Seeing Impact: genres referencing journal articles

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Abstract

This paper examines the societal impact of research from the perspective of interconnected genres. Information reaches professionals outside academia through many different types of documents. Those documents often connect with scholarship by referencing academic work, mentioning professors, or publishing articles authored by scholars. Here patterns of referencing journal articles are compared across professional genres. Such citation counts make visible societal impacts to the extent that a field engages a genre, and different genres favor different fields. Biomedical sciences are most visible in patent citation counts. News and social media most often reference medicine. Policy documents make heavy use of social science. Ulrich's indexing of trade journals, magazines, and newspapers suggests social sciences engage heavily with the professions through trade press. However, caution is warranted when using citations to indicate societal impact. Engagement with scholarship occurs not only through referencing but also through authorship and mentions. Not all citations indicate substantive engagement, particularly in social media. Academic literature is but one of many types of sources referenced in professional genres. And scholarship engages with many genres beyond those currently indexed, most notably trade press. Nevertheless, understanding citation patterns across heterogeneous professional genres offers a promising frontier for information sciences to provide a foundation for the analysis of scholarship's societal impact.

Keywords

Societal impact, patents, Twitter, Facebook, newspapers, genre, policy, Overton, PlumX, citations

Introduction

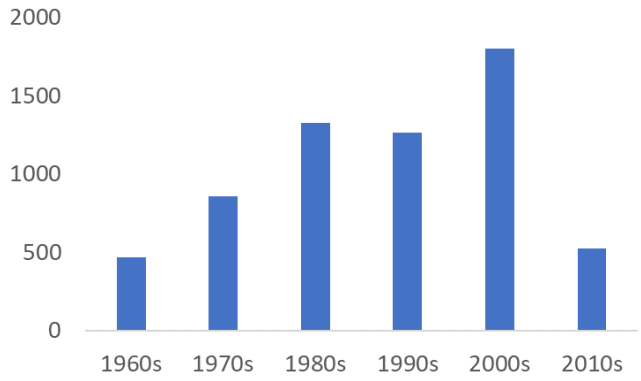
Increasingly, researchers, universities, and funders are interested not just in the scholarly impact of research but also the broader societal impact. Bibliometricians have responded by analyzing how often research articles are cited in genres other than journal articles. Mendeley uploads and Tweets linking to journal articles have been counted. References to journal articles have been counted in: trade press (Van Steijn andRip, 1988; Nederhof and Meijer, 1995), blogs (Bornmann, 2015), newspapers (Begum et al., 2016), regulatory impact analyses (Desmarais and Hird, 2014), policy documents (Bornmann et al., 2016; Pinheiro et al., 2021; Szomszor & Adie, 2022; Vilkins & Grant, 2017), clinical trials documents (Thelwall and Kousha, 2016) a drug information database (Thelwall et al. 2017) and clinical practice guidelines (Grant et al. 2000; Kryl et al. 2012; Lewison & Sullivan, 2008; Thelwall and Maflahi, 2016). Counts of references in these documents are used to signify broader societal interest in research output.

These analyses tend to examine one type of source, or genre, using one database and explore constructing indicators of broader impact using that source. The number of genres explored across these studies suggests a bigger picture awaits exploration. Shifting focus from the counts to the genres highlights the many different types of documents through which information reaches professionals outside academia. Those documents often engage with scholarship and record that engagement using references. This paper examines the pattern of referencing across genres as well as evidence of the complexity of genre intertextuality. That is, I examine the societal impact of research from the perspective of interconnected genres. Professional information genres are the frame of reference, and their interconnection with scholarship is the phenomenon of interest.

Background

Sources of information have proliferated over the past century, with ever more scientific journals being published, and ever more newspapers, magazines, and patents appearing. The advent of digitization about twenty years ago accelerated expansion. The internet challenged existing periodicals to adapt and build a digital presence. As well, new sources and new genres multiplied. In the dental trade press, print magazines were joined by digital forums, commercial news websites, news aggregators, and independent bloggers (Hicks, Isett & Melkers, 2019). Facebook and Twitter were established and became another way for professionals to share technical information with the added possibility of conversation and engagement with a broader audience. Ulrich's indexes trade press journals and magazines, and Figure 1 displays the number of trade press journals, newspapers, and magazines established in each decade since the 1960s. The trade literature expanded every decade, with the strongest growth in the 2000s, more than double the growth rate in the 1970s and 2010s, suggesting digitization took off during those years.

Figure 1 *Number of US trade journals established in recent decades*



Source: Ulrich's web[1]

The internet has revolutionized the accessibility of every genre. Of course, Twitter and Facebook were established as platforms to post content accessible to all. Subscription trade press and newspaper articles are now findable and often readable one at a time without paying. Ad-supported news sites, both trade press and mass media, are open to all. The patent database used to be accessible to specialists who acquired physical copies of the tapes containing the database. Now the patent database is online, searchable through Google, and readable by everyone. The National Academies removed the paywall from their reports in 2011, and now about half of report use traces to the general public, i.e. those outside teaching and university research (Hicks et al., 2022). Governments and think tanks post their policy reports online for anyone to read for free. The Overton database of policy documents shows strong growth in the number of documents indexed over time likely because digitization has made policy documents much more accessible[2]. The expansion in numbers and genres of professional information sources and the reduction in barriers to accessing them has revolutionized professional information systems, which are much more complex, accessible, and used than even 20 years ago.

Professional information genres are not self-contained. Referencing is primarily associated with journal articles; indeed, almost all scholarly journal articles contain references. Most links between documents are to other documents of the same genre. Thus, journal articles primarily reference other journal articles, and patents primarily reference other patents. Therefore, most analytical attention is devoted to characterizing the networks these links establish between documents. However, referencing is found throughout professional genres. Though not all items contain references, some do, and among those, some contain references to scholarly journal articles.

