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Science in pre-independent India: a scientometric perspective

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Scientific publications and different types of collaboration pattern in pre-independent India are mapped using scientometrics and social network analysis tools. Publication data of Indian authors published before 1947 are downloaded from the Scopus database of Elsevier science. The study traces the literature growth patterns, core journals, productive authors, authorship collaboration patterns, productive institutions and their collaboration patterns. The result shows that maximum literature was published in the year 1936. The growth of publications during the mid-1930s was evident as many scientific institutions were established by that time. The subject-wise maximum activity was observed in chemistry followed by agricultural and biological science. *Proceedings of the Indian Academy of Sciences* was the most preferred journals. Universities played the prominent role in scientific research. Some private institutions with 'nationalistic' enthusiasm, for example, *Indian Institute of Science* and *Indian Institute for Cultivation of Science* were very productive institutions and also prominent in institutional collaboration. These institutions started in the colonial period continue to be the pillars of modern science in India.

Keywords: Colonial Science; Scientometrics; India, Social Network Analysis; History of Science

Introduction

Over the last couple of decades, there have been growing interests in the history of science in British India. Development and institutionalization of science and technology (S&T) under British imperialism and its establishments in former British colonies are termed as colonial science. The important contributions of Basalla[1], Kumar[2, 3, 4], MacLeod[5], Raina[6] had enriched and legitimatized the concept of colonial science[7, 8]. "This term colonial science broadly refers to the status of S&T activity under colonialism in the colonies, and its subjugation to the imperial political and economic interests in the metropolis"[7]. Basalla's three stage model for the diffusion of Western science acted as a pillar for colonial science. Basalla proposed that science originated in the Western Europe and diffused in colonies in the three stages. In Phase I, the non-scientific society or nations provided a source for European science. In this initial phase of exploration, colonies provided raw data and materials for scientific analysis in the West. The Phase II was the period of actual consolidation of colonial science and advanced scientific activities. Finally, the Phase III was the independent scientific tradition or cultures that were gradually evolved in the British colonies[1].

This idea of colonial science has been contested, confronted and refined over the years[2-12]. According to these historians, science existed even before the establishment of the British colonies. They argued that Basalla had carefully excluded the rich scientific and cultural heritage that already existed in the ancient Indian and Chinese civilizations[7,13]. Rather colonial science was the science in the colonies that were planned activities that originated from the United Kingdom (UK). The colonies were given the lower level of tasks for example; 'data exploration'. However, the data analysis and synthesis took place in London. These kind of science lacked intellectual essence and the proper scientific practice in the colony[4,7].

This paper is an attempt to map the science in pre-independent undivided India (including India and Pakistan) extracting data from the Scopus database of Elsevier Science.

Objectives of the study

- To study the literature growth patterns of Indian researchers during the British period;
- To identify core journals during pre-independent India;
- To examine the prominent subject areas of research;
- To list productive authors and examine the authorship collaboration patterns; and
- To identify productive institutions and institutional collaboration patterns.

Methodology

This paper uses the analytical framework of scientometrics for mapping the growth of literature, subject-wise activity, core journals, authorship and institutional collaboration patterns[14,15]. The authorship and institutional collaboration patterns are mapped using the Social Network Analysis (SNA) tools. A social network is a set of individuals or groups, each of which has connections of some kind to some or all of the other actors[16]. SNA is a multidisciplinary approach based on mathematical Graph theory[17]. The authorship and institutional collaboration pattern represented through the graph are examined from a macro- (the whole network) or from a micro- (individual actor) perspective. The macro-structure of a graph shows how the actors are embedded in the network that arises out of the physics of its connections[18]. In macro-level analysis shows the overall centrality, density, clustering coefficient, geodesic path etc[19].

Scopus of Elsevier launched in 2004 is the largest abstract and citation database of peer-reviewed literature. It covers more than 21,500 titles from more than 5,000 international publishers in the fields of S&T, social science and humanities. According to Scopus content coverage guide (updated in January 2016), it has over 60 million core records. Over 22 million records of Scopus are pre-1996 publications, which go back as far as 1823. The database continuously updates its collection and approximately 3 million new records are added every year[20].

