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Abstract. Citation indexes are based on the principle of authors citing previous articles of relevance. The paper demonstrates the long history of citing for precedent and notes how ISI's citation indexes differ from *Shepards Citations*. The paper analyses some of the criticisms of citation counting, and some of the uses for which citation analysis has been employed. The paper also examines the idea of the development of an Acknowledgements Index, and concludes such an index is unlikely to be commercially viable. The paper describes a citation study of Eugene Garfield, and concludes that he may be the most heavily cited information scientist, that he is a heavy self-citer, and that the reasons why other authors cite Garfield are different from the reasons why he cites himself. The paper concludes that citation studies remain a valid method of analysis of individuals', institutions', or journals' impact, but need to be used with caution and in conjunction with other measures.

Introduction

This paper is based on the ISI lecture. ISI and citations are, of course, synonymous. The relationship between ISI and the Institute of Information Scientists is also a close one. Eugene Garfield, the founder of ISI, joined the Institute of Information Scientists in 1958, the year that the Institute was founded. He must have been one of the first, if not the first overseas member of the Institute. He became an Honorary Fellow in 1989. As further evidence of the close relationship between ISI and the Institute, the very first advertisement to appear in *The Information Scientist*, the journal of the IIS that was launched in July 1967 and that is the precursor of *Journal of Information Science*, was from ISI. There were four advertisements in the launch issue; one, from BDP Ltd, was for tape typewriters, a primitive dedicated word processor. There was an advertisement from a firm of technical translators. There was a job advertisement from the Institution of Electrical Engineers for abstractors to work on *Science Abstracts*, now part of *INSPEC*. However, the first advert readers would come across, on page 15 of Volume 1, Number 1, was from ISI. This advertisement promoted ISI's 'ten unique information services'. These were as follows:

Automatic Subject Citation Alert, ASCA™

Science Citation Index

Three editions of Current Contents

Index Chemicus™ and its annual cumulation

ISI Search Service

ISI Magnetic Tapes

Original Article Tear Sheets (OATS)™

All of these services still exist. Some have grown, and some have changed their names. ASCA™ is now called Research Alert, and continues to provide current awareness based on clients' profiles; the ISI Search Service has changed its character as it no longer offers straightforward bibliographic searches on a bureau basis, but ISI still will undertake in-depth citation analyses for clients for a fee; the magnetic tapes continue to sell; OATS™ is now called *The Genuine Article* – a clever name for a document delivery service. *Index Chemicus* remains an important chemical abstracting and indexing service. *Current Contents* (there are now many more than three titles in the range) continues, of course.

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Citation indexes

But what of *Science Citation Index*? It has been joined since that 1967 advertisement by a number of fellow citation indexes covering other areas, such as social sciences, arts and humanities, and biotechnology. ISI continue to dominate the citation index business. Where did the idea for such indexes come from? Why do people cite? And how reliable are citation indexes and citation analyses?

Citation indexing is important to information scientists for three reasons. Firstly, it is the earliest example of a commercially successful automatic indexing technique. For many years, ISI has made a good business creating and selling citation indexes, and the technique is purely automatic – it is run by computers, and involves no human added value.

Secondly, citation indexing gives insight into the way science – including social sciences and the humanities – is carried out, and provides material for studying the prestige of academics, the importance of universities, and the efficiency of entire countries' scientific research. It is this aspect of citation indexes that our paper discusses.

Finally, citation indexes are tools that information scientists routinely exploit when they carry out searches.

A citation is, of course, a reference to some previously published work that is relevant to the argument the author wants to make. The author may be criticising the earlier item, may be building on it, may be using it to enhance his or her argument, or may be acknowledging an early pioneer. Maybe an author makes a citation simply to imply that the author has read widely around his or her subject. Authors use citations to illustrate, to elaborate, to build on or to criticise. The author believes the earlier item is relevant and wishes to draw the reader's attention to it.

A citation, therefore, links the earlier cited paper to the later one that cites it. A citation index is built around this link. Because there is no human intervention in having to decide subject index terms, citation indexes are cheaper to prepare than standard subject indexes. If you are a traditional database producer, you must carefully read the paper to decide what the paper is about, and then select the indexing terms that are most appropriate. With citation indexing, the author of the paper has done all the work for you already. The author has decided what he or she regards as the relevant earlier papers, and has conveniently listed them.

This approach, therefore, eliminates the need for intellectual indexing by providing the author's own indexing. However, authors are fallible and are not trained to be indexers. The papers they cite will be the ones they have conveniently to hand, the ones they feel it would be politic to cite, and so on. According to how energetic they are, they may cite no papers at all, or far too many. The list of cited papers is likely to include earlier papers written by the same author. This is not just because the author is an egomaniac (though often this is the case) but also because the author knows his or her own papers best [1].

Of course, if you check every citation in an article, you will find a proportion that is irrelevant or has nothing to do with the subject. They are false drops. We are not aware of any study of the proportion of such false drops to see if it is as low as the proportion of false drops you would get from using a controlled language index. Some studies have been carried out that demonstrate that citation searching either gives better recall than subject matter searching, or that it gives a different kind of retrieval which complements that of subject based searching [2].