Therefore, the proliferation of professional information genres in recent decades offers ever-expanding opportunities to analyze the links between documents, though analysis is challenging in the absence of comprehensive indexes. Of course, well-established, high-quality databases - Scopus, Web of Science, Dimensions, and PubMed -track the expanding scholarly literature. And patents have always been

[1] Search for: Status:("Active") Serial Type:("Journal" "Magazine" "Newspaper") Content Type:("Trade") Language of Text:("English") Format:("Print" "Online") Country of Publication:("United States")

[2] Therefore, it is impossible to discern the contribution to perceived growth originating in the number of reports produced versus the increased posting of reports on the internet (Szomszor & Adie, 2022).

indexed, so our understanding of the impact of scholarship is heavily shaped by the analysis of patent referencing. The expanding digitization underpinning the proliferation of genres also enables indexing. Databases such as Altmetrics, PlumX, and Overton were founded to index references in social media and policy documents, and the picture they provide of research impact differs. The indexing of references to journal articles originating in other media opens up analytical opportunities to identify the research of most interest to different audiences. Taking advantage of these indexes, this paper compares referencing to journal articles in trade press, policy reports, news, blogs, Twitter, and patents. These patterns are compared with two other indicators of public interest in research, downloads of journal articles and UK REF impact cases.

Genres referencing journal articles

Many genres reference research, but genres' goals differ, and therefore they reference for different reasons. Genres also differ in their pattern of referencing across scientific fields, indicating that audience interests vary. In what follows, I characterize professional genres referencing scholarship and their pattern of referencing journal articles.

To represent each genre, I provide sample titles. The titles concern a single topic, a dental imaging technique called cone beam computed tomography (CBCT). In CBCT, an X-ray source rotates around the patient's head, obtaining hundreds of distinct images, which software compiles into a three-dimensional image. The first CBCT scan was taken in 1994, and the first dental CBCT paper appeared in 1998. In 2001 the FDA approved the first CBCT scanner for the US market. Use in US dentistry took off only in 2006-07 (Schulze 2015), marked by the first sessions on CBCT at the American Dental Association national conference (Hicks, Melkers & Isett, 2019).

First, I set a baseline with the pattern of referencing in Scopus which is then contrasted with the pattern of referencing in news and social media, patents, policy documents, and trade press. Counts report citations to/mentions of papers published in 2018 or after. Cited fields are aggregated into five high-level categories: life sciences, including agriculture and molecular biology; health, including medicine and allied health professions; physical sciences, including chemistry, engineering, computer sciences, and environmental sciences; social sciences, including economics and psychology; and multidisciplinary journals.

Journal articles

Journal articles exist to communicate research results to the scholarly community and serve as the output of research projects. Although a blog could serve the same purpose, authors value the additional services journals provide which include peer review to certify that an article is worth reading, editorial oversight to certify for readers that these complex documents meet minimum standards of legibility, findability in indexes and search, registration or independently associating a discovery with an author and a time, and keeping the article available in perpetuity. Journals are, in addition, being asked to certify an expanding list of article characteristics on behalf of readers: that the authors actually performed the research, that text isn't plagiarized, that images are not manipulated, that research was conducted ethically, that the underlying data are available to interested readers, and so on.

Journals vary in their relationship to non-scholarly use of research. This is easily seen in a research area closely connected to professional practice, dentistry. Table 1 shows titles from four dental journals. The first two specialist journals serve dental researchers and are indexed in the Web of Science. In contrast,

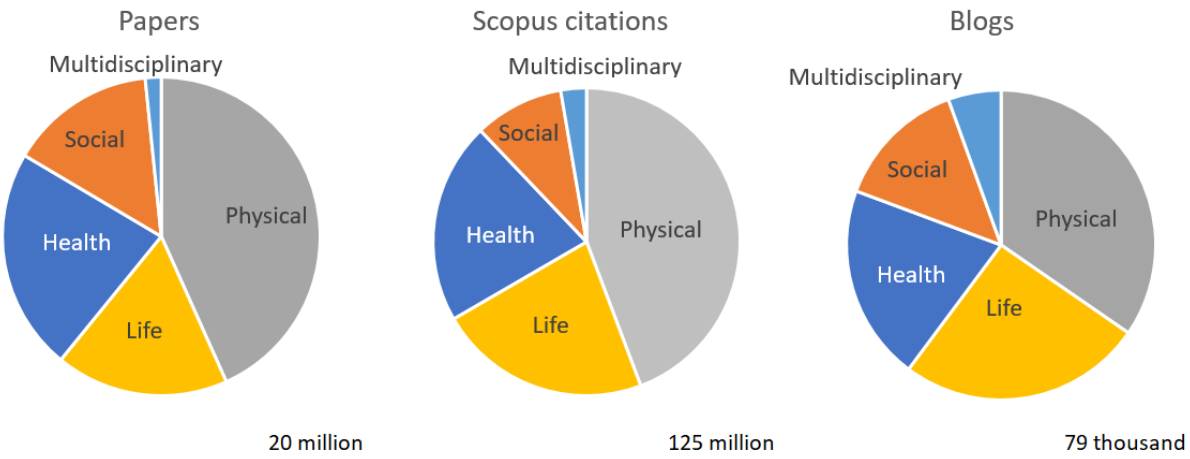
General Dentistry and *Journal of the American Dental Association* (JADA) also serve dentists in practice and are indexed in PubMed only. Titles in the two specialist journals exhibit precision and technical complexity in their language use, in this case anatomical vocabulary, concern with technique – sialography - and with measurement. Using CBCT to obtain measurements of variable jaw geometry and ascertain ranges in the population was a prominent topic in the academic CBCT literature. In contrast, *General Dentistry* and JADA use anatomical vocabulary that overlaps with general vocabulary – for example, "teeth" and address their readers' concern with care – diagnosis and treatment.

Table 1 *Journal article sample CBCT titles*

Journal	**Sample Article Title**
Journal of Oral and Maxillofacial Surgery	CBCT and SimPlant Materialize Dental Software Versus Direct Measurement of the Width and Height of the Posterior Mandible: An Anatomic Study
Dentomaxillofacial Radiology	CBCT sialography of Stafne bone cavity
General Dentistry	CBCT for diagnosis and treatment planning of supernumerary teeth.
JADA	CBCT and the ortho-surgical management of impacted teeth.

