ensure that:

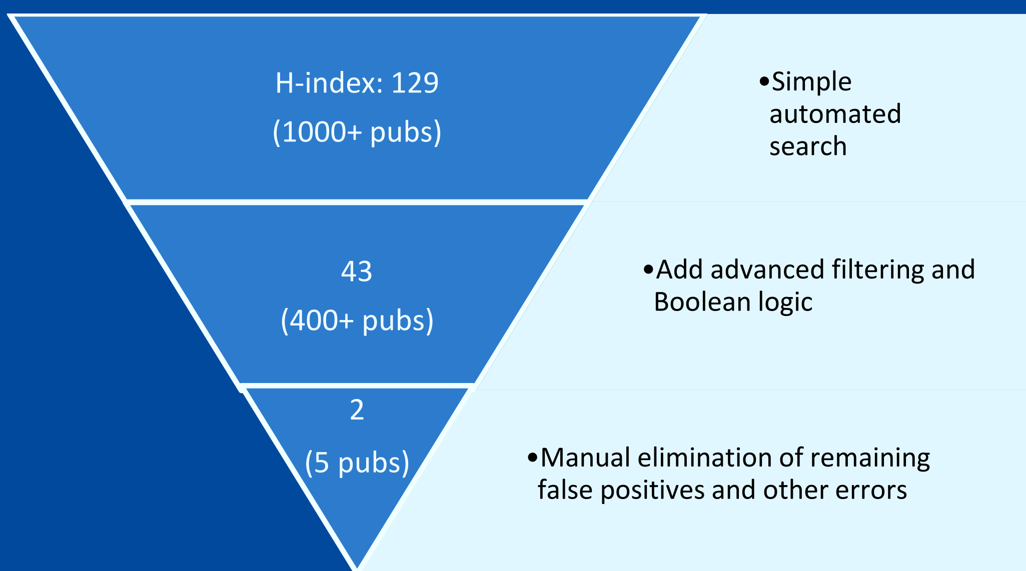
- The search term used accurately reflects the name used by the researcher in his or her publications.
- Publications written by similarly named researchers are excluded.
- The articles, books and other publications included are only counted once.

The second point is especially important. It is not uncommon in large-scale bibliometric analysis for publications to be inaccurately attributed to a researcher due to a similarity in names. While a manual assessment methodology does not eliminate all errors, it dramatically reduces their incidence. Most importantly, by eliminating cases of high over-attribution, it dramatically increases the accuracy of this tool when used to compare groups of researchers.

The data cleaning process

For any given researcher, data was cleaned in a three-step process. First, publication data for each researcher was automatically screened to reduce the most obvious errors. Second, a human agent reviewed the data, and improved the search terms to accurately reflect the name used by the researcher in his/her publications and to narrow search results if necessary. Lastly, publications were manually reviewed to identify and correct false attribution and metadata errors.