Literature data for this study was searched and downloaded from Scopus putting 'India' or 'Pakistan' in the 'affiliation country' search field. The retrieved set of results was restricted till the year 1947, the year of India's independence and the creation of two separate nations India and Pakistan. The retrieved sets of records were downloaded and taken for further analysis.

The network maps of authorship and institutional collaboration patterns were drawn using social network analysis software UCINET. The software is developed by Borgatti, et.al and distributed by Analytic Technologies. The integrated freeware program with UCINET called NETDRAW is used to visualize and draw network maps[21, 22]. Social network analysis software Gephi was also used to get the whole network level statistics. Gephi, is an open-source software for the visual representation and the analysis of complex social network[23].

The study has the following limitations. Firstly, it is based only on the scholarly publication data from Scopus. Although the Scopus has extensive coverage of global literature, it has English language bias. Secondly, many of the Indian publications of pre-independent India may not be covered in the Scopus considering that the citation database is a relatively new database and no citation or bibliographic database exhaustively covers all the Indian S&T publications. For example, Bhattacharya et al. (1989) found about 2,124 science publications in Indian languages between 1875 and 1896. The Calcutta Book Society, formed in 1817, contained 333 journals, book and other forms of publications in various fields of S&T[24, 7]. Despite the known limitations of Scopus, it was used to examine the trends as revealed through this data set.

Analysis

For the period 1807 to 1947, 6,008 records were retrieved from the database. The records were downloaded and further analyzed. The categorization of the whole set of 6,008 records, based on the document types are as follows; Articles 4,899; Letters 880; Notes 125; Errata 48; Reviews 43; Conference Papers 7 and Short Surveys 6. There were 5,505 records (92 percent) in English followed by 498 records (8 percent) in German, 4 records in French and 1 in Italian.

Literature growth patterns

The literature growth pattern from India during pre-independent period is shown in Figure 1. From

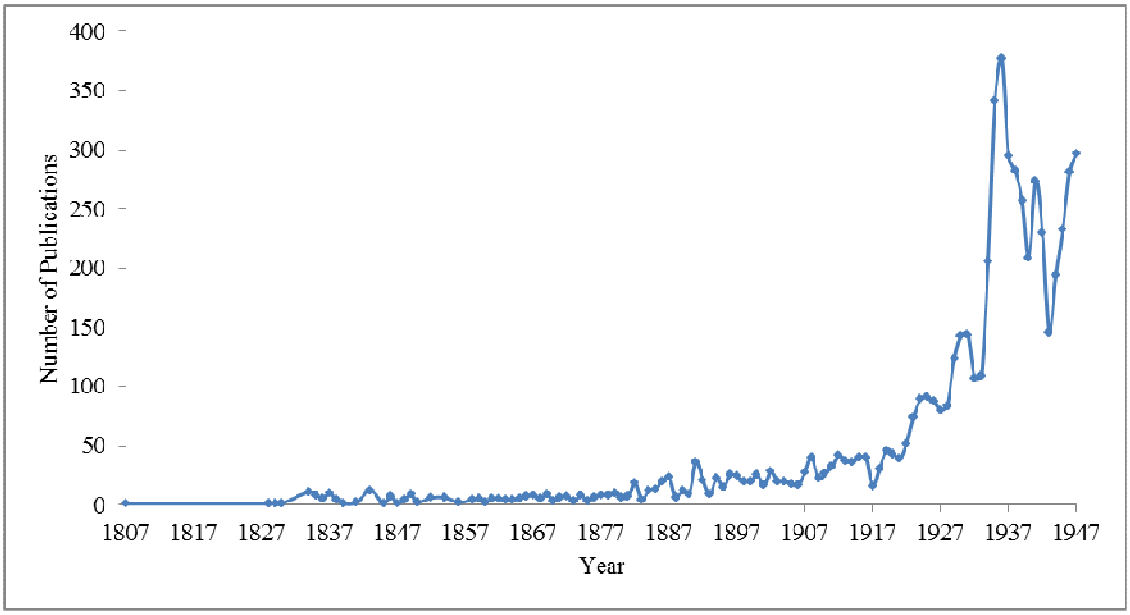

Fig. 1—Growth of scientific publications from India during 1807-1947

the earliest publication in 1807 till 1858, the publication history from India was very sporadic. With a span of 51 years only about 99 articles had been published. A three digit growth is seen from 1929 onwards with 123 articles published in that year. The highest number of publications was in the year 1936 with 377 articles published from India. Perhaps the growth of publication in 1930s was due to the consolidation of institutional building process.