The distribution of references in journal articles across scientific fields depends on both the number of papers in a field and how long reference lists are in a field. Figure 2 displays the distribution of scholarly papers and citations across fields, with the total number of papers and citations recorded in the lower right corner. The physical sciences have the largest presence in Scopus. Health and biomedical sciences together would be comparable to physical sciences

Figure 2 *Academic pattern of referencing: the distribution of (1) papers indexed in Scopus, (2) the citations to those papers, and (3) the blog mentions referencing those papers across disciplines.*



Note: Total counts of the entities are included. Publications and citations/mentions may be applicable to multiple disciplines.

Interpretation of the pies also depends on the structure of the classification system. The next level of the hierarchical field classification scheme contains 27 fields. If the pies displayed 27 fields, medicine, with 14% of Scopus citations, would account for the largest share, because at the 27 field level medicine accounts for 88% of the five fields comprising health sciences (the others are nursing, health professions, veterinary, and dentistry). Oncology, infectious diseases, epidemiology, 49 subfields in total (more than double the number of any other field) are not split out at this level. In contrast, engineering, the largest component of physical sciences, accounts for only 18% of physical sciences because materials science, physics, chemistry, and computer science are split out at the 27 field level. The same is true of all the pies discussed below; that is if the pies displayed 27 fields, medicine would account for the largest share.

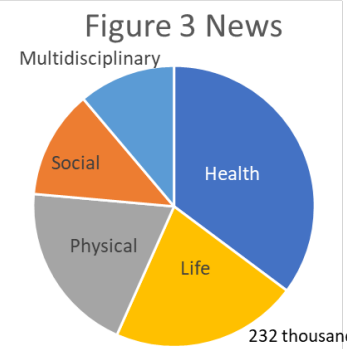
The pattern of referencing from blogs is also shown in Figure 2, as it is almost identical to the pattern in the scholarly literature, with physical sciences accounting for the largest share of citations from blogs, followed by life and health sciences. Medicine accounts for 13%. This might suggest that blogs referencing scholarly literature are primarily written by academics.

Public interest

Newspapers seek to entertain, educate and inform the public about current events. Items are news to the extent they have a big impact, involve conflict, happen nearby, involve well-known people, and deviate from everyday happenings. Current research advances sometimes meet these criteria, providing newsworthy items. For example, CBCT met these criteria once for The *New York Times*. The headline in Table 2 shows why; there was something to worry about. The article questioned the increasingly widespread use of CBCT, particularly in orthodontics for children, because CBCT delivers a higher radiation dose than traditional dental x-rays (Bogdanich and McGinty, 2010).

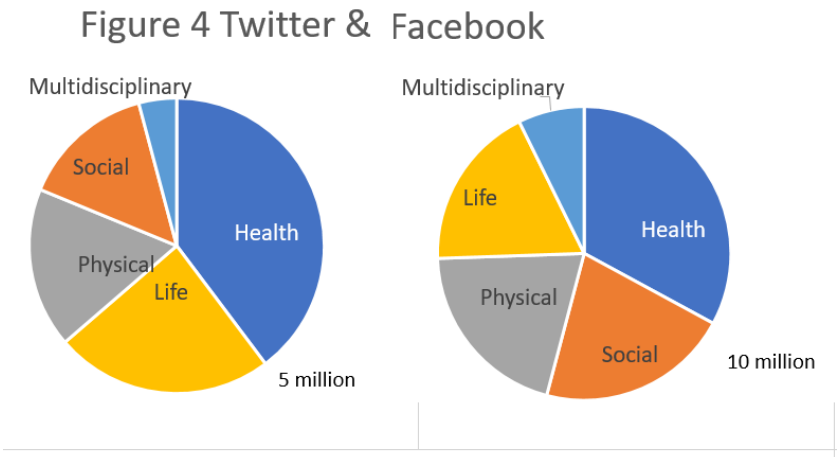
Table 2 *News and social media sample CBCT article titles*

Genre	Publication	Sample article title
Newspaper	New York Times	The radiation boom: radiation worries rise with 3-D dental images
Social media	Twitter	CBCT-based #root-canal length measurements are accurate and reliable when compared with a gold standard. [URL] #endodontic
		[URL] CBCT X-rays should not be done on every patient. At this point there is too much radiation. Impactions yes #majeroni



Advances in medicine are most often seen as newsworthy, garnering the most coverage, and accounting for over 34% of citations from news sources to journal articles (with 1% more coming from the other health sciences fields), Figure 3. Physical and life sciences each account for over 20% of news citations, with social and multidisciplinary each accounting for slightly more than 10%. Papers in multidisciplinary journals received outsize attention from newspapers as multidisciplinary journals such as *Nature, Science,* and *PNAS* publish and publicize the most dramatic scientific advances with the broadest implications. In addition, journalists often use academics as sources to provide context and depth to coverage of current events.

Facebook and Twitter exhibit different patterns of interest. Twitter is used to learn about fast-moving news, build awareness of information and build celebrity. In this environment, current research advances provide newsworthy and comment-worthy content. Of tweets referencing CBCT journal articles, 70% simply provided the paper's title and URL, which accurately reflects tweeting about dental journal articles in general (Robinson-Garcia et al., 2017). Table 2 lists other tweets that more usefully convey the conclusions of papers. Figure 4 shows that on Facebook and Twitter attention seems to be more evenly distributed across the four scientific areas, with health sciences garnering the most interest. Medicine accounts for 38% of references to journal articles on Twitter and 30% on Facebook. On Twitter life sciences, which is closely linked to health sciences, follow whereas on Facebook social sciences, which include psychology, is the second most referenced scientific area.