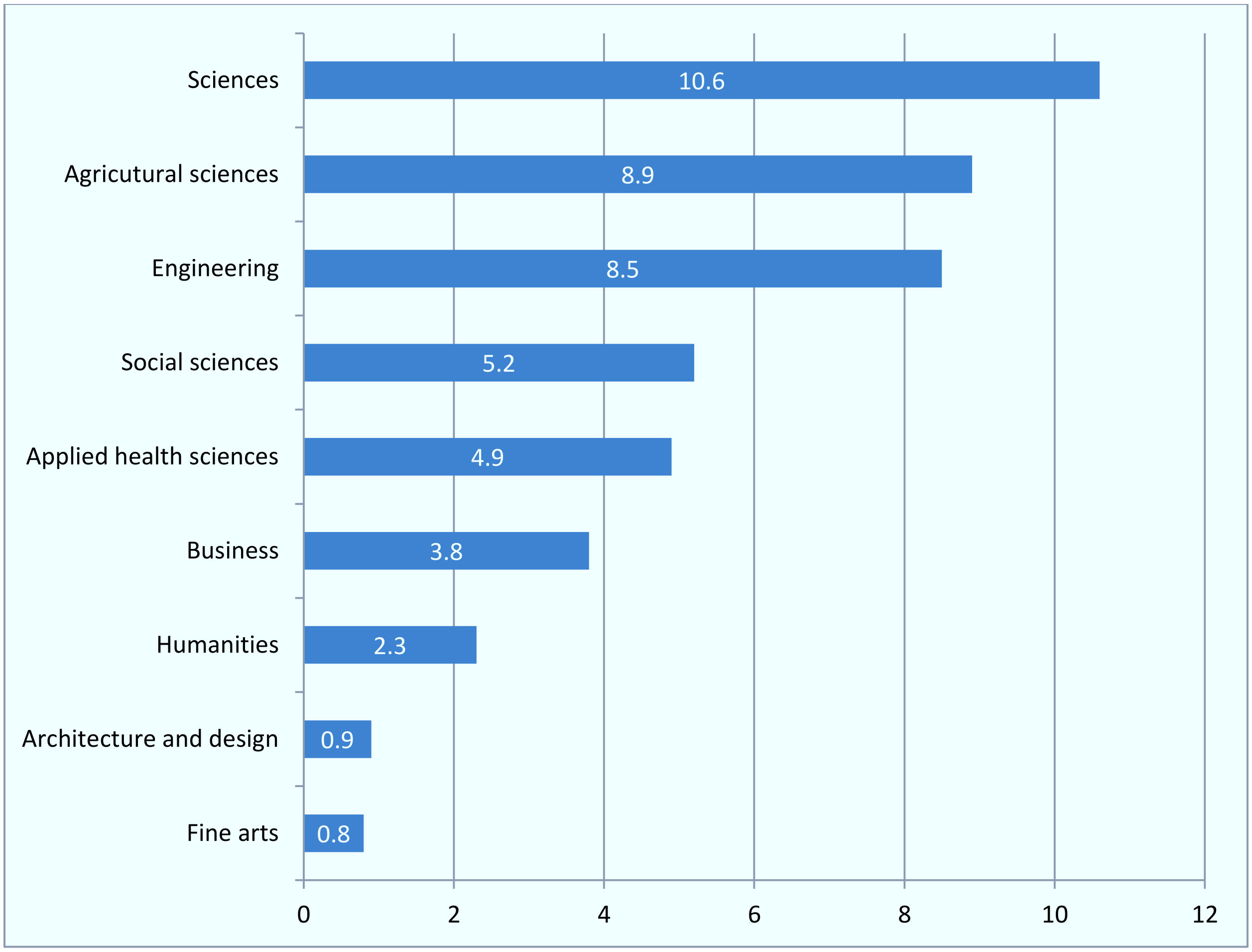
The example below shows the number of publications attributed to an associate professor at the University of Toronto, at each stage of the process, illustrating the importance of a manual review process to maintain the integrity of the data. While the numbers here represent a real case, this is a particularly dramatic example in which the number of false positives was unusually high because a number of high-performing researchers shared their last name with the scholar being analyzed.



Part III – Results

The main result of this process was the quantification of differences in publication cultures by discipline among Canadian scholars, as measured by mean H-index scores. Figure 1 shows the difference in mean H-index scores by field of study across all academics included in the study.

Figure 1: Mean H-index Scores by Field of Study



The sciences have the highest mean H-index at 10.6, while agriculture and engineering trail slightly at 8.9 and 8.5, respectively. Business, social sciences and applied health science have relatively similar average H-index scores, ranging from 3.8 to 5.2. Humanities are somewhat lower at 2.3, while design/architecture and fine arts both have mean indexes below one. This is what one would expect. Fields of study which are highly quantitative and empirical in nature fall at one end of the scale, while fields which are more creative in nature fall at the other end of the scale.

This is an important result in that it reflects the H-index of an entire population – the majority of all researchers at Canadian universities. Two important caveats apply here, however. The first is that these differences only apply to publication cultures *among scholars based in Canada*. If one were to do this same exercise with a wider group of scholars, national strengths and weaknesses would be reflected. As the Council of Canadian Academies (2006) has shown, there are some fields in which Canadian scholars are known to have stronger publication records than their counterparts elsewhere in the world (notably psychology & psychiatry) and ones where our record is significantly weaker (notably engineering). While these results capture the publication culture among Canadian academics, they are no more than broadly indicative of differences in global publication cultures.