History of citation indexes

Many people know that the idea of *Science Citation Index* came to Gene Garfield through his knowledge of *Shepard's Citations*. This service was founded in 1873 for the US legal profession. The legal profession, especially in the UK and USA, relies heavily on precedent. The doctrine is known as *Stare Decisis*, and states that all courts must follow their own precedents as well as those established by higher courts [3]. Therefore, if a court case comes up, judges always want to know what similar cases have come up previously, what the decision was in that case, and why.

Judicial reports have for a long time listed the cases cited [4]. For example, an English publication from 1743, entitled *Raymond's Reports*, contains a table of the names of the cases in which the cases reported in italics are the cited cases. In 1783, *Douglas's Reports* included as a separate table 'Index of cases cited'. The first book-length citation index appears to have been produced by Simon Greenleaf, a US lawyer, who published a book in 1821 entitled *A Collection of Cases Overruled, Doubted or Limited in their Application*. It covered both US and English law. Other such one-off legal citation books appeared regularly throughout the nineteenth century. *Shepard's*

Citations appears to have been the first regularly updated service. A former vice-president of the firm that produced *Shepard's Citations*, William C. Adair, wrote to Garfield in 1953, having read an article about the Welch Project in which Garfield had been involved [3], to suggest the use of citation indexes for scientific literature. The Welch Project was an indexing project, carried out at the Johns Hopkins Welch Medical Library. The project was sponsored by the Armed Forces Medical Library, and was supervised by the Committee of Consultants for the Study of Indexes to Medical Literature. The chairman of this committee, Dr Chauncy Leake, suggested that project workers should examine review articles in connection with their investigation of the problems with subject indexes to medical literature.

Taking up this suggestion, Garfield realised that nearly every sentence in a review article is supported by a citation to a previous work. He realised that a review article could really be considered as a series of indexing statements. The problem then became one of transforming these statements into a consistent format that would be useful as an index. It was as a result of making the connection between the ideas generated from the Welch project, and the structure of *Shepard's Citations,* that the format of a citation index for scientific literature was developed by Garfield.

However, as Adair pointed out [5], *Shepard's* adds value. Against citing references you sometimes find small letters. The small letter 'e' means that the subsequent case explains the earlier case in depth; the small letter 'd' means that the cited case was distinguished from the later case as to fact; and the small letter 'a' means that the earlier case was affirmed or confirmed by a higher court, so it is still good law. Finally, an 'r' or an 'o' showed that the earlier case had been subsequently reversed or over-ruled. Thus, the searcher, at a glance, has at his or her fingertips the subsequent history of the legal doctrine contained in the starting case. Many other cases have no letter against them, and are probably of less significance as they are simply citing the earlier case for precedent. Thus, a searcher can see at a glance the current state of play. In contrast, ISI's indexes add no value of this type, although there is much added value elsewhere, such as in the PERMUTERM™ indexes, and the identification of items as editorials, letters, etc. It would be more helpful if – as Adair recommended at the time – ISI's citation indexes included small letters, such as 'a' for affirmed or confirmed the results of the earlier paper, and 'd' for disputing or criticising the earlier paper. Unfortunately, this would involve considerable manpower and would increase the costs of ISI's indexes. Also, in some cases it would be difficult to judge if a cited paper was being criticised or not; legal judgments tend to be more clear cut in their language. The only way forward is likely to be the use of some form of artificial intelligence to scan the full text of documents and to identify whether citations were likely to be affirming or criticising, judging from the words near to the citation in the text.

To conclude: it is clear that the lawyers are the parents of citation indexes, although they may not recognise ISI's indexes as their progeny.

What about the origin of the idea of citation counting? Librarians seem to have got in first on this act. The librarian of the Smithsonian Library, one Jewett, in 1849, listed the numbers of citations in the back of books in chemistry, anthropology and law in order to justify the budget request he was making for building up his own library [6]. However, this was an isolated incident and, thereafter, the lawyers were the active ones. In the late nineteenth century, a number of entrepreneurial legal publishers were issuing lists of citation counts, showing which cases were being cited the most. Although these publishers were from the USA, they often covered US and UK cases. Regular articles appear to this day with analyses of legal citations. The majority of such studies appear in legal journals, but our literature is not immune; in December 1990, *Journal of Documentation* published an article on the topic which showed, among other things, that the decay rate for legal precedents is much longer than for science [7]. For example, 0.5%–1.5% of the citations in English court cases were to cases more than 200 years old.

The idea of using citation indexes to identify cases cited in court is only possible, of course, if the cases themselves are recorded. This dates back to 1275. A statute in Edward I's time, in 1275, established that the date of Richard I's coronation – 3rd September 1189 – was the legal limit of memory. Up until that time, in order to argue a case in law, a lawyer would bring some elderly person into court who said 'I remember in a previous court case the following decision was reached . . .'. The 1275 statute forced all courts to keep records of their transactions. Courts would now look to documentary evidence of earlier decisions rather than someone's memory [8]. As with all things mediaeval, however, things were not quite as clear cut as that. In 1291, the same Edward I, needing some evidence of his claims to the Scottish Crown, made no attempt to search English court records. Instead, he ordered that a set of Scottish chancery rolls be broken open and

searched, thus providing a precedent which modern computer hackers now emulate. In fact, it was only about 1320, in the last years of the reign of Edward I, that systematic archiving of legal records began, and the systematic creation of libraries of textbooks for legal reference also started.