Note: Total counts of the mentions are included. Publications and so mentions may be applicable to multiple disciplines. Source: PlumX data supplied by Elsevier's ICSR Lab

Figure 5 - Harvard DASH respository

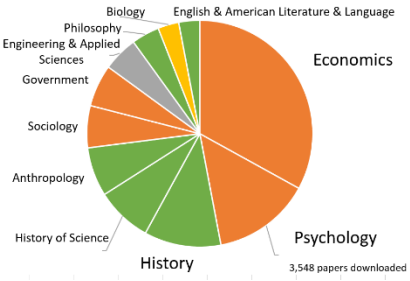


Figure 5 provides another view on public interest as revealed by comments left by people using gmail and ISP email accounts when downloading journal articles from the Harvard Dash repository. Here we see heavy interest in social sciences, primarily economics, as well as humanities. The fields portrayed here make up 99% of downloads but only 50% of papers in the repository (Doshi, 2023, table 5.1)

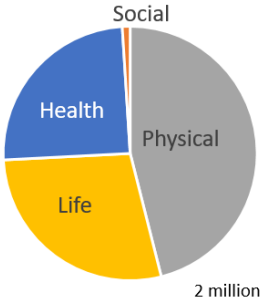
Patents

The classic measure of research use is referencing from patents. Patents protect inventions by awarding property rights to inventors. In return, they reveal knowledge of how an invention works. The patent office mandates that patent titles are short, accurate descriptions of the invention useful for indexing, classifying, and searching. Patent examiners will remove certain words from titles, including new, improved, and novel[3]. Although inventors may not wish to reveal their technical advance in the widely viewed title, patent titles are specific, technical, and convey the purpose of the invention, Table 3.

Table 3 *Patent and policy document titles*

Genre	Title
Patent	Methods and apparatus for super resolution scanning for CBCT system and cone-beam image reconstruction
	Method for teeth segmentation and alignment detection in CBCT volume
Policy Report	Cone beam CT for dental and maxillofacial radiology: evidence-based guidelines. (Directorate-General for Energy - European Commission)
	The Use of Cone Beam CT in Dental, Oral, and Maxillofacial Surgery, and Otolaryngology Settings (Canadian Agency for Drugs and Technologies in Health)
	Compliance Guide for Dental Radiology including Dental Cone Beam CT (New Zealand Ministry of Health)

Figure 6 Patents



Source: NSF Science and Engineering Indicators 2022 Table SINV-82

References in patents identify prior art, serving to establish the required novelty of the invention given prior art. Patent citations are taken to represent use of research in innovation. USPTO patents exhibit the highest rates of referencing to journal articles, and the first pie in Figure 6 reports referencing to journal articles in USPTO patents issued 2018-2020. The pattern of referencing from patents to scholarly literature is similar to that of referencing between journal articles in Scopus with physical sciences accounting for the greatest share, followed by life and then health sciences. The presence of social science is much reduced in patents compared to the journal literature. Thus life and health sciences are more visible, accounting for more than half of patent citations.

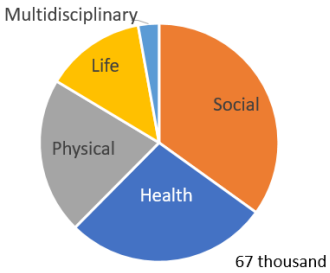
[3] https://www.uspto.gov/web/offices/pac/mpep/s606.html

Policy documents

Policy documents are written primarily for or by policy-makers and are intended to influence legislation, regulation, or other policymaking.[4] Policy documents are a heterogeneous genre system containing, for example: blog posts, forms, infographics, legislation, meeting agendas, meeting minutes, memos, policy briefs, posters, press releases, slide decks, speeches, and testimony. Policy reports help prepare policy-makers for legislating or regulating by teaching them about an issue and possible approaches to governing it. They help shape agendas and narratives around issues of concern.

Policy reports aim to cover technical topics for non-specialist audiences comprehensively. Therefore, their contents cannot be summarized in a title, and report titles are reduced to conveying topic areas. Table 3 shows three CBCT-related policy report titles. The titles are generic, establishing the association with CBCT and a concern with regulation but little else. In fact, readers may need to know the source of the document to motivate reading, so Table 3 also lists the authoring agency. The EU doesn't regulate dentists, so it aims to provide guidelines consistent with minimizing radiation exposure and a guide to future research, which the EU funds. The Canadian report establishes background knowledge to inform the regulation of manufacturers. The New Zealand document advises clinicians and manufacturers on meeting the requirements of radiation protection legislation.

Figure 7 Policy Documents



Policy document citations to Scopus-indexed papers. PlumX data supplied by Elsevier's ICSR Lab

Policy reports are written by university-trained writers. Presumably, universities trained writers in referencing, suggesting referencing in reports serves the classic purposes of avoiding plagiarism, providing resources to readers, and enhancing the text's credibility. Figure 7 suggests that policy-makers' attention is directed very differently than the public's. Policy documents, likely mostly reports, most heavily reference social science literature, which includes economics and accounts for 37% of references. Health and physical sciences follow with 24% each. Life sciences attract less interest from policy documents than from any other genre.

Trade journals, news & blogs

The professional press provides news relevant to the practice of a profession and, in many fields, continuing education opportunities. The distinction between journals and trade magazines is not always clear cut. Two of the trade magazines in Table 3, *Compendium* and *Dentistry Today,* are partially indexed in PubMed. Professional magazines contain articles analogous to those in peer-reviewed journals as well as articles on topical subjects, news items, reviews, and surveys. Magazines and news sites are supported by advertisements targeted to those in the field. Unique to professional media is the product announcement. New or improved materials and equipment are introduced continuously and announced in press releases. Professional media undertake to inform their readership of these developments. Professional channels also seek to inform readers of upcoming conferences and report on highlights of recent conferences for those who could not attend.

[4] https://help.overton.io/article/whats-your-definition-of-a-policy-document/

Table 4 *Professional magazine, news, and blog sample CBCT titles*

Genre	Publication	Sample Article Title
Magazine	Compendium	CBCT in endodontics: are we there yet?
	Inside Dentistry	CBCT: A Clinician's Perspective
	Dentistry Today	Utilizing Digital Imaging to Enhance the Team Approach to Implant Treatment
News website	Dr Bicuspid	Conebeam and multislice CT measurements found equally accurate
		CBCT findings raise liability questions
Blog	Endo blog	Uses of CBCT in Endodontics CBCT in Endodontics to Treat Difficult Anatomy, Preserve Teeth
	dentaltown	Cone Beam Imaging is Great, But What Am I Looking At?
	Flucke blog	Thanks to Everyone Who Attended my Ultradent 3D Course Yesterday
		We've installed the Gendex CB500

Table 4 shows that in contrast to journal articles, patents, and policy reports, articles in professional media have a more informal style and cover less technical sides of practice. In comparison with the general dentistry journals, the magazine article titles in Table 4 deepen the concern with practice, explicitly taking the perspective of one who is a team manager as well as a clinician and asking if the innovation is ready for application. Magazine titles offer enticements to read – promising to answer a question or sharing the reader's perspective.