Subject areas

Scopus widely covers peer-reviewed literature and web sources in all branches of knowledge. It classifies the universe of knowledge into four broad subject clusters (life sciences, physical sciences, health sciences and social sciences & humanities). These subjects are further divided into 27 major subject areas and more than 300 minor subject areas[20]. The subject-wise distributions of articles shows (Figure 2) that publications in chemistry were more in number.

Preferred journals

Ranking of journals is one of the most commonly used analytical tools in bibliometric research[15, 25, 26]. The 6,008 Indian scholarly publications appered in 244 journals. The maximum number of publications were published in *Proceedings of the Indian Academy of Sciences Section A* (1432 papers, ~24 percent) followed by *Proceedings of the Indian Academy of Sciences Section B* (621 papers, ~10 percent), *British Medical Journal* (555 articles, ~9.24 percent), *Nature* (420 ~7 percent) and so on. These three journals altogether published about 50 percent of total articles. The other 50 percent articles are scattered in 240 journals. The top journals with more than 50 articles are shown in Table 1.

Authorship pattern

If two or more individuals are recorded as co-authors of the same publication, it is assumed that those people must have collaborated in research. Also, it is quite possible that researchers who collaborate in any scholarly publication become co-authors[27,28]. There are altogether 3,443 authors for the total 6,008 articles. Table 2 shows the most productive authors with more than 20 publications as available from the Scopus database. The most productive author was T.R Seshadri from Andhra University with 175 articles in the area of chemistry followed by N. R. Dhar with 143 articles from University of Allahabad and C. V. Raman with 74 articles from Indian Association for the Cultivation of Science and Indian Institute of Science.

Authorship collaboration network

Among the retrieved set of 6,008 articles 1,948 (33 percent) articles are collaborative articles. Among the 1,948 collaborative articles, 1,395 are two authored, 346 are three authored, 56 are four authored, 17 are five authored and rest have more than five authors.

