Journal of Scientometric Res. 2018; 7(3):210-214
http://www.jscires.org

Research Article

Visualizing Garfield's Scientific Performance

Rouhallah Khademi

Department of Knowledge and Information Science, Faculty of Psychology and Education, Semnan University, Semnan, IRAN

ABSTRACT

Aim/Background: Garfield is one of the most important and influential figures in information science, bibliometrics and scientometrics. This paper aimed to investigate, analyze and visualize Garfield's scientific outputs using the scientometrics technique. **Materials and Methods:** Data were gathered from the Web of Science core collection database by searching "Garfield E" based on which 1542 documents were extracted. Co-author analysis, co-citation analysis and also historiography techniques were used for data analysis. Some software such as HistCite, VOSviewer, Ucinet and NetDraw were also used for drawing the maps and analyzing data. The process of data analysis was conducted in three phases using three software. **Results:** The results showed 1542 written documents by Garfield indexed in WoS databases. As for word occurrence, "Science" and "Citation" were the most frequent ones. Most of these documents were published by *CURRENT CONTENTS* and *Scientist publications*. The highest number of products were observed in 1987 and 1988. The historiographical map of these documents were drawn for 1954 and 2004 and relevant clusters were formed. The co-citation map was also designed with clusters. Meanwhile, the co-author network was developed into a big cluster. According to the results of co-author analysis, Garfield mostly appeared as a co-author with Sher, Welljamsdorof and Pudovkin. The density of co-author network was 0.0679 in which Garfield with 133 and Sher and Reversz, each with 17 degrees, had the highest degree of co-authorship compared with other authors. **Conclusion:** The scientific maps provided by the present research, in line with those of the previous studies, support Garfield's influence and role as one of the leading figures in the world of information science and scientometrics.

Keywords: Eugene Garfield, Co-citation analysis, Co-author analysis, Historiographical map, Scientific performance, Information visualization.

Correspondence
Rouhallah Khademi,
Department of Knowledge and Information Science, Faculty of psychology and education, Semnan University, Semnan, IRAN.
E-mail: r.khademi@semnan.ac.ir

Received: 15-09-2018
Revised: 26-10-2018
Accepted: 10-12-2018
DOI: 10.5530/jscires.7.3.33

INTRODUCTION

The increased volume of information, the spread of information science and prevailing positivism paradigm after World War II brought about extensive quantitative approach in science that yielded Bibliometrics and Scientometrics studies.[1] Conferences, associations, seminars etc. also played their own parts along with attempts by major scientists as other effective factors.

One of the influential scientists in this regard was Eugene Garfield (September 16, 1925 – February 26, 2017) who created *Science Citation Index* (SCI) and founded the Institute for Scientific Information (ISI) to develop and promote the SCI and related databases such as the Social Sciences Citation Index and the Arts and Humanities Citation Index and other bibliographic database services such as *Journal Citation Reports*.

In 2007, he launched HistCite, a bibliometrics analysis and visualization software package. He also published many scientific outputs and had lots of scholarly contributions that make him one of the most important and influential figures in information science, bibliometrics and Scientometrics. Small[2] believes that "No other individual has had a greater influence on the fields of scientometrics, informetrics and information science generally than Eugene Garfield". These such claims together with his death on 26 Feb. 2017 led us to map his scientific performance in Web of Science during his scientific life.

"Mapping Science" ("Mapping knowledge", "Visualizing the Science", "Visualizing the Knowledge", "Information Visualization" etc.) is one of the applications of Scientometrics. Small[3] noted that "A map of science is a spatial representation of how disciplines, fields, specialties and individual papers or authors are related to one another as shown by their physical proximity and relative locations, analogous to the way geographic maps show the relationships of political or physical features on the Earth". Documents, authors, universities and institutes and countries and scientific fields can be the unit of

analysis in a science map. A number of techniques can also be applied in this case, which include citation, co-citation, bibliographic coupling, co-author and co-word.