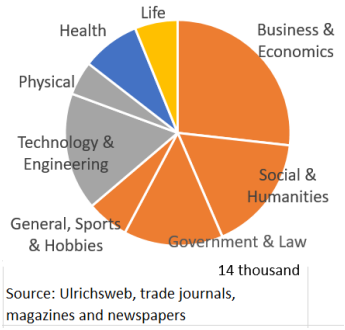
Professional news sources aim to deliver practical, trustworthy, and relevant material to professionals to help them improve their practice and profitability. They rely on experts, cover widely discussed issues about which there is disagreement, as well as professionally relevant new social and technological trends. In contrast to magazine article titles, the news titles provide the takeaway up front with the article furnishing details for those interested in learning more. The sample titles from professional news source *Dr. Bicuspid* report findings in the journal literature on measurement accuracy and discuss liability, a business issue.

Most professional blogs do not reference research. The blogs in Table 4 vary in their approach with the first being more professional, almost magazine-like, and the others being extremely informal and chatty. Blog titles reveal an even stronger practitioner focus, firmly grounded in the dentist's point of view.

Professionally oriented blogs, news sites, and magazines differ in publishing models and content. Publications source articles differently, value different types of information and vary in their presentation. Important values such as technical sophistication, the credibility of peer review, grounding in the realities of clinical practice, and being attuned to shifting pressures in dental care are accommodated to differing degrees in different channels. Each channel disseminates information to practicing dentists about advances in knowledge and information about the profession and management of a practice. Although their reliability is not held in high regard, empirical analysis

suggests that information in professional media may be as accurate as peer-reviewed literature where it overlaps (Hicks et al. 2019).

Figure 8 Trade press



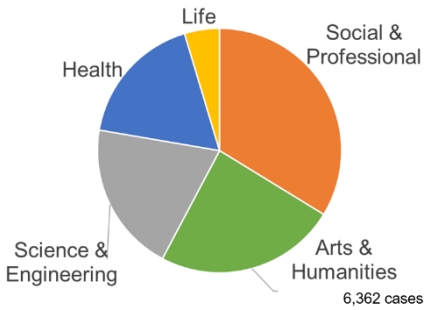
Source: Ulrichsweb, trade journals, magazines and newspapers

Figure 8 reports the distribution of trade journals, magazines, and newspapers published in the United States as indexed in Ulrich's. In contrast to the other pies, social sciences account for 64% of trade journals, with business & economics alone accounting for 27%. The references in peer-reviewed articles in trade journals indicate that the author may have read the journal article, and it shaped their thinking, i.e. knowledge flow. References in the trade press are not indexed, but the author's analysis of trade press indexed in Scopus suggested that the distribution across fields of references from the trade press mirrors the distribution of titles across fields. That is, business and economics trade journals likely cite mostly business and economics journal articles. Scopus does index some trade press content, though the distribution differs with half of Scopus-indexed trade journals and magazines in engineering. 28% of trade press articles indexed in Scopus contain references, with articles averaging 15.6 references, half of which are indexed in Scopus (Elsevier, 2022).

UK REF impact cases

A final genre, not usually thought of as such, are the case studies written for the UK university assessment of societal impact. Like other genres examined here, these documents reference journal articles. However, they are unusual in being authored by university researchers to make visible the societal impact of their work. In 2021, one of these cases mentions CBCT. Its title is: Bayesian approaches to X-ray imaging for material inference, dose reduction and improved image quality. Again we detect concern with the higher radiation dose of CBCT compared to other types of dental x-ray.

Figure 9 *Field distribution of UK REF impact cases*



Each case is assigned to a field so that it can be read by the appropriate field committee. Figure 9 shows the distribution across fields of 6,000 cases written for the 2021 REF assessment. As with trade journals above, this is not a distribution of citations but a distribution of documents. Because every UK university department is required to participate in this exercise and the number of cases they submit is proportional to their size, this is the only source that provides a comprehensive mapping of societal impact across disciplines. In figure 9 social and professional fields comprise the largest slice. Most unusual is the appearance of the arts and humanities. It is even possible to see the societal impact of philosophy by reading REF impact cases.