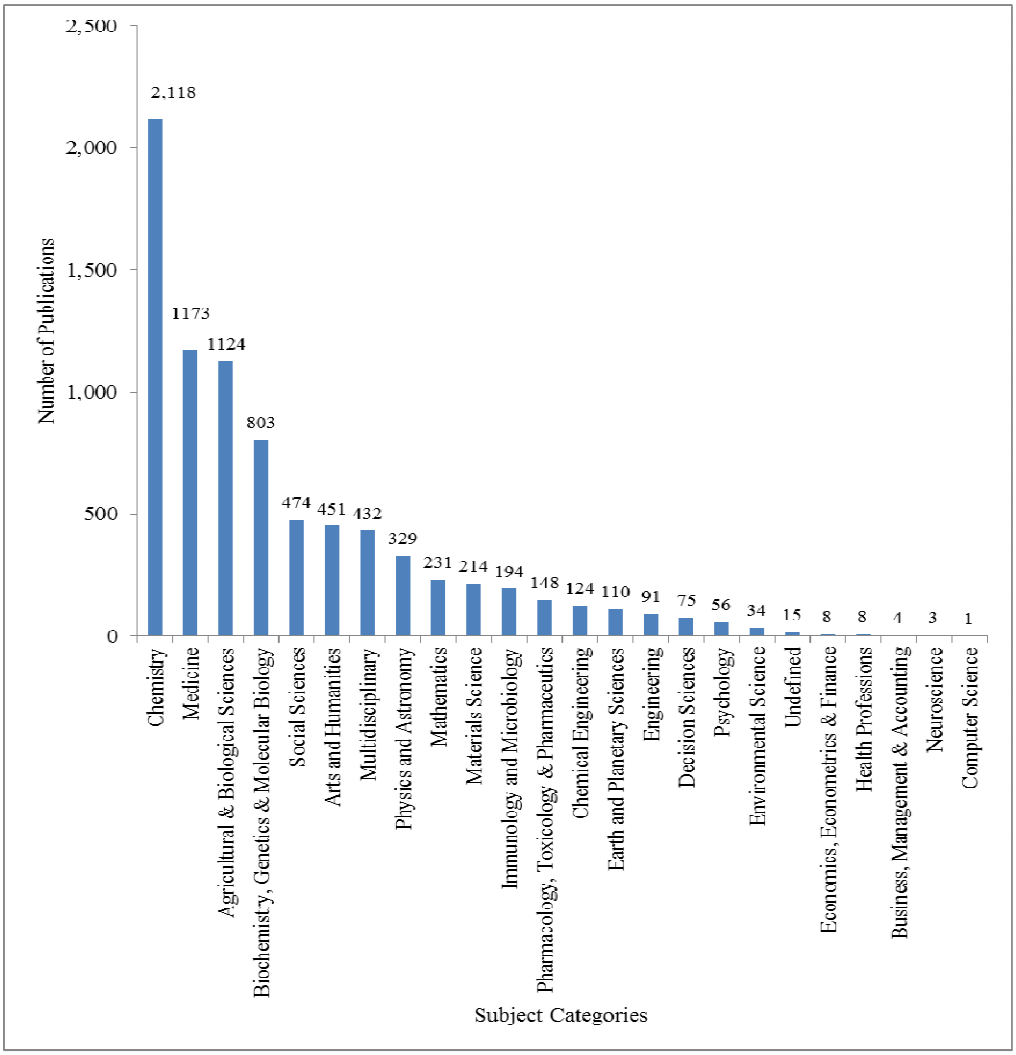

Fig. 2—Subject wise distributions of articles

A network or graph in social sciences are the collections of vertices joined by edges. Vertices and edges are also called and actors and ties in sociology[29,30]. The collaborative authorship network in the present study has 1,892 nodes and 1,644 ties. The network average degree is 1.738 and average weighted degree is 1.932. This is far below of the average observed statistics for a number of networks. For example, Newman has found that network average degree of mathematics is 3.92, physics is 9.27 and biology is 15.53[30, 31].

Diameter of an ego network is the length of the longest path between connected actors. The network diameter is the span or extensiveness of the network. This measurement shows the distance between the two furthest actors situated in a network. In this network, the actors are not very far apart in the ego networks of most actors[19]. Network diameter of the authors' collaboration network is 24. It means from one author to reach another author located at the furthest point it requires 24 nodes to cross.

One important characteristics of social network is the small average distance between a pair of nodes. It is general measured by the shortest path length (*Average geodesic distance)* between two nodes. The concept was drawn from the famous "six degrees of separation". Scientific collaboration networks also exhibit the similar phenomenon. The average path length in this authorship collaboration network is 10.005. This long path length shows that authors were not quite close to each other. Newman shows that the average distances in co-authorship network are different branches of knowledge are follows; 4.92 in Biology, 6.19 in Physics and 7.57 in Mathematics[31,32].

Table 1—Top 20 journals with more than 50 publications

Rank	Journal	Number	Cumulative	Percent
1.	*Proceedings of the Indian Academy of Sciences - Section A*	1432	1432	23.83
2.	*Proceedings of the Indian Academy of Sciences - Section B*	621	2053	10.34
3.	*British Medical Journal*	555	2608	9.24
4.	*Nature*	420	3028	6.99
5.	*Journal of the Royal Asiatic Society of Great Britain & Ireland*	130	3158	2.16
6.	*Zeitschrift für Physik*	128	3286	2.13
7.	*Zeitschrift für anorganische und allgemeine Chemie*	121	3407	2.01
8.	*Notes and Queries*	112	3519	1.86
9.	*Kolloid-Zeitschrift*	110	3629	1.83
10.	*The Muslim World*	97	3726	1.61
11.	*BJOG: An International Journal of Obstetrics & Gynaecology*	89	3815	1.48
12.	*Physical Review*	81	3896	1.35
13.	*Soil Science*	79	3975	1.31
14.	*Journal of Physical Chemistry*	79	4054	1.31
15.	*Transactions of the Indian Ceramic Society*	77	4131	1.28
16.	*Journal of the Chemical Society, Transactions*	74	4205	1.23
17.	*Journal of the Chemical Society (Resumed)*	69	4274	1.15
18.	*Transactions of the Royal Society of Tropical Medicine and Hygiene*	66	4340	1.10
19.	*Parasitology*	61	4401	1.02
20.	*Proceedings of the Zoological Society of London*	52	4453	0.87