Small[4] (1973) introduced the co-citation technique which is used for science mapping. Many Bibliometrics and Scientometrics researches are conducted based on this technique.[5-10] Garfield, Pudovkin and Istomin[11] introduced the Algorithmic citation-linked historiography—mapping the literature of science by HistCite software. Later, many researches used this technique to examine an author, a country, a university or a research area.[12-16] Co-author and mapping co-author networks have also been the subject of many Scientometrics studies.[17-19]

Garfield has been the subject of some Scientometrics studies such as Leydesdorff[20] who has visualized his oeuvre using title words, co-authors and journal names. Bhattacharya[21] attempted to trace Garfield's contributions in four key domains: in data analytics, in influencing scholars involved in the study of science as an epistemic practice and a knowledge product, his engagement with scholars in developing countries and in innovation and entrepreneurship. Reference Publication Year Spectroscopy (RPYS) of Garfield's publications was conducted by Bornmann, Haunschild and Leydesdorff.[22] They noted "that EG was a pioneer not only in shaping the citation index, but also in many lines of research in bibliometrics". Chen[23] studied Garfield's scholarly impact. Similarly, Bar-Ilan[24] investigated Eugene Garfield on the Web in 2001. The five major search engines at that time were queried. 9711 different URLs were identified, out of which 4120 were related to Eugene Garfield, the information scientist. The findings showed that the most frequent themes were the use and theory of citation analysis, Citation Indexes as products and the Impact Factor and use of JCR data. Over 50% of the pages were scientific in nature and more than a third of the pages formally cited Garfield's works.

Aims and Objectives

This paper aimed to investigate, analyze and visualize Garfield's scientific outputs. To achieve this general goal, the researcher answered the following questions:

1. How many of Garfield's scientific outputs are indexed in Web of Science Core Collection Indexes? Which journals have published most of them? How is their yearly distribution? Which words have the highest frequency?
2. How is the historiographical map of Garfield's scientific outputs indexed in Web of Science Core collection indexes?
3. How is the co-citation map of Garfield's scientific outputs indexed in Web of Science Core collection indexes?
4. How is the co-author network of Garfield's scientific outputs indexed in Web of Science Core collection indexes?

METHODOLOGY

Scientometrics was selected as the research method. Data were gathered from Web of Science core collection database by searching "Garfield E." in the author field. Our version of WoS covered a timespan from 1900 to 2017. No time limit was applied and "All years" option was selected based on which 1542 documents were extracted. Co-author analysis, co-citation analysis and also historiography techniques were used for data analysis. Some software such as HistCite,[25] VOSviewer,[26] Ucinet[27] and NetDraw[28] We are also used for drawing the maps and analyzing the data. The process of data analysis was conducted in three phases and using three software.

After data collection, the data were firstly added to HistCite for descriptive analysis and for drawing historiographical map. Through trial and error thresholds, top 100 LCS[1] documents were selected as the threshold. Then, data were analyzed using coauthor.exe, from which a coauthor matrix was extracted. Thus, a 90 by 90 symmetric matrix was developed. The matrix was analyzed using Ucinet software for developing a file suitable for analysis by NetDraw software. Next, co-author map of Garfield was drawn by the software. Also, some centrality measures of co-author network such as degree were extracted by Ucinet. In another analysis, data were extracted via WoS and was fed into VOSviewer software for drawing the co-citation map of Garfield. By applying 20 as the minimum number of citation for cited references, 29 references met the threshold and were selected for co-citation analysis. Finally, the maps and other results were interpreted.

RESULTS

The results showed 1542 documents by Garfield indexed in WoS core collection databases. Based on word occurrence, "Science" and "Citation" were the most frequent words. The top ten frequently used words are shown in Table 1. In this table and other tables, LCS (LOCAL CITATION SCORE) is the number of times a paper is cited by other papers in the local collection. GCS (GLOBAL CITATION SCORE) provides the Citation Frequency based on the full Web of Science count at the time the data is downloaded.[29] These scores are considered important as they show how often the documents are cited and accordingly had impact on other documents.

According to these scores, documents including "Citation", "Science", "Cited" and "Journal" had the highest GCS. This is because the most important works of Garfield are about Science Citation Index and Journal Impact Factor.

1. Local Citation Score

Table 1: The Top Ten Frequently Used Words in Garfield's scientific outputs.

	Word	Recs	LCS	GCS
1	SCIENCE	283	298	16059
2	CITATION	271	398	19174
3	CITED	167	20	15149
4	RESEARCH	138	42	6333
5	INFORMATION	129	69	7232
6	ISI	127	31	7967
7	JOURNAL	116	88	11274
8	NEW	111	141	6712
9	SCIENTIFIC	108	43	5849
10	JOURNALS	100	124	9345

Table 2: The Most Productive Journals have Published Garfield's Scientific Outputs.