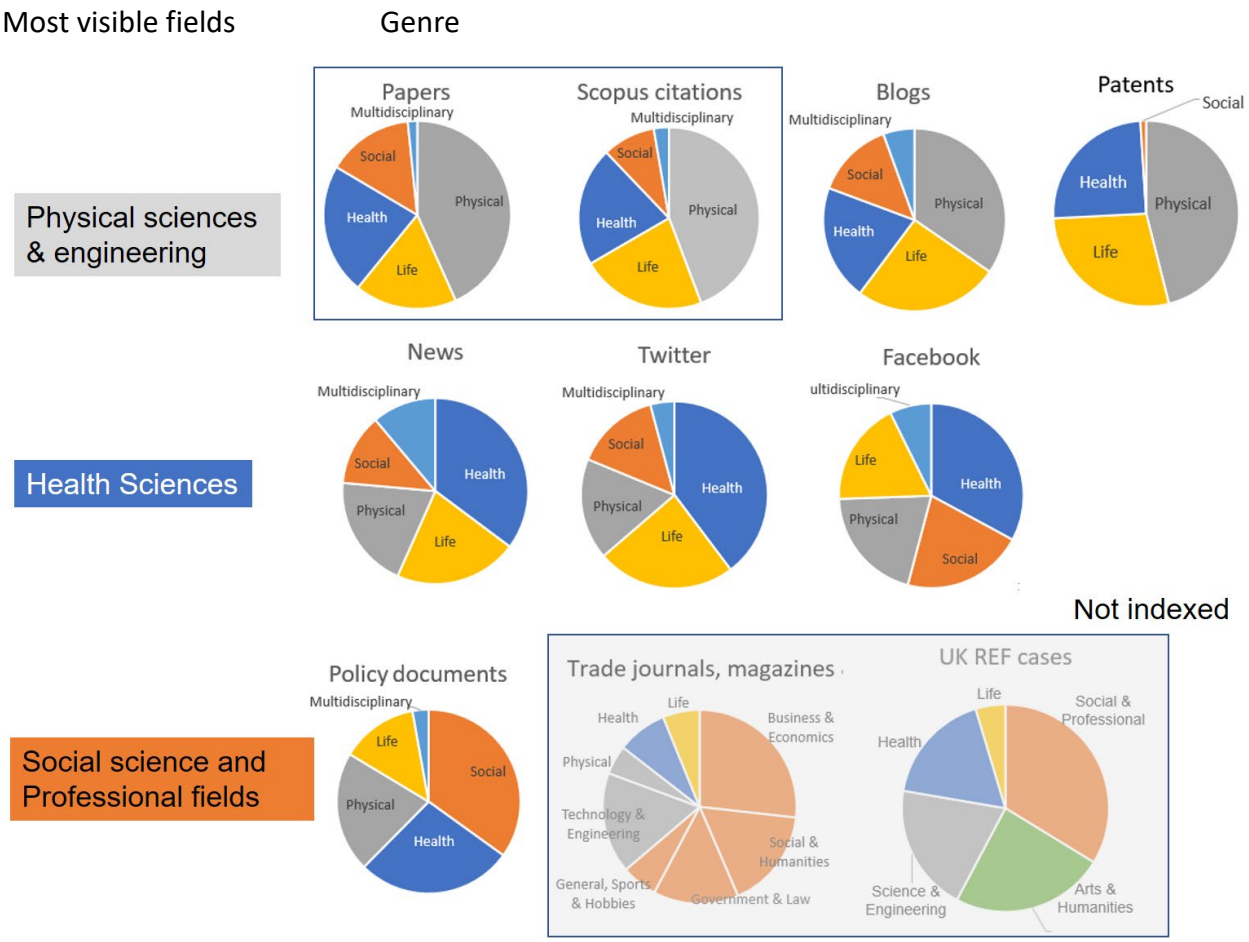
Whose impact do we see?

Journal articles, patents, trade press, policy reports, newspapers, and social media provide information for different purposes and more or less often use references to journal articles to support those goals. From a researcher's perspective, citations from other genres suggest their work is helpful to people outside academia, hinting at societal impact. Therefore counting citations from other genres has

attracted increasing attention in recent years, and developing databases to make such counts possible has become a viable business proposition.

Such citation counts make visible societal impacts to the extent that a field impacts a genre. Different fields are relevant to different parts of society. For example, while some industries may rely heavily on trade secrecy, chemistry and pharmaceuticals are very well served by the patent system, and advances in these technologies are quite closely related to advances in research. Therefore, biomedical sciences are most visible in patent citation counts. Patent-to-paper citation counts have been available for several decades, having first been analyzed in 1997 (Narin et al., 1997). When only patent citation counts were available, only biomedical sciences and, to a lesser extent, physical sciences seemed to be applicable outside academia. In 2011 Plum Analytics and Altmetrics.com were founded, making it possible to count citations from news and social media sources. These sources quantitatively confirm the intuitively obvious public interest in medical advances. Only in 2019, with the founding of Overton.io, did it become possible to see the heavy use of social science outside academia in a comprehensive, analytical fashion. An unindexed pool of references remains in the trade press. Ulrich's indexing of trade journals, magazines, and newspapers suggests even more engagement occurs here between social sciences and society, specifically with professionals, and would be visible in referencing patterns. Figure 10 summarizes this argument by compiling all the pie charts into one diagram.

Figure 10 *Summary of reference distribution across fields in each genre*

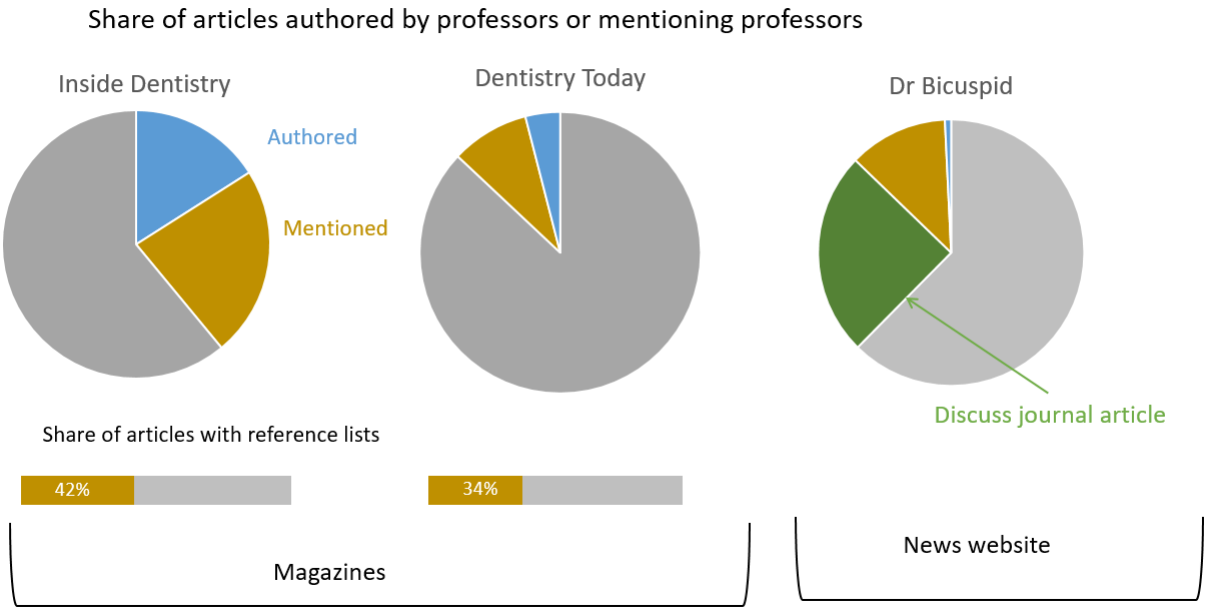


The visibility accompanying citation counts helps researchers and universities being evaluated on their societal impact. But beyond that, such visibility supports arguments that the money government spends on a field helps society. It is important to remember that field visibility varies across genres and that we have blind spots corresponding to unindexed genres. Even beyond that, there are societal engagements that do not register in documents of any type. Such impact can only be seen comprehensively in collections of case study narratives like those provided by the UK REF exercise. Citation indexes make citation counts possible across many more genres, but those numbers do not account for everything.