Table 2—Top 10 productive authors

Rank	Author	Number	Major Affiliations
1.	T. R. Seshadri	175	Andhra University
2.	N. R. Dhar	143	University of Allahabad
3.	C. V. Raman	74	Indian Association for the Cultivation of Science / Indian Institute of Science
4.	R. D. Desai	64	Muslim University, Aligarh/ St. Xavier's College, Bombay/ Department of Chemical Technology, Bombay University
5.	A. N. Puri	53	University Chemical Laboratory, Lahore, India/ Irrigation Research Laboratory, Lahore, India
6.	S. Bhagavantam	51	Indian Institute of Science and the Andhra University/ Indian Association for the Cultivation of Science
7.	R. S. Krishnan	50	Indian Institute of Science, Bangalore
8.	B. K. Singh	43	University of Allahabad/ Science College, Patna/ Government College, Lahore
9.	S. Chowla	39	Andhra University/ Government College, Lahore
10.	B. N. Singh	38	Benares Hindu University

Graph density is the measurement of the closeness of a network. In an ideal condition, the graph density will be equal to 1 if it is a complete graph with all possible ties are present. In this co-authorship collaboration network the graph density is 0.001. It means that only 0.01 percent of possible ties are present[19].

A weak component is the largest number of actors who are somehow connected. It ignores the direction of the ties in undirected data[19]. Number of weakly connected component in this co-authorship network is 376. The largest component has 641 nodes with authors like N.R. Dhar, T.R. Seshadri, R. D. Desai, S.S. Bhatnagar and so on. The second largest component consists of 36 authors. The prominent among them are B. N. Desai, J. N. Mukherjee, P. M. Barve, A. M. Patel, K. Prosad and so on. The third largest component consists of 26 collaborative actors with B. S. Rao, K. S. Rao, K. S. G. Doss, T. Krishnappa and so on are among the prominent authors.

Among the large components with more than 10 author collaborations, the component number 96 (size 17), 89 (size 12), 93 (size 16), 158 (size 16), 128 (size 13) are formed solely by the interaction among the British authors. It is also important to note here that there are very limited collaborations happened between Indian and British scientists at that time.

The clustering coefficient measures the average probability that two neighbors of a vertex are themselves neighbors. In effect it measures the density of triangles in the networks. It is of interest because in many cases it is found to have values sharply different from what one would expect on the basis of chance[30]. Average clustering coefficient 0.176 is quite low in this case. It can be seen from the Figure 3 that a few actors are surrounded by local neighborhoods that are fairly dense. It is mentioned earlier that the overall density of the entire graph in this population is also low (.001). However, the density of local neighborhoods is higher than the density of the whole graph because of the presence of some prominent actors.

In almost all social network analyses, the micro level or individual actor level centrality stress on four centrality measures. These centrality measures are Degree, Betweenness, Closeness and Eigenvector (Table 3). Degree centrality of a node is the number of edges that are adjacent to that node[21,33,34]. Betweenness centrality is the measure of how often a node appears on shortest paths between nodes in the network[16,35,36]. Closeness centrality is the average distance from a given node to all other nodes in the network[19]. It measures how close a node is to all the other nodes[37]. According to Opsahal et.al, the distance between nodes in disconnected components of a network is infinite. So, this is the limitation of closeness centrality measure because it cannot be applied to networks with disconnected components[34,37]. Eigenvector centrality shows the importance of an actor in a network depend on its connection with other important node. A node is considered important if it is relatively close to all other nodes. A node is central to the extent that the node is connected to others who are central[38].

Productive institutions

During the British period, research was conducted both in government as well as private research institutions[39]. The top institutions in their decreasing order of publications are shown in Table 4. Indian Institute of Science (IISc), Bangalore is the top institute with 600 publications. IISc was established in 1909, with monetary grant from Sir J.N. Tata and the Maharaja of Mysore. The institute conducted basic and applied research in many fields of science and technology. The second most prominent institute established with private initiative was Indian