The second caveat is that while there are large differences across fields of study, there are also very large differences *within* fields of study. It is to this issue that we now turn.

Comparing Disciplines

The first step to creating a discipline-normalized bibliometric measure is to calculate average H-index scores for each discipline. Differences in discipline averages are, in essence, a measure of the differences in publication cultures. In this section we explore the differences in the H-index across disciplines, on a field by field basis. Later we demonstrate the use of discipline-normalized scores.

H-indexes in Sciences

Table 2 provide the average H-index score for each science discipline. The table also provides the institution with the highest H-index in that discipline, and the researcher with the highest H-index in the discipline in Canada.[16] Although the field average for sciences is 10.5, this figure hides an enormous amount of diversity across science disciplines. Environmental science and mathematics & statistics have lower H-indexes of between 6 and 7 – in fact, not enormously different than what we see in the more quantitative social sciences like economics. At the other end of the scale, however, Canadian astronomy and astrophysics (which has a somewhat anomalous publication culture where multiple authors are common) professors had a mean H-index score of 20.3.

The University of British Columbia has the top publication records in three disciplines, the University of Toronto and the University of Saskatchewan are top in two each, with Western, Alberta and Université de Montreal being top in one each. However, top researchers can also be found further afield, at the University of Manitoba (natural resource management) and Lethbridge (neuroscience).

[16] Note that in this table, and in all tables that follow, H-index averages are only reported in disciplines with at least 25 researchers.

Table 2: Mean H-index by Discipline: Sciences

Discipline	Mean H-index	Top Institution (score)	Top Researcher, institution (score)
Astronomy/astrophysics	20.3	U Toronto[17] (24.7)	Ray Carlberg, U Toronto (66)
Biology	13.4	UBC (20.5)	Robert E. W. Hancock, UBC (81)
Chemistry/biochemistry	11.9	U Toronto (21.2)	Stephen G Withers, UBC (68)
Environmental Science	6.7	U Saskatchewan (9.8)	John P. Geisy, U Saskatchewan (66)
Geology and Earth Sciences	9.5	U Saskatchewan (19.5)	Jan Veizer, U Ottawa (43)
Math/Stats	6.6	UBC (11.1)	
Natural resource management & forestry	9.1	U Alberta (14.4)	Kermit Ritland, UBC (41) Fikret Berkes, U Manitoba (41) (tie)
Neuroscience	11.3	UWO (15.9)	Ian Whishaw, U Lethbridge (58)
Physics	12.4	U de Montréal (21.1)	Ray Carlberg, U Toronto (66)
All sciences	**10.6**	-	-

H-indexes in Agriculture

In contrast to science, H-indexes within the agriculture field vary little across disciplines, ranging between 8.6 and 9.4. The University of British Columbia is the top university in two of three disciplines, and McGill in one, with Guelph and Manitoba also contributing some top researchers.

Table 3: Mean H-index by Discipline: Agriculture

Discipline	Mean H-index	Top Institution (score)	Top Researcher, institution (score)
Agricultural biology	9.4	McGill U (12.3)	Clarence Swanton, U Guelph (30)
Horticulture	8.6	UBC (16.0)	Tim A Mcallister, U Manitoba (33)
Nutritional sciences	9.2	UBC (14.1)	Errol B. Marliss, McGill U (51)
All agriculture	**8.9**	**-**	**-**

[17] Unless otherwise noted "University of Toronto" refers to departments at the St. George campus only.

H-indexes in Engineering

Rather like sciences, engineering disciplines show a wide dispersion of H-index means across disciplines. Biological engineering, for instance, has a mean H-index of over 13, rather like its cousin discipline of biology. Civic engineering, on the other hand, has an H-index of just 4.5, which is lower than the mean in social sciences. In terms of top institutions, University of Toronto and McGIll can each claim pre-eminence in two disciplines, while McMaster and Queen's can claim one each.