Caveat: Interaction is more than just referencing

Genres interact not only through referencing but also through authorship and mentions. Academics are listed as inventors on some patents. They host blogs, tweet, and post professional information on Facebook. Academics also author policy reports and white papers. Particularly in the social sciences, enlightenment literature can be considered one of the four kinds of literature through which knowledge is advanced and disseminated (Hicks, 2004). Enlightenment literature is a term used to denote periodicals dedicated to knowledge transfer to non-specialists, i.e. non-scholarly literature. Social science builds on enlightenment literature; 67% of references in social science articles are to literature outside Scopus (Elsevier, 2019, Figure 4). Studies have found that one-quarter of publications of social science university departments were in the enlightenment literature, or periodicals not indexed in the social science citation index (Hicks, 2004). Therefore, academics will author articles in the *New York Times* (Hicks & Wang, 2013) and in the trade press. In dentistry, several prominent authors with more than 100 papers indexed in Medline authored articles in dental magazines and on news sites. Professors who also write for the professional literature can serve a valuable role in diffusing state-of-the-art knowledge into practice (Hicks, Melkers & Isett, 2019).

Figure 11 *Appearances by academics in professional media vary with editorial policies*



Newspapers and trade press quote professors to provide context and depth to coverage of current events. In addition, professors' work is occasionally newsworthy enough to merit an article discussing a just published peer-reviewed journal article. The *New York Times* mentioned academics in 24% of articles in 2011[5]. Similarly, *Inside Dentistry* quoted professors in one-quarter of its articles. Combined with the 16% of articles authored by professors, almost 40% of articles involved academics. The news website Dr. Bicuspid quoted professors in 16% of articles (Hicks, Melkers & Isett, 2019). Figure 11 illustrates the extent of multiplex interaction with scholarship across professional dental literature, involving not just referencing but also authorship and quotation/mentions, and suggests that differing editorial policies influence interaction.

Caveat: Citations should be weighted

If we interpret appearance in another genre as use of research, it behooves us to consider how much the encounter in another literature engages a reader with the research. Perhaps the most substantial engagement is offered by articles about a research advance. Newspapers such as the *New York Times* or the *Economist* will write articles explaining recent discoveries of broader interest. As Figure 11 shows, professional news sites will also write articles about recent advances reported in the scholarly literature. In this way, broader audiences learn a great deal about a recent advance. Scholars who author articles in enlightenment or professional literature convey knowledge informed by their research to wider audiences. If use of research includes advancing public understanding of the world we live in, then such broader coverage achieves use.

Referencing also implies a substantive knowledge flow, if not between the scholarship and the broader audience, then between the author of the enlightenment or professional article and the scholarship. Similarly, references from patents to papers establish substantive use. Patent references legally delineate prior art, meaning that the invention offers a novel advance beyond what was reported in the referenced paper. Such references are taken to indicate knowledge flow between the researcher and the inventor. References in enlightenment and professional literature might suggest that the article's author read and used knowledge learned from the referenced paper; therefore, such references could indicate knowledge flow.

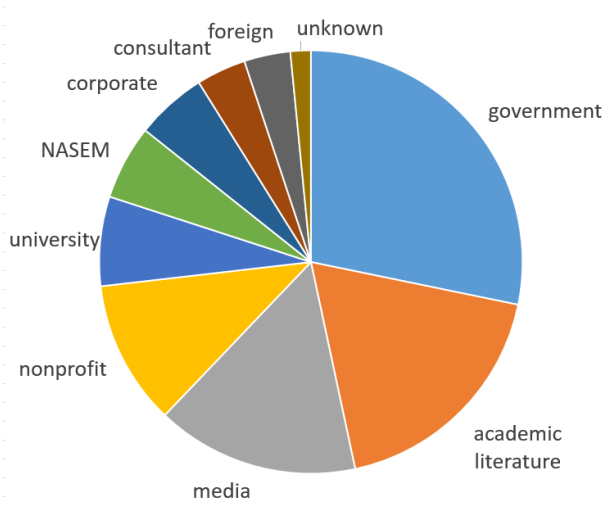
Mentions of professors in news or professional articles seem to be a weaker link. The article's author presumably contacted the professor to provide context and background to the issue discussed. This seems less like knowledge flow than an acknowledgment of the professor's credibility as a pundit in the topic area. Similarly, close reading of tweets in dentistry suggested only a small percentage involved substantive engagement with the paper by the tweeter or offered the reader substantive information about the paper beyond metadata such as title or URL. Advocates claimed that tweets were conversational, reflecting discussion beyond disciplinary boundaries (Priem & Costello, 2010). However, a conversation would require a human behaving like a human on both sides of the transaction. Many dental tweets turned out to be less than human in being generated by easily automated processes such as hitting the retweet button to send a paper title and URL. Hitting a button to generate a tweet of metadata is hardly conversational. And the high-frequency activity so generated leads to information overload on the side of readers, prompting withdrawal instead of engagement, again not a conversational behavior (Robinson-Garcia et al., 2017). Mentions and tweets, though countable, convey

[5] mentioning university, professor or study (Hicks & Wang, 2013)

less and therefore probably should carry lower weight than other indicators of more substantial use and interaction between scholarship and broader audiences.

Caveat: Many sources of information are used

Figure 12 *Types of material referenced in policy reports*



Analysis of references to journal articles risks creating a blind spot because journal articles are not the only information source referenced in most genres and may not even be the most common source of information. Patents, for example, reference many more patents than journal articles. Policy reports reference a broad range of material. Drawing on a study of US state-level policy development in autonomous vehicles, Figure 12 reports the distribution of references in US state reports about autonomous vehicles.