To return to the present. Although there is no UK equivalent to *Shepard's*, most legal databases do include citation indexes of one type or another, and legal textbooks will always provide an index of cases cited. However, citation indexes in science, and citation indexes based on an author's name rather than an anonymous case name, had not been considered until Garfield came on the scene. In 1955, he published the seminal paper on citation indexes in scientific disciplines in the learned journal *Science* [9]. The idea of basing a citation index on author's name was the unique idea brought to citation indexing by Garfield, but was only possible because scientific papers have authors. This was not always the case. In Mediaeval Europe, books were indexed by title, not by author. This derived from the notion of the supremacy of the Deity and that we as mere humans were on the Earth for just a short period of time and were of no importance as such [10]. Early scientific books were published without an author's name, or even where an author was named, it would be catalogued under title only. However, by the seventeenth century, the idea of associating scientific works with named individuals, and recording the names on a catalogue had become commonplace.

Garfield thought the idea of a printed citation index was feasible, but he did not at the time have enough money to launch a product. He tried for US Government funding, but was turned down. So he took the financial risk himself. Production started in 1956 in a converted chicken coop – the classic US start-up success story. Originally, Garfield called his company DocuMation Inc., but it soon changed its name to ISI. Initially, it produced a genetics citation index and *Current Contents*. Then, in 1961, ISI published the first edition of *Science Citation Index*. *Social Sciences Citation Index (SSCI)* was launched in 1973. Others soon followed. Now, thousands of major commercial, academic and scientific libraries around the world use citation indexes, in print, online or on CD-ROM.

Citation studies

From the very first edition of *Science Citation Index*, people have considered the possibility of using its machine-readable data to carry out citation studies. Citation studies are not new, as we have already indicated, but now they could be conducted on a much larger scale using ISI's machine-readable data. There are many potential uses of citation studies. They include: citation studies to evaluate scientific research and as a science management tool; citation studies into the history of science; mapping the current structure of science and how it is developing [11]; citation analysis of journals, sometimes using a measure that Garfield developed [12] called impact factor – and sometimes using other measures of assessing journal status [13, 14].

Citation studies have also been used for the prediction of Nobel prizewinners [15, 16]; patent citation studies have been used to assess the flow from research to development [17]; and other studies to show the impact of one country on another's research [18]; they have also been used to assess the research output, and therefore the long term prospects, of biotechnology companies, with recommendations that companies with good citation counts but low share prices are worth investing in [19]; the usefulness of this technique is doubtful as there never has been any suggestion that citation counts are related to commercial success. Citation studies have also been used to assess scientists themselves. There have even been studies on uncitedness – the characteristics of that majority of papers which never get cited [20]. Interestingly, this paper indicates that the more papers you cite in your own article, the more likely it is that your article will subsequently be cited!

The numbers of articles on citations, citation indexing and citation analysis is enormous. The best overview can be obtained from Cronin's book [21] and from books by Garfield himself, one called *Citation Indexing* [22], the others a series entitled *Essays of an Information Scientist*, which contain a wealth of musings and commentaries on the use of citation analysis [23]. The *Essays* books series, based on articles penned by Garfield and entitled 'Current Comments' at the start of each issue of *Current Contents*, continue to appear. It is perhaps unfortunate that so much of Garfield's research appears in this vehicle, as the journal *Current Contents* itself, by its very nature, is not stored by libraries for lengthy periods of time, and the *Essays* are not purchased by that many libraries. For this reason, it is unfortunate that services such as *Science Citation Index* and *Social Sciences Citation Index* continue to use *Current Contents* as a source journal when, in practice, so few libraries hold back issues.

Citation analysis is controversial and has attracted criticism. It is worth noting these criticisms right away.

Criticisms of citation studies

We would classify the objections to citation studies into two broad headings. Firstly, not all citations are the same. The reasons that someone cites an earlier paper are complex and numerous. So not all citations are equal. Yet large scale number crunching of citations implies one is dealing with a uniform body of citations. So the first criticism is that it is misleading to make decisions or draw conclusions based on citation counting.

The second criticism is that citation counting reduces everything down to mere numbers, and more subtle criteria such as 'quality' and 'influence' are not taken into account.

In short, the first criticism is that citations are unreliable; the second says even if they are considered to be reliable, other factors should be taken into account.

Why do people cite?

What sorts of reasons are there for people to cite an earlier paper? They include the following:

- paying homage to pioneers in the field;
- giving credit to related work;
- the reference to a standard methodology or piece of equipment that has been used, citing rather than describing it in detail;
- providing broad background to the topic;
- correcting or criticising the previous paper;
- quoting earlier papers that offer corroboration for one's ideas or claims;
- alerting researchers to your forthcoming work. This will be a forward citation, for example: 'L.M. Baird and C. Oppenheim, paper submitted to *Journal of Information Science*';
- drawing attention to previous work that is not well known, but ought to be;
- identifying an earlier publication from which the author obtained the original idea for his or her work;
- eponymic citation – the first reference to an idea, term or technique that has a person's name;
- citing a major figure because it makes your research look more respectable;
- citing a major figure because you think he or she may be a referee of the paper when you submit it to the journal;
- citing articles that fit the author's perceptions of the journal's readers and what they are expecting. In other words, to fit the characteristics and status of the journal that the author is submitting the paper to;
- citing according to the author's knowledge of the subject area (for example, the author's use of the relevant abstracting and indexing services to get a good idea of the prior literature will affect the articles he or she cites);
- citing according to the influence of his or her mentors. There is evidence [24] that 40% of citations to an author derive from that author's personal influence over the individuals who cite him or her;
- the author's carelessness. Many citations are miscited, and it is obvious the author has never read the original paper that he or she is citing. This is often because the author has copied citations he or she found in some other people's papers;
- the comprehensiveness (or lack of it) of the author's private reprint collection.