Table 4: Mean H-index by Discipline: Engineering

Discipline	Mean H-index	Top Institution (score)	Top Researcher (institution) (score)
Biological engineering	13.4	U Toronto (17.6)	Kullervo Hynynen, U Toronto (53)
Chemical engineering	9.7	McMaster U (19.7)	S. Zhu, McMaster U (40)
Civic engineering	4.5	Queen's U (9.3)	Peter Rasmussen, U. Manitoba (38)
Computer science, computer engineering, and electrical engineering	10.3	UBC (17.7)	Geoffrey E. Hinton, U Toronto (53)
Materials engineering	9.2	McGill U (13.0)	Bruce R Lennox, McGill U (33)
Mechanical engineering	6.1	McGill U (9.3)	Ravin Balakrishnan, U Toronto (45)
All engineering sciences	**8.5**	**-**	**-**

H-indexes in Applied Health Sciences

As noted earlier, our study was not able to include fields in medicine because of the difficulty in determining who constituted active faculty members. We were, however, able to look at applied health disciplines such as nursing, and kinesiology since these, for the most part, are administered in separate faculties. Where these disciplines are subsumed within the Faculty of Medicine, or where there are significant cross-postings with the Faculty of Medicine, our data may under-report the actual strength of these programs. We believe this is particularly a problem at the University of Toronto, but may affect other institutions as well. Data in this field of study should therefore be examined with more caution than data for others in this report.

These disciplines also show considerable diversity of publication culture. Nursing and dentistry have publication cultures similar to many humanities disciplines, while veterinary medicine looks more like an engineering discipline. Excellence in these fields appears to be spread relatively widely across Canada, with the University of Manitoba having the top scores in two departments, McGill, Waterloo, Saskatchewan and Guelph having one each, the University of Montreal having the top researcher in two disciplines.

Table 5: Mean H-index by Discipline: Applied Health Sciences

Discipline	Mean H-index	Top Institution (score)	Top Researcher (institution) (score)
Dentistry	3.4	McGill U (11.6)	Jeffrey Mogi, McGill U (42)
Kinesiology	5.8	U Waterloo (15.3)	Richard Hughson, U Waterloo (47)
Nursing	2.1	U Manitoba (8.3)	Lesley Degner, U Manitoba (30)
Pharmacy	5.8	U Manitoba (8.5)	Francoise M. Winnick, U Montréal (36)
Public health	5.9	U Saskatchewan (7.5)	Jack Siemiatycki, U de Montréal (37)
Veterinary medicine	7.4	U Guelph (8.5)	W. Allan King, U Guelph (36)
All health sciences (excl. medicine)	**4.9**	-	-

H-indexes in Social Sciences

There are a large number of disciplines within social sciences. Most of them have average H-indexes between two and five; however Economics at 6.0 and Psychology at 9.6 appear to have publication cultures nearer to those seen in the physical sciences. In terms of concentrations of academic talent, McGill, Queen's and UBC each come top in three disciplines, Montreal with two, with the other spots taken by Lakehead, Wilfrid Laurier and the University of Toronto. The Universities of Alberta and Western Ontario, as well as York, Dalhousie and Simon Fraser also show up in Table 6 due to the presences of some of the country's top researchers at these schools.

Table 6: Mean H-index by Discipline: Social Sciences

Discipline	Mean H-index	Top Institution (score)	Top Researcher (institution) (score)
Aboriginal studies	2.0	Lakehead U. (3.7)	Regna Darnell, UWO (14)
Anthropology	4.6	McGill U. (7.4)	Colin Chapman, McGill U. (23)
Criminology	3.2	U. de Montréal (7.0)	Paul J. Brantingham, SFU (19)
Culture and communications	2.2	U. de Montréal (5.4)	Andrew Feenberg, SFU (20)
Economics	6.0	UBC (13.2)	John Whalley, UWO (42)
Gender and women's studies	4.6	Queen's U. (7.5)	Geraldine Pratt, UBC (25)
Geography	5.1	McGill U. (9.9)	David Ley, UBC (36)
Law	2.8	U Toronto (6.9)	Rebecca Cook, U Toronto (26)
Linguistics	5.6	McGill U. (16.9)	Fred Genesee, McGill U. (44)
Political science /public policy	5.0	Queen's U.(9.5)	André Blais, U de Montréal (37)
Psychology	9.6	UBC (17.8)	Patrick McGrath, Dalhousie U. (61)
Religious studies	2.8	Wilfrid Laurier U. (4.0)	Michael Lambek, U Toronto (21)
Social work	3.7	UBC (6.5)	Jane Aronson, McMaster U. (19)
Sociology	5.2	Queen's U. (10.5)	Barry Wellman, U Toronto (59)
All social sciences	**5.2**	-	-