	Journal	Recs	LCS	GCS
1	CURRENT CONTENTS	1061	177	86933
2	SCIENTIST	147	25	1549
3	CURRENT CONTENTS/LIFE SCIENCES	88	2	550
4	JOURNAL OF INFORMATION SCIENCE	13	18	240
5	JOURNAL OF CHEMICAL DOCUMENTATION	12	35	142
6	NATURE	12	70	435
7	SCIENTOMETRICS	12	4	375
8	ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY	11	0	1
9	JOURNAL OF THE AMERICAN SOCIETY FOR INFORMATION SCIENCE	11	18	102
10	SCIENCE	10	169	2370

Most of these documents were published by *CURRENT CONTENTS* and *Scientist publications*. In Table 2, the most productive journals publishing Garfield's scientific outputs are shown. The results showed that documents published by Current Contents received the highest number of citations.

The highest number of scientific products appeared in 1987 and 1988. In Chart 1, Garfield's yearly outputs are presented. As the chart shows, the most productive years in Garfield life are 1960 to 2000. This can be related to establishment of ISI and Citation indexes in 1960s. However, from 2000 onwards, there is a decline in Garfield's outputs.

The historiographical map of these documents was formed from 1954 to 2004 and some clusters were developed. This map is shown in Figure 1.

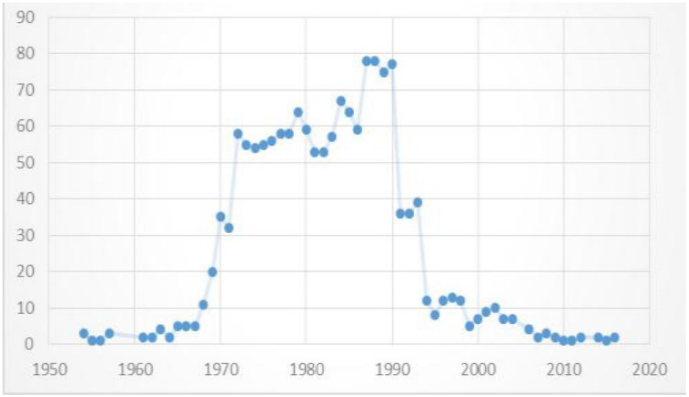

Chart 1: Yearly outputs of Garfield.

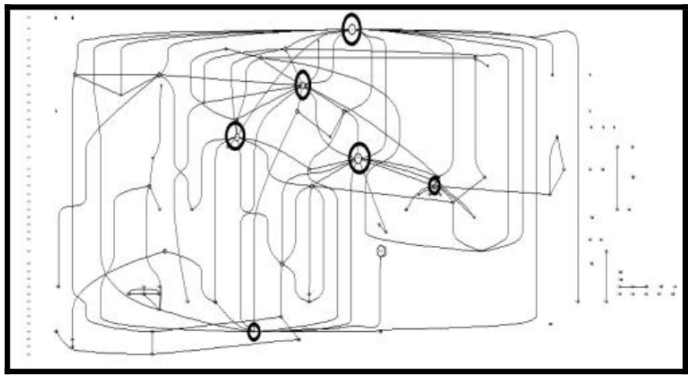

Figure 1: Historiographical map of Garfield's scientific outputs.

Table 3: The most important articles in historiographical map.

	LCS	GCS
GARFIELD E, 1955, SCIENCE, V122, P108	63	880
GARFIELD E, 1964, SCIENCE, V144, P649	30	180
GARFIELD E, 1972, SCIENCE, V178, P471	64	1279
GARFIELD E, 1976, NATURE, V264, P609	19	116
GARFIELD E, 1970, NATURE, V227, P669	33	216
Garfield E, 1998, LIBRI, V48, P67	2	48

Some articles of high importance are specified in the Historiographical map. The bibliographic information of these articles are demonstrated in Table 3. The first of such works was **"CITATION INDEXES FOR SCIENCE- NEW DIMENSION IN DOCUMENTATION THROUGH ASSOCIATION OF IDEAS"** that starts the map. **The top-cited article is "Garfield, E. (1972). Citation analysis as a tool in journal evaluation. *Science*, *178*(4060), 471-479." This article has the highest LCS and GCS.**

The co-citation map was also designed with clusters shown in Figure 2. Four clusters can be seen in this map. In addition to Garfield, some well-known and important Bibliometrics and Scientometrics scholars such as Small and Price also appeared in the map. The co-citation map of Garfield's output formed four clusters.