There are other factors which can complicate the situation. For example, ISI sort their printed and online citation indexes by the surname of the first author. Since authors in papers are often presented in alphabetical order of surname, citation counting using the printed services will favour people with names at the start of the alphabet over others. Citation analyses of an author using the commercial ISI services must therefore obtain a comprehensive bibliography of the author's works and then undertake citation counts on the first author of each paper identified. In contrast, ISI's own studies use a comprehensive database which avoids these difficulties. There are other technical limitations of citation indexes, such as mixing up authors with the same names, or splitting authors who change their names; there are also clerical errors and the fact that the ISI indexes do not cover all the world's literature. Some people claim it is biased against Third World countries' publications [25]. Some typical examples of errors in ISI's services can be found in [26].

Then, there is the danger of citation oblivion. If you make such a major and important contribution to the field that it becomes generally accepted, you no longer get cited. After all, it is argued, who bothers to cite Einstein's original paper which had the famous equation: $E = mc^2$? The paper is still cited regularly, although not as heavily as many more modern papers [27, pp. 91–95].

The question of eponymy – that is to say, when a scientific law or technique is named after an individual, so that the individual no longer gets cited but his or her name is used in the text – has rarely been studied, and deserves to be. The study described in [28] is a good example of the sort that can be under-

taken, and which shows that citation counts do seem to fall significantly when eponymy takes place, and yet the number of references to the name in the full text continues to rise. This might seem to argue for the development of a further measure of someone's influence – how often their name appears in the text of articles. However, in some cases, such as Alzheimer's Disease, this would result in a massive increase in the perceived impact of the individual (Alzheimer) – perhaps greater than would be justified.

Finally, different subject areas have different citation practices and traditions, so that they cannot be compared to each other.

Looking at some of the criticisms

There have been some studies examining journal articles and carrying out comprehensive literature searches on the topic. These have shown that authors fail to cite relevant earlier articles that they ought to be citing. Typically, only 30% of the references that should be listed are listed [29]. Even bearing in mind that the authors of these studies are necessarily subjective in their views of what is relevant, there appears to be no question that authors are careless or biased in their citing habits.

What about self-citing? Some authors are notorious for this practice. Whether this distorts citation analyses or not is unclear. It may be that the self-citing is fully justified.

The fact that citations perform different functions is well known. Various authors in the 1970s [30–33] have developed classifications of reasons that people cite. However, reading the text of the paper does not necessarily provide a clue as to why that author cited that particular paper at that point. A better way than trying to guess from the context is by the much more labour-intensive way of interviewing the author and exploring why he made the citations. Pioneering studies [34–36] have done just that. Their results show that most authors utilise previous literature to advocate their points of view and to self-justify. However, they found that the situation is complex and sometimes self-contradictory and that simple classifications are therefore probably inappropriate. What is clear, from both the studies of texts and from interviews with scientists, is that negational citations - that is to say, where an author is criticising an earlier paper – are rare. MacRoberts and MacRoberts [37] review the whole subject.

What about careless citing practices? Two recent studies [38–39] looked at how reliable library science journals were in their citations. Randomly selected citations were followed up. The results were that 2%–29% had major errors, including those in the author's name, and in the journal title, volume number and pagination. In one case, the article was so miscited that the researcher could not identify it at all. A comparison with biomedical areas has shown major error rates of 7%–30% [39].

It is, therefore, not unreasonable to assume that 20% of the records in ISI's citation indexes are erroneous. ISI do have validation procedures [40], but they cannot correct all the possible errors that an author can introduce. It is clear that authors, referees and journal editors are not paying enough attention to the citations in articles [41]. We agree with Symons [42] that editors and referees should try to be more rigorous in checking the citations used by their authors.

In theory, an article with deliberate errors in it will provoke many replies. Each reply will cite the original article. Citation counts will therefore rise. An interesting study [43] considered a scientific fraud case involving one John Darsee. This life scientist published articles in the late 1970s and early 1980s in which there had been systematic falsification of data. Reviewing his 55 papers, a committee in 1985 concluded that only seven were valid, 40 were questionable or worse, and eight were clearly fraudulent. He ceased publishing in 1981. Kochan's study showed that between 1982 and 1990, 298 papers cited Darsee's work. The smallest proportion (17) discussed the fraud. A few more – 25 papers, cited Darsee and were disagreeing with his results. Incredibly, 256 papers cited Darsee approvingly, using his fraudulent material to support their own arguments. Some went further, and referred to Darsee's work as 'good' or 'well conceived'. Darsee's work is not cited as often as it used to be – 14 citations in 1990, compared to 87 in 1982. This is not surprising due to the combination of general recognition that his work is dubious and because his published work is becoming very dated, and so is less likely to be cited anyway. Here is a case where Adair's [5] suggestion of the addition of small letters – in this case to show that Darsee's work had been criticised – would be very helpful.