H-indexes in Business

Business has a similar mean H-index to social sciences, but the spread is considerably smaller. Unsurprisingly, the highest scores come in the economics-related disciplines, and the lower ones in the much more applied domains of administration and accounting. The University of British Columbia has the country's strongest departments in three of the six disciplines in this field, while Toronto, Dalhousie and Victoria each come top in one.

Table 7: Mean H-index by Discipline: Business

Discipline	Mean H-index	Top Institution (score)	Top Researcher (institution) (score)
Accounting	2.8	UBC (7.1)	David Cooper, U Alberta (28)
Administration	2.1	Dalhousie U (3.1)	Chris Robinson, York U (17)
Business economics	4.8	U Toronto (14.1)	Richard Florida, U Toronto (37)
Finance	5.3	UBC (8.6)	Randall Morck, U Alberta (42)
Management	3.6	UBC (14.7)	Henry Mintzberg, McGill U (58)
Marketing	4.2	U Victoria (8.3)	Joffre Swait, U Alberta (29)
All business	**3.8**	**-**	**-**

H-indexes in Humanities

As one might easily surmise from the literature on bibliometrics, average H-index scores in the humanities are low. Because books – which obviously take longer to write than articles – are a major form of scholarly communication in the humanities, scholars in the humanities tend to publish less frequently. Less well known is the fact that they also tend to be cited less frequently than other disciplines. In fact, roughly one-third of professors in humanities have an H-index of zero – meaning either that person is not published or (more likely) that their work has never been cited. (In the sciences, by comparison, about one-eighth have an H-index of zero).

In terms of top institutions in the humanities, the University of Toronto's St. George takes the top spot in Classics and History, while the Mississauga campus takes it in Language and Translation. Queen's has the top publication record in English/Literature and Philosophy.

Table 8: Mean H-index by Discipline: Humanities

Discipline	Mean H-index	Top Institution (score)	Top Researcher (institution) (score)
Classics	2.5	U Toronto (5.8)	Brad Inwood, U Toronto (13)
English/literature	2.0	Queen's U (5.0)	Henry A. Giroux, McMaster U (51)
Language and translation	1.4	U Toronto (Mississauga) (2.7)	Lynne Bowker, U Ottawa (25)
History	2.8	U Toronto (4.9)	Natalie Z. Davis, U Toronto (20)
Philosophy	3.6	Queen's (8.0)	Mario Bunge, McGill U (34)
All humanities	**2.3**	-	-

H-indexes in Design and Fine Arts

Architecture, design and fine arts are all clearly areas where the written word is simply not central enough to scholarly communication for bibliometric measures like the H-index to be especially useful; more than two-thirds of professors in these disciplines have H-indexes of zero.

Table 9: Mean H-index by Discipline: Architecture, Design and Fine Arts

Discipline	Mean H-index	Top Institution (score)	Top Researcher (institution) (score)
Architecture	0.9	U Waterloo (1.44)	Branko Kolarevic, U. Calgary (9)
Design/urban Design/urban Planning	2.6	McGill U. (6.3)	Cormack Gates, U Calgary (21)
All architecture & design	1.0	-	-
Art history	1.8	McGill U (3.7)	Richard Prince, McGill U (32)
Music	0.6	UBC (1.8)	Stephen McAdams, McGill U (24)
Theater	0.9	U Guelph (3.5)	Susan Brown, U Guelph (16)
Visual arts	0.7	U Toronto (1.8)	Rob Shields, U Alberta (17)
All fine arts	**0.8**	-	-

Calculation of Normalized Scores and Practical Implications

The mean H-indexes by discipline shown above measure the differences in publication culture among disciplines. Because these represent almost all Canadian researchers, they accurately measure how discipline affects H-indexes, when calculated using the specific methodology applied by this research. Mean H-index by discipline can then be used to calculate a discipline-normalized H-index score.