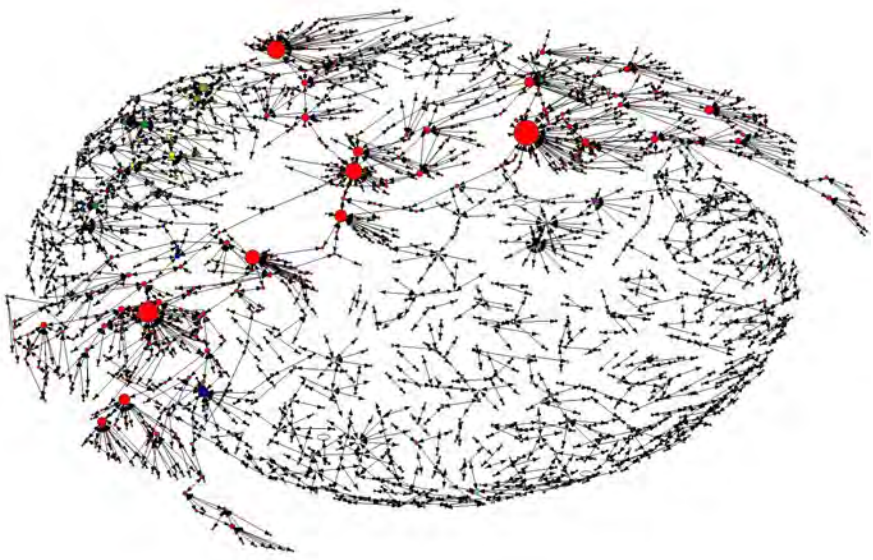

Fig. 3—Authorship collaboration network

Table 3—Centrality measures of productive authors

Author	Degree centrality	Author	Betweenness centrality	Author	Closeness centrality	Author	Eigenvector centrality
N. R. Dhar	49	B. K. Singh	113097.49	A. K. Chattopadhya	2378792	N. R. Dhar	0.674
T.R Seshadri	38	S. S. Bhatnagar	100040.30	N. K. Dutt	2378792	S. Ghosh	0.213
R. D. Desai	34	B. N. Singh	85437.16	B. K. Goswami	2378792	S. Prakash	0.159
S. S. Bhatnagar	31	S. Prasad	75433.19	A. K. Majundar	2378792	D. N. Chakravarti	0.12
B. N. Singh	28	S. Rajagopalan	74525.16	S. N. Maulik	2378792	M. N. Chakravarti	0.12
B. K. Singh	21	N. R. Dhar	73529.49	P. B. Sharkar	2378792	S. N. Banerji	0.12
C.V. Raman	20	K. Ganapathi	67530.20	P. Chandra Mukherjee	2378295	L. S. Bhatia	0.12
M. Prasad	17	M. Singh	66927.89	S. Chandra Sen Gupta	2378295	K. C. Sen	0.116
A. N. Puri	16	A.B. Lal	63496.40	N. Nath Ghosh	2378295	H. L. Dube	0.113
T. Fowler	16	R. C. Ray	63338.90	R. De	2378287	L. N. Bhargava	0.113
K. Venkataraman	15	P. B. Ganguly	61764.40	M. L. Dey	2378287	P. B. Ganguly	0.11
K. C. Pandya	15	B. B. Dey	44673.00	A. C. Ghosh	2378287	A. K. Bhattacharya	0.109
E. B. Ford	15	C.V. Raman	38587.00	S. C. S. Gupta	2378287	M. R. Mehrotra	0.109
T. H. D. La Touche	15	R. Samuel	38251.00	J. N. Rakshit	2378287	W. V. Bhagwat	0.107
S. Bhagavantam	14	H. Lessheim	37884.00	K. C. B. Ray	2378287	K. N. Malaviya	0.106
S. Ghosh	13	P. Krishnamurti	37375.00	J. N. Sen	2378287	S. Gosh	0.106
B. S. Rao	13	B. Singh	32162.49	K. N. Choudhury	2378171	B. C. Banerji	0.106
R. Samuel	12	M. Sreenivasaya	30708.83	K. Choudhuri	2378171	S. N. Chakravarti	0.098
R. N. Chopra	12	V. I. Vaidhianathan	30007.99	K. N. Choudhuri	2378171	G. G. Rao	0.098
G. N. R. Ayyangar	12	S. Rangaswami	28729.74	K. Nath Choudhuri	2378171	N. G. Chatterji	0.095
K. Neelakantam	11	R. F. Hunter	28584.00	P. Ray	2378153	C. C. Palit	0.095
V. Subrahmanyan	11	D.L. Shrivastava	26525.74	P. Chandra Ray	2377656	A. C. Chatterji	0.095
S. Rangaswami	10	S. Ghosh	25768.00	P. C. Ray	2377648	P. N. Bhargava	0.095
V. I. Vaidhianathan	10	A. N. Puri	25213.99	P. N. Das Gupta	2377540	B. K. Mukerji	0.093
R. F. Hunter	10	M. Srinivasan	23394.82	T. C. Sarkar	2377540	S. K. Mukerji	0.093
H. B. Dunnicliff	10	T. R. Seshadri	23274.96	H. Saha	2377532	P. B. Ganguli	0.093
R. L. Datta	10	E. M. Taylor	23116.98	M. K. Bose	2377526	A. Ram	0.091
B. N. Desai	10	R. W. Linton	22021.82	S. R. Seth	2377381	N. N. Biswas	0.091
J. K. Thornton	10	B. N. Mitra	21390.82	P. R. Mehta	2377377	J. K. Verma	0.091