A final criticism is that people tend to cite important figures rather than unknowns, or over-cite to prove how clever they are. They may deliberately refuse to cite a rival. The evidence to support such claims is tenuous, but deserves further investigation.

Acknowledgements and citations

Another important factor is that citations only record the formal published items that influenced an author. What about informal influences? Cronin has developed over the last few years his idea of recording Acknowledgements [44, and references cited therein]. Acknowledgements are the pieces of text in the paper which thank individuals for advice, technicians for their assistance, grant bodies for their funding, and so on. Many of these acknowledgements are fairly trivial, but some, where a mentor has provided advice on the research, or suggested the avenue of research to pursue, are arguably as important, or even more important, than some of the citations made in the article resulting from that research. Cronin and his co-workers have gone so far as to develop a new term for this sort of study, *influmetrics* - the science of measuring influence. They found that certain individuals do get intensively acknowledged by authors for their guidance and mentoring. Cronin is arguing that ISI, or some other organisation, should develop an Acknowledgements Index, analogous to *Science Citation Index*.

We are not convinced by Cronin's arguments for such an index. Who would use it, and why? Unlike the ISI's citation indexes, whose *raison d'être* is for bibliographic searching and only incidentally are used for citation studies, an acknowledgements index would have little value except to the sociologists of science. Furthermore, an acknowledgements index would be more expensive to produce than a citation index, as it would require human indexers to scan the text of papers for these acknowledgements – which are not always under a heading entitled 'Acknowledgements' – and then rejecting the perfunctory ones to grant aid bodies and to the technician down the corridor. So, the acknowledgements index would not be commercially viable.

It would be interesting to learn if the heavily acknowledged individuals are also heavily cited. If there is a strong correlation between citation counts and acknowledgement counts, then we can forget acknowledgement counts because citations are easier to deal with. The research mentioned earlier [24] would lead one to expect this to be the case. If there is not a clear correlation, then we are measuring two different things and we need to explore why the acknowledgements are different to the citations. We also need to interview some authors to assess why they acknowledged who they did. Nonetheless, Cronin's work is of some interest because it broadens the picture of the relationship between individuals in research, and provides a secondary measure of an individual's contribution to the development of science.

Are citation studies valid?

Taking all these points into account, one might wonder whether there is any validity at all in citation studies. Many studies have been carried out to compare citation counts to other objective or subjective studies of the value of an individual, an institution, a journal, or an entire country. The studies have used a number of measures, including:

- receipt of the Nobel Prize;
- membership of major scientific academies, such as the Royal Society or the National Academy of Sciences;
- receipt of large awards of research funding;
- assessment of status by peer group;
- assessment of the status of a journal by readers;
- use of the scientist by Government, e.g. as a member of an advisory committee;
- prestige of a University in the country.

All of these measures, whether objective (did he get the Nobel Prize or not?) or subjective (how good do you think *Journal of Information Science* is compared to *Journal of Documentation*?) can be measured.

What is embarrassing for the critics of citation counting is this fact: whatever measure you take for the eminence of an individual scientist or of a journal or of an institution, citation counts provide strong correlation with that result. This must be very frustrating for the people who criticise citation counting, but demonstrates that, despite the 'noise' produced by the vagaries of citations, the 'signal' still comes through strongly.

So, despite the many valid criticisms of the crudity of citation counting, the fact is that they reasonably reflect the esteem that a particular author or paper enjoys. Citation counts provide an easily calculated measure of the impact that the author has had on his or her community.

So, does this mean that if an author writes an article, and it is highly cited, then it is important? No it does not. Rather, what it means is the chances are the paper is important. On the other hand, if the author writes a series of papers that are all highly cited, then it is very probable he or she is a major leader in the field. In other words, high citation counts mean a statistical likelihood of high quality research.

Clearly, one can extend this idea beyond individuals.

One can use citation counts to assess the quality of research in a University department, in the University as a whole, in an entire country, and in particular journals [23, 45]. There have been many studies analysing the strengths and weaknesses of countries' research using citation counting, for example [46, 47].

Identifying 'hot topics'

Various attempts have been made over the years to use citation analyses to identify where new disciplines are emerging and what the hot topics are. These are often associated with co-citation analysis [48–54]. An interesting new idea is that of the 'Hot Topic Index' [55]. This is defined as Density divided by Recency. 'Density' is the number of citations per 1,000 words of journal article text; 'Recency' is the median age of the citations (in years) of the cited articles compared to the publication date of the citing article. The higher the Hot Topic Index, in other words the more references there are to very recent older articles, the more likely it is we are dealing with a fast growing 'hot' topic. Kidd [55] contends that a high Hot Topic Index score may predict the emergence of high activity topics well before any other means. We find this idea interesting and intriguing, and it deserves to be followed up.

Related records

An intriguing use of citation indexing is to the novel 'Related Records' feature that has recently been launched by ISI [56]. It is a transparent form of the well-known bibliographic coupling technique (which relates papers that share a high proportion of identical citations) [57]. The user carries out a title word search, and highlights items that he or she regards as hits. The user then calls up in the hypertext window a ranked bibliography of supplementary references. These are items on the CD-ROM that cite the same references as the citations in the articles identified as relevant. This enables a searcher to start with a simple query, and, with minimal effort, to identify an extensive bibliography. A recent study by Ali [58] has shown that use of this feature produces bibliographies which have a large number of articles in the same subject field. In other words, it demonstrates the validity of the technique. Another recent study [59] has used the Related Records feature to undertake a bibliometric study on the impact of research carried out by a Hungarian pharmaceutical company.