The normalized score is calculated by dividing each scholar's H-index by the disciplinary average. A researcher with a discipline-normalized score of one has an H-index equivalent to the average for his or her discipline. A score of two implies that the H-index is, on average, twice that of the discipline average. For example, a scholar working in a discipline where the mean discipline H-index is 10 who has an H-index of 9 would have a (discipline-normalized) standard score of 0.9.

Using a discipline-normalized H-index allows for a straightforward comparison across disciplines. It can also be applied to improve comparisons among groups of scholars where there are differences in the composition of disciplines. For example, imagine one wished to know which school, out of a group of research institutions, had the greatest research strength in the social sciences. Without field normalization, one can easily confuse an institution with a larger proportion of its staff working in disciplines with high mean H-index scores with an institution that genuinely has strength across a range of disciplines.

Illustrating this point, Table 10 below shows mean normalized and raw H-index scores for two groups of institutions. Within each group, the H-index scores have been discipline-normalized using the procedure described above. Group A shows scores in social sciences, while Group B shows scores in sciences. The rank ordering of the universities in the table changes depending on whether raw H-index scores are used, or discipline normalized scores are used.

Within Group A, Université de Montréal has a slightly higher normalized score than the University of Alberta, despite having a lower raw mean H-index. This reflects the high performance of Université de Montréal in several disciplines where publication culture is less active.[18] Similarly, in Group B, the University of Saskatchewan has a high normalized score than the University of Ottawa despite a less impressive raw H-index – again reflecting good performance in disciplines with less active publication cultures.[19] Emphasizing the point made earlier, all raw H-index scores in Group B are higher than those in Group A – but the normalized scores tell a different story. For example, relying on discipline-normalized H-indexes shows that on average, social science faculty at the University of Alberta have higher scores than science faculty at the University of Western Ontario despite a much lower mean H-index.

[18] Specifically, Université de Montréal scores highly in criminology and in communications – both disciplines with less active publication cultures, and lower mean H-indexes.
[19] Specifically, University of Saskatchewan performs highly in geology and environmental sciences – both disciplines with less active publication cultures, and lower mean H-indexes.

Table 10: H-index and discipline-normalized score: social sciences and sciences (select institutions)

Group A: Social Sciences only	Mean DN H-index*	Mean Raw H-index
University of Manitoba	1.15	5.63
McMaster University	1.16	6.74
University of Alberta	1.21	5.52
Université de Montréal	**1.22**	**4.59**
University of Waterloo	1.24	6.54

Group B: Sciences only	Mean DN H-index*	Mean Raw H-index
University of Western Ontario	1.14	12.17
Concordia	1.14	11.20
University of Ottawa	1.34	14.22
University of Saskatchewan	**1.36**	**11.56**
University of Toronto – St. George	1.60	17.72

* Discipline normalized

A similar calculation can be used to compare groups of researchers at a more detailed level, for example, comparing performance by discipline or by department. As above, using a discipline-normalized metric reduces the effect of differences in publication cultures. Table 11 provides an example where each discipline within the social sciences is presented for comparison. Instead of presenting the results of a particular university, the U-15 have been merged to illustrate the particular strengths of the U-15. The discipline-normalized scores show how the U-15 compare with the average of all Canadian universities. In all social science disciplines, the U-15, as a group, has above average H-indexes.

The disciplines with the highest mean H-indexes in the U-15 are psychology and economics. However, an examination of discipline-standardized scores reveals that the U-15 stand out more in environmental studies and criminology score, which have the highest normalized scores.