Although many policy documents are short and unreferenced, most reports contain references. Here, reports are defined as sophisticated documents containing evidence and analysis to influence or lay the groundwork for decision-making, extending to at least ten pages, and written by or for policy-makers. Of 76 state reports found through internet searching, 56 contained references, and the 2,635 references of 54 of these are displayed in Figure 12[6]. Reports produced by federal and state transportation agencies are the most commonly referenced source of information in state reports. Government reports accounted for 28% of references, while academic sources - journal articles, conference papers, and books - accounted for 18%. Media, at 15% of references, was almost as heavily used as academic literature. Reports produced by nonprofits (11%), university transportation research centers (7%), and consultants (7%) together accounted for one-quarter of the information sources. The National Academies of Sciences, Engineering and Medicine (NASEM) is prominent in the transportation information space because it houses the Transportation Research Board, which runs the National Cooperative Highway Research Program, an annual conference, and a journal (*Transportation Research Record*). Together these accounted for 6% of the citations in state AV reports. Corporate information, such as websites of car companies or Waymo gathered 5% of citations from state AV reports.

Figure 12 establishes that academic literature is one of many different sources informing writers of policy reports. Media proves especially useful to policy-makers attuned to current events. Consulting companies are often employed to write policy reports, which are then cited in later reports. Most policy areas are a focus for research centers, both nonprofit and based in universities. They also seek to contribute to the conversation by writing reports, which in turn serve as sources for authors of subsequent reports. Policy-makers are understandably attuned to what other governments and agencies are thinking and so most heavily reference other policy-makers' reports. Among these many players, academic research has a place, though by no means the dominant position in informing policy

[6] Two of these reports were very unusual in their referencing pattern, having three times the number of references of any other report and skewing highly academic. They were excluded from figure 12.

deliberations as exhibited in reports produced by and for US state governments considering how to govern autonomous vehicles on their roads.

Caveat: Usage can be indirect.

The US National Academies of Science, Engineering and Medicine (NASEM) produces reports commissioned by federal government departments and so read by federal agencies. Being referenced in one of these reports is taken as having impact on policymaking. However, other people read them too meaning their impact is much broader than just federal policymaking. When downloading a report, readers are asked how they intended to use the report. Anaysis of 1.6 million comments left by US downloaders of National Academies reports found half of report use to be academic - research, teaching or studying. The other half revealed many users beyond the Federal government. Adults across the country seek the high quality information in National Academies' reports to improve how they do their job, to help family members, to satisfy their curiosity and to learn (Hicks et al., 2022).

Caveat: Scholarship engages many genres

Journal articles build on information beyond the journal literature. One out of four references indexed in Scopus is to material outside Scopus, which can be taken to be references to genres other than scholarly journals. Referencing to non-scholarly material, ranges from about 20% in biochemistry, molecular biology, immunology, microbiology and neurology to 67% in social sciences and 80% in arts and humanities (Elsevier, 2019, Figure 4).

Newspapers are one genre not indexed in Scopus but sometimes referenced by journal articles. Among newspapers, the *New York Times* is by far the most commonly referenced. Close examination of references to the *New York Times* revealed that use of the *New York Times* in journal articles was growing over time and had several motivations. The *New York Times* is referenced by papers studying the *New York Times* or New York City; or when a topic's importance is established with reference to public interest, as evidenced by press coverage. Roughly half the time, a reference to the *New York Times* brings into a journal article a quote from a famous person or information about an event, either very recent or historical. Sometimes references to the *New York Times* are indistinguishable from references to journal articles, the most famous case being an article reporting how two journalists broke the anonymization of an AOL data file. Academics sometimes publish in the *New York Times* or its magazine, Paul Krugman being the most prominent example, and journal articles will reference these pieces (Hicks & Wang, 2013).

Another blind spot created by counting references in indexed genres, especially single genres, is that publicly engaged research works across many genres, and the genres differ with the type of societal impact. The UK REF exercise provided an opportunity to see this. This national university research evaluation required departments to submit narratives describing cases in which research had a societal impact. References must corroborate not just that the research was published but also the statements describing the societal impact. This was relatively easy in, for example, inorganic chemistry, where references supporting impact were to patents, corporate websites, and letters from company managers testifying to their use of the technology.

The field facing perhaps the most difficult challenge in establishing societal impact was philosophy. Examining the publicly available REF cases in philosophy revealed that philosophers do have a variety of ways to engage the public including: public dissemination, issuing provocations, exploring the

philosophy of everyday items such as wine or information technology, or engaging with people such as prisoners, teachers, the court system, or doctors and helping them address their problems (Hicks & Holbrook, 2020). Examining the references supporting the impact statements in these cases reveals that each case touched multiple genres, and the genres involved were highly heterogeneous. They included: blogs, podcasts, radio and television shows, advertisements, newspapers, trade press, exhibits, movies, policy reports, white papers, policy organization meeting agendas and minutes, and nonprofit, government, event, and video websites. Perhaps the only certainty is that if there is a genre of cultural expression, academics have engaged with it. Undue focus on counts of tweets risks under-appreciating scholarship's full cultural impact.

Conclusion

Tracking the interactions between genres can provide a window into the use of knowledge throughout society. Such analysis has become more available with digitization, but beyond that, high-quality indexing is required to facilitate analysis. Resources such as Altmetric, PlumX, and Overton are central to allowing analysis to extend beyond the scholarly literature indexed in WoS and Scopus or patents, indexed in patent office databases. This frontier in bibliometric analysis of societal impact offers many avenues to explore. What role do other genres play, and how does drawing on research support that? Do authors reference for the classic reasons of avoiding plagiarism, providing resources to readers, or enhancing the credibility of a text? Or are there additional purposes served by referencing in non-academic settings? Can we comprehensively track references, mentions & authorship?

Citation counts create visibility for societal impact of research. This visibility can help to support arguments for research funding because it visualizes the connection between research and societal benefit. However, some fields benefit more than others, not perhaps because their societal impact is greater, but because more of their connections result in indexed citations. Therefore, there are blind spots corresponding to unindexed genres and to unreferenced connections. Only expensive exercises such as constructing comprehensive sets of narratives or building further citation indexes can overcome the blind spots. In the meantime, analysts of societal impact should remain aware that there exists rich and complex cultural engagement that they are unable to see.

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