Citation studies on individuals

While many citation studies look at the work of a specific subject area, or the range of publications from an entire country, there have also been a few studies conducted on the work of either a very important article (which has been seen as being very influential in the subject field), in order to assess whether the citation rate can be used as a measure of the article's significance; or, alternatively, the entire work of an eminent scientist can be studied to trace a successful career pattern. An example of a citation study on the work of an individual is the recent analysis which was published on the writings of Ranganathan. This study was performed to gain a picture of the 'depth and breadth' [60] of Ranganathan's influence in the field of librarianship. The citation patterns of his books and journal articles were traced. The authors concluded that Ranganathan is cited because his name is 'frequently used by writers to give their papers some academic respectability'. Critics of citations may suggest that the idea of citing a renowned author merely to gain personal respectability for an otherwise mediocre piece of research belittles the work of an eminent author. Other examples of a citation search on an individual can be found in [61, 62].

Citation analysis to understand the history of a subject

Citation analysis can also be used to write the history of a subject and identify the key turning points in the development of the subject. Studies on the history of AIDS research [63] and the history of physics in the 1920s [64] are typical. This technique is applicable not just in pure science. One of us has completed citation analyses of patents to obtain the histories of technical subjects, like the hovercraft [65].

The basic principles are clear enough, and assume that the history of the topic is reflected by the history of its publications. Now, of course, that is a gross oversimplification. Much science is carried out by informal communication. Many of the tensions, likes and dislikes never appear in print. The journal article is a sanitised version of the crises that took place in the research. Nonetheless, the journal article is the best tool available and does seem to provide a reasonable picture of the way science grows and develops. Starting with the latest papers and seeing what they cite, one goes back in time, taking earlier papers to see

what they cite, and so on. In that way, one can track the entire development of a scientific discipline, perhaps over a period of 150 years or more.

One can then print out the results on a diagram, often called a historiograph. The historiograph is organised in time order, so that the chain of development is clear. Of course, in a major scientific discipline, one may be talking about thousands or even tens of thousands of journal articles. Special techniques are needed to draw the historiographs in a clear fashion. Developing software to draw historiographs clearly and concisely is an area of research in its own right.

One problem with historiographs is that they are hard work. One cannot include *every* paper cited by an author. One must select just those which are relevant to the discipline being studied. This involves considerable research time. Although justified by simplifying the historiograph, the work is tedious.

Finally, the historiograph is compared with some standard history. For example, in the case of research on hovercraft, Oppenheim interviewed Sir Christopher Cockerell, the inventor, about his recollections of the history [65]. If the two accounts match up, then it is another victory for citation indexing. The results of such studies have been a little variable. They usually confirm the value of the technique. Sometimes, a highly controversial paper attracts many citations but turns out to be a dead end. This distorts the citation analysis.

On the other hand, Garfield has argued that citation analysis can draw out significant historical events that are overlooked or forgotten by historians of science, and he provides some evidence for this argument in his book [22]. He also points out that, apart from the selection of items to ensure that they are relevant, the entire process is mechanical and one does not need to be an expert in the subject, or a historian, to undertake the analysis.

Eugene Garfield

This Department has recently undertaken a research project on the topic 'Who cites Eugene Garfield, and why?' [66]. The purpose of the research was to establish citation patterns of the work of Eugene Garfield and, by conducting a citation analysis of work referring to Garfield's writing, to establish what impact his work has had.

To begin with, Garfield's name was checked in the Author Index of *Library and information Science Abstracts* (*LISA*) from 1976 to 1993. This gave a rough count of the number of journal articles Garfield has published. *LISA* does NOT include Garfield's articles that appear in *Current Contents*. Up until recently, Garfield wrote one article per week, i.e. 52 such articles per year, but more recently this has reduced to about one every two weeks.

The *Science* and *Social Science Citation Indexes* between 1981 and 1993 were then used to gather information about journal articles that cite Garfield's work.

As well as conducting citation searches on Garfield, similar cited author searches were carried out on Cronin and Robertson, two well-known information scientists, to compare their citation rates to those of Garfield. The *Essays of an Information Scientist* for the years 1973 and 1983 were also analysed to discover self and other author citation rates in the articles written by Garfield. We also looked at two specific items – Garfield's pioneering 1955 *Science* article [9] and his 1979 book on citation indexing [22] – to see how often these two works are being cited.

To decide on which system to use in analysing why people cite, we examined the work of Moravcsik [30], and of Oppenheim and Renn [33], but in the end developed our own classification of the reasons that people cite, as we found that the ones we looked at did not suit our requirements. We then examined a sample of more than 100 articles that cite Garfield to assess why these individuals were citing him.

The first in-depth study of the quality of citations was published in [30]. The authors thought that there were two main reasons for a lack of in-depth citation studies at that time. Firstly, it was because use of citations was relatively recent, and, secondly, because any work that had been done up until then had been researched by individuals who were not considered to be 'equipped to understand the technical scientific content of the papers they handle'.