Table 11: Standardized score and H-index: social science disciplines, U-15 only

Discipline	Mean H-index	Mean DN*
Aboriginal Studies	2.72	1.33
Anthropology	5.73	1.24
Archeology	4.27	1.17
Criminology	5.06	1.58
Culture and communications	2.27	1.03
Development Studies	4.73	1.38
Economics	7.82	1.31
Environmental Studies	6.64	1.78
Gender and women's studies	6.23	1.37
Geography	6.93	1.36
History	3.26	1.16
International Relations	6.00	1.17
Law	2.93	1.03

Table 11 continued

Linguistics	6.51	1.17
Political science	6.20	1.25
Psychology	12.52	1.31
Social work	4.79	1.28
Sociology	7.10	1.37
Social sciences average	6.10	1.29

* normalized by discipline

Conclusion

This paper demonstrates that it is possible both to examine H-index scores within disciplines, and to create discipline-normalized H-indexes for interdisciplinary comparisons. The same approach can be applied to other bibliometric measures and be used to improve comparative metrics.

This is especially important for several common types of bibliometric comparisons. The first is international rankings, such as the Shanghai Jiao Tong *Academic Ranking of World Universities* (ARWU, or Shanghai Rankings, as it is colloquially known). In the 2011 edition, 20% of this ranking was determined by research output. This was measured by number of papers cited in Nature and Science, and papers indexed in Science Citation Index-expanded, and Social Science Citation Index (which were given double the weight of papers indexed in Science Citation Index-expanded). Another 20% was determined by "highly cited researchers in 21 broad subject categories."[20] The absence of discipline-normalization means that this ranking does not control for publication cultures and the biases that they can generate. As a consequence, institutions with more faculty members in highly productive disciplines have an advantage. This issue is not unique to ARWU – while some ranking systems break out their comparisons by field of study, none to date have implemented valid discipline-normalization.

Secondly, comparisons within institutions can be strengthened by discipline normalization. When institutions assess the relative performance of academic departments or units, often as part of unit review processes, using accurate discipline-normalization to control for publication culture provides a more valid comparison.

Lastly, bibliometrics are increasingly applied to hiring decisions within universities. When candidates' fields of study differ (as would be the case for a dean of science, for example), discipline normalization helps to ensure that the hiring committee understands differences in publication records (and corresponding H-indexes) in the context of differences in publication cultures.

It's time for applications of bibliometrics to become more sensitive to publication culture. Just as importantly, users of bibliometrics need to be aware of the dramatic biases that publication culture can generate. We hope that this paper inspires both scholars and professionals to use accurate and normalized measures when applying bibliometrics to their research, assessment, and decision-making activities.

[20] Academic Ranking of World Universities. 2011. *Methodology.* Accessed online on 12/06/2012 at http://www.shanghairanking.com/ARWU-Methodology-2011.html

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Appendix A

Acadia University
Algoma University
Athabasca University
Bishop's University
Brandon University
Brescia University College
Brock University
Canadian Mennonite University
Cape Breton University
College Universitaire de Saint-Boniface
College Universitaire Dominicain
Concordia University
Concordia University College of Alberta
Dalhousie University
École de Téchnologie Supérieure
Emily Carr University of Art and Design
First Nations University of Canada
Grant MacEwan University
Huron University College
King’s University College
King's Universtiy College at the University of Western Ontario
Kwantlen Polytechnic University
Lakehead University
Laurentian University
Laurentian University of Sudbury
Lethbridge University
Luther College
McGill University
McMaster University
Memorial University of Newfoundland
Mount Allison University
Mount Royal University
Mount Saint Vincent University
Nipissing University
Ontario College of Art & Design University
Queen's University
Royal Roads University
Ryerson University
Simon Fraser University
St. Francis Xavier University
St. Thomas University

The King's University College
Thompson Rivers University
Université de Montréal
École des hautes etudes commerciales de Montréal
Université du Québec à Chicoutimi
University of Alberta
University of British Columbia
University of British Columbia-Okanagan Campus
University of Calgary
University of Guelph
University of Lethbridge
University of Manitoba
University of New Brunswick
University of Northern British Columbia
University of Ontario Institute of Technology
University of Ottawa
University of Prince Edward Island
University of Regina
University of Saskatchewan
University of Sherbrooke
University of the Fraser Valley
University of Toronto-Mississauga
University of Toronto-St. George
University of Victoria
University of Waterloo
University of Western Ontario
University of Windsor
University of Winnipeg
Wilfrid Laurier University
York University

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