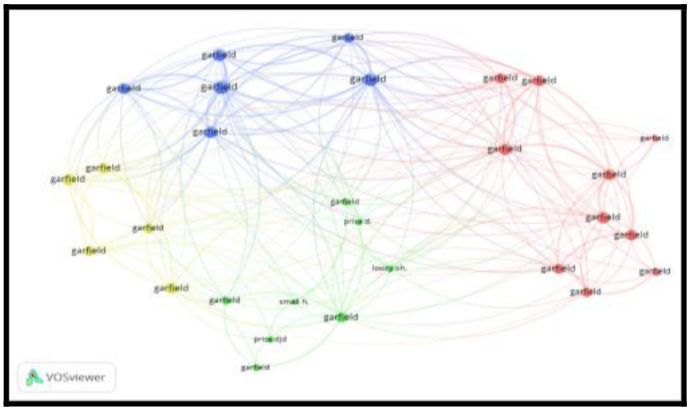

Figure 2: Co-citation map of Garfield's scientific outputs.

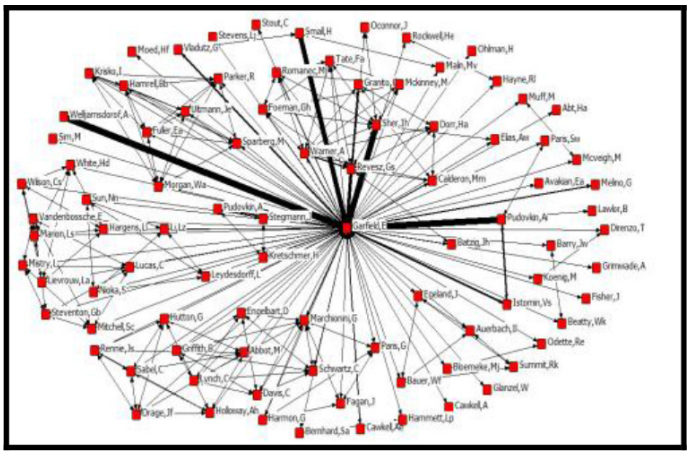

Figure 3: Co-author map of Garfield's scientific outputs.

The co-author network developed a big cluster shown in Figure 3. The results of coauthor analysis showed that Garfield was mostly a co-author with Small, Sher, Welljamsdorf and Pudovkin.

The density of coauthor network was 0.0679; in which Garfield with 133 and Sher and Reversz each with 17 degrees had the highest degree of co-authorship among the other authors in the study. This map shows an expanded network formed by co-authorship with Garfield.

CONCLUSION

The development of Bibliometrics and Scientometrics is indebted to contributions from many scientists. As for Garfield, although he has already been known as the founder of ISI due to his services and indexes, our results tried to document his pivotal role and position.

Many scholars have stressed Garfield's scientific role and position. For example, Bornmann, Haunschild and Leydesdorff[22] having studied Garfield's publications by RPYS, believe that "EG was a pioneer not only in shaping the citation index, but also in many lines of research in bibliometrics". Similarly, Small[2] argues that no one has had a greater influence on scientometrics, informetrics and information science generally than Eugene Garfield.

In line with the above-mentioned researches, the current paper studied Garfield's outputs indexed in web of science core collection. The results revealed "science" and "citation" as the most frequently used words in Garfield's documents mainly because Garfield's major and fundamental studies focused on (Science) Citation Index. Garfield's articles were largely published by Current Content that explains why the given journal received the highest number of citations among others. The most productive years in Garfield's lifetime were 1960 to 2000 probably because this period coincided with the establishment of ISI and Citation indexes in 1960s. Garfield's articles on citation analysis were the most important ones on the historiographical map. As another finding, the science mapping in our study demonstrated his close collaboration with other well-known scientists in Information Science, especially in Bibliometrics and Scientometrics.

The data for the current study were collected from WoS; hence, it is suggested that other studies be performed using data from other bibliometric databases such as Scopus or Google Scholar.

ACKNOWLEDGEMENT

I would like to thank Professor Osareh for valuable comments and suggestions for improving the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ABBREVIATIONS

LCS: Local Citation Score; **GCS:** Global Citation Score.

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