The conclusions to citation studies made by social scientists or librarians were felt to be limited, since the quality of the cited paper and the context of the citation were thought to be such that the subtlety of the context in which the citation was made could be lost on anyone other than an expert in the field of science which was the subject of the paper. We find this argument dubious. An information scientist, with an understanding of the layout of a scientific article, which tends to follow a set structure, i.e. introduction, methodology, results and conclusion, would have few problems in understanding the context of the citations. The classification system of reasons for citing developed in [30] was:

(1) conceptual or operational;
(2) organic or perfunctory;
(3) evolutionary or juxtapositional;
(4) confirmative or negational.

These four reasons for citing were applied to the references of 30 articles published in the journal *Physical Review* in the years 1968–1972 on the subject of theoretical high energy physics. The results of the analysis were tabulated and percentages worked out for the number of references to fit each of the four reasons for citing.

The study found that a large percentage of the references was 'perfunctory', which was seen to suggest doubts about citations as a quality measure, since it would be possible for an individual or group of people to gain high citation counts by writing on 'fashionable subjects' which would then be cited as 'also ran' references. The issue of self-citation in this way was not mentioned in the study, but the fraction of disputed papers was noted. It was stated that 'all scientific papers turn out to be wrong eventually' in the sense that they are all replaced by something better. The problem of 'wrong' papers has since been extended in terms of the problem of references that are wrong for reasons of inaccuracy. In contrast, Oppenheim and Renn [33] looked into the reasons that certain old papers are still highly cited many years after their publication. The papers used for the basis of this study were 23 old papers published between 1896 and 1921 which are still heavily cited. The seven categories of reasons for citing the papers were:

A: historical background;
B: description of other relevant work;
C: supplying information or data, other than for comparison;
D: supplying information or data for comparison;
E: use of theoretical equation;
F: use of methodology;
G: theory or method not applicable or not the best one.

Each of the reasons for citing listed was explained in detail, and some categories covered several reasons for a citation. The analysis carried out on 978 citing articles revealed 'a number of outright errors in the citations authors made to the cited articles studied'. There were several reasons that errors were found; for example, the Oppenheim and Renn study found that on two occasions, when a couple of references were included under a single reference number, only one reference was entered in *SCI*. Errors of data in terms of incorrect spelling of authors' names was a problem of which the extent of error in *SCI* was difficult to gauge, because of the arrangement of *SCI* by the name of the first author, followed by the year of publication, so that incorrect citations to authors' names, for example, could only be detected by chance.

The main conclusion of the Oppenheim and Renn study was that the reason for 40% of the citations of old papers was purely historical, but for 60% – more than half – the reason 'old papers continue to be highly cited is that they are still relevant'.

We found that conducting a search on Garfield is a problem. Searching for citations to his original *Science* article and his 1979 book are straightforward enough. However, because of the large numbers of citations referring to the many articles written by Garfield in *Current Contents*, a search to discover what are the most highly cited articles written by Garfield is difficult. The problem was further compounded by the number of errors in the ISI indexes on DIALOG, whereby Garfield is Garfield, E.; Garfield, E.E.; Garfield, E.F., and so on. We worked through the cited references between 1984 and 1990.

The classification system we used was loosely based on the system developed by Oppenheim and Renn. The reasons for citing Garfield were divided into six categories which will be described shortly.

Because a large number of the citing articles found in the search were from *Current Contents*, we decided to split the results of the citation analysis into two. First, we examined 45 citing articles which were found in journals other than *Current Contents* and which were written mainly by authors other than Garfield. We also examined 123 articles from *Current Contents*. Forty-four were rejected because the article did not cite Garfield; and of the remaining 79 articles, 57 were by Garfield and he cited himself; 22 were by other authors, and cited Garfield.

We found that the vast bulk of articles that Garfield writes appear in *Current Contents*. As indicated earlier, he wrote 52 articles per year in this vehicle until the end of 1990, and since then has written 26 articles per year in it. In contrast, a search in *LISA* demonstrated that it picked up just 39 articles in total in the period 1976 to mid-1993. The numbers are declining; the abstracting service identified only five articles in the period 1987 to date.

However, in terms of numbers of citations to Garfield, it is clear that he is a heavily cited information science author. The search on *Science Citation Index* identified 1,149 citations to Garfield in the period 1981 to June 1993, and the search on *Social Sciences Citation Index* identified 1,371 citations in the same period. Since there is some overlap between the two services, it is difficult to know what the total number of citations to

Garfield was in the period, but it may well have been as much as 2,000. The numbers of citations to Garfield are declining over time; in 1983 there were 393 citations to Garfield's earlier papers, whilst in 1992 there were 39. For comparison, Cronin received 47 citations in *Science Citation Index* and 388 citations in *Social Sciences Citation Index*, and Robertson received 179 citations in *SCI* and 402 in *SSCI* over the same 1981–1993 period. However, many if not most of his citations are self-citations. In all his essays in *Current Contents* published in 1973, Garfield cited himself 113 times in total, and other people 126 times; in all his essays in 1983, he cited himself 260 times and others 928 times.

It is clear that the person who cites Garfield most is Garfield himself. He may well be the most cited information scientist, but it is not certain that he is cited the most when one subtracts self-citations. Looking at his *Science* article, for example, in *SSCI* over the period 1981–1993, he was responsible for 39% of the 38 citations to this work, and in *SCI* he was responsible for 62% of the 34 citations. Looking at the 1979 book on citation indexing, in *SSCI* he was responsible for just one per cent of the 73 citations, whilst on *SCI* he was responsible for 16% of the 112 citations to the book. All these self-citations appeared in *Current Contents*.

We examined all 45 journal articles published in the period 1985 to 1992 that were available in any University library in Glasgow, and that had cited Garfield, in order to see why he had been cited. Of these articles, only two were from the library and information science literature; others who cite Garfield do so in journals devoted to medicine, to science, to technology and to social sciences. One hundred and eleven of Garfield's articles were cited in these 45 citing articles. In other words, an author who cites Garfield cites an average of 2.5 Garfield papers. The breakdown of reasons for citing Garfield were as follows:

A: statement, reference to a quotation; mention of a previous study; historical fact; reference to the first paper in a series of papers with the same title (this latter reason did not apply to these non-Garfield articles) – *17 citations (11%);*

B: detailed description of previous study; description and results of previous study – *20 citations (13%)*;

C: definition of a term; correction; reference to further reading, backing up a statement; reference to, or discussion of, a previous study – *59 citations (39%)*;

D: reference to a previous study for comparison of data or results; reference to another study in the same area; backing up a factual statement; verbatim quote from a previous study – *31 citations (21%);*

E: source of data used – *20 citations (13%)*;

F: use of methodology – *4 citations (3%).*

These numbers are higher than the number of Garfield articles cited because sometimes the same Garfield article was cited more than once in the same citing article. In all, there were 151 citations to the 111 Garfield articles – in other words, on average, each author citing a Garfield paper cited it 1.4 times.

We also examined all of the appropriate articles in *Current Contents* published between January 1989 and September 1991. The 79 articles contained citations to 339 different Garfield articles. In other words, on average, if an author in *Current Contents* (nearly three-quarters of the time Garfield himself) cites Garfield papers, he cites an average of 4.3 Garfield papers – significantly higher than other authors. The 339 cited articles were referred to, in total, 412 times – in other words, Garfield and other *Current Contents* authors citing one of Garfield's papers, on average, cites it 1.2 times – marginally less often than other authors. The breakdown of reasons that we identified for *Current Contents* authors' citations are as follows (using the same letters as in the previous breakdown):

A: 131 citations (32%);
B: 53 citations (13%);
C: 89 citations (22%);
D: 132 citations (32%);
E: 7 citations (2%);
F: 0.

It is clear, therefore, that Garfield and his fellow *Current Contents* authors have very different reasons for citing him than other authors do. They primarily cite him for reasons A (historical background) and D (corroboration of evidence). Together, they account for two-thirds of his citations, whilst for other authors they count for less than one-third. On the other hand, other authors use C (in-depth discussion and corrections) far more often than Garfield and other *Current Contents* authors do.

This research demonstrates that Garfield is a heavy self-citer, and writes more in *Current Contents* than in professional journals. It also shows that he is possibly the most heavily cited information science author, and the reasons that other authors cite Garfield are very different from those why Garfield cites himself.

Some concluding remarks about the value and impact of information

One of the abiding difficulties for all librarians and information scientists is the justification of the time,

money and effort spent on acquiring, storing and retrieving information to a dubious and cost-conscious management. Under pressure from the Government, this justification is spreading to the public library sector where, too, justification is being demanded. This raises the awkward question of the value of a piece of information, or of a collection of information. Similarly, individual academic researchers and academic departments are being increasingly assessed for their contributions to knowledge [67].

There are many ways to approach this question. The amount of money spent by industry on patents is a good measure of the value industry places on that type of information. This Department has recently been funded by the British Library Research and Development Department to undertake a study of this question.

A quite different measure, intended to assess individuals, as proposed in [68], is the Hierachically-adjusted Author Proportiometric Index, which becomes the acronym 'HAPI'. This index is obtained by multiplying the number of pages published by an individual by an index of that author's influence. The index would be by agreement with the authors on a co-authored paper on the proportion of effort each one contributed. Not a very realistic approach, one would have thought, as the boss will always insist his or her contribution was crucial. Vinkler [69] has suggested a more rigorous approach to assigning author contribution, but, even so, it is difficult to see how pressure from senior staff to enhance their own contribution's worth can be avoided.

A key problem lies in the fact that impact of research on fellow scientists, value to practitioners and value to industry are not the same. For example, Wilson [70] has shown that there is no correlation between the citation count for articles in certain social work journals and the number of photocopy requests for articles in these journals. The criticisms of research trying to correlate citation counts to biotechnology companies' share price have already been noted. All this means that there is not, and never can be, one single measure of the value of information that will be universally acceptable. However, there are a number of measures that might, in combination, lead to some sort of index of the value of a piece of information, an individual's research contribution, or a collection of information. These will include, as minor factors, things such as numbers of acknowledgements and the number of times the person is named in the text of articles. However, we have no doubt that citation counts and peer group assessment will be the most important inputs of such an index.

Note

Readers interested in this subject area are advised to read the recently published review by Liu (Liu, M., The complexities of citation practice: a review of citation studies. *Journal of Documentation*, 49, 370–408.

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