Table 4—Productive institutions with more than 20 publications

Rank	Institute	Publications	First publication year	Year of establishment
1.	Indian Institute of Science	617	1914	1909
2.	Andhra University	387	1932	1926
3.	Allahabad University	280	1896	1887
4.	Banaras Hindu University	191	1920	1916
5.	Calcutta University	163	1913	1857
6.	Central College, Bangalore	158	1887	1858
7.	Mysore University	136	1925	1916
8.	University of Madras	120	1885	1857
9.	Muslim University, Aligarh	116	1936	1875
10.	University of Lucknow	107	1923	1867
11.	University College of Science, Calcutta	107	1918	1914
12.	Medical College Calcutta	103	1859	1835
13.	Royal Institute of Science, Bombay	96	1924	1920
14.	Presidency College, Calcutta	93	1882	1817
15.	Government College University Lahore	91	1885	1864
16.	Agricultural Research Institute, Coimbatore / Pusa	82	1911	1905
17.	Annamalai University	79	1929	1929
18.	Indian Association for the Cultivation of Science	66	1914	1876
19.	University of the Punjab Lahore	66	1920	1882
20.	Calcutta School of Tropical Medicine	54	1921	1914
21.	St. John's College Agra	49	1898	1850
22.	University of Bombay	46	1866	1857

Association for the Cultivation of Science, in Calcutta. This institute ranked 18th with 66 publications. The institute was established in 1876 by Dr. Mahendra Lal Sircar, initially aimed to popularizing science and scientific subjects. Gradually it started fundamental research in physics and chemistry, 'Raman Effect' was discovered by Sir C. V. Raman when he was in this institute.

Institutional collaboration network

Out of the total of 6,008 publications, about 339 publications are an outcome of institutional collaborations. The institutional collaboration network has 380 nodes and 628 edges. Average degree is 1.653 and average weighted degree is 1.916. The network diameter is 14 and average path lengths are 5.66. With these overall statistics, it can be observed that the network is not very dense and populated by many locally and isolated institutional actors collaborating with each other.

The collaboration network has the graph density of 0.004 which means that only about 0.4 percent of possible collaboration. The graph has an average clustering coefficient of 0.142. There are total 95 weakly connected components and total 12 triangles present in the network. The largest component is the size of 123 actors. The important actors in this component are Indian Institute of Science, Allahabad University, Calcutta Medical College & Hospitals, Benares Hindu University, J. J. Hospital; Bombay, Government College; Lahore, Haffkine Institute; Bombay, Central College; Bangalore, University of Lucknow, Punjab University; Lahore and University of Madras. Almost all productive institutions were somehow connected at that time and had active collaborations. The second largest component size is of 9 actors and Samaritan Free Hospital; United Kingdom (UK) is the most prominent actor in this component. The institutional collaboration network is shown in Figure 4.

The actor level institutional centrality measures show that Indian Institute of Science had the highest degree of centrality (14). Indian Institute of Science also played a prominent role in collaboration. The actors with high centrality scores are: Allahabad University (10), Calcutta Medical College & Hospitals (9), Samaritan Free Hospital; United Kingdom (8), Benares Hindu University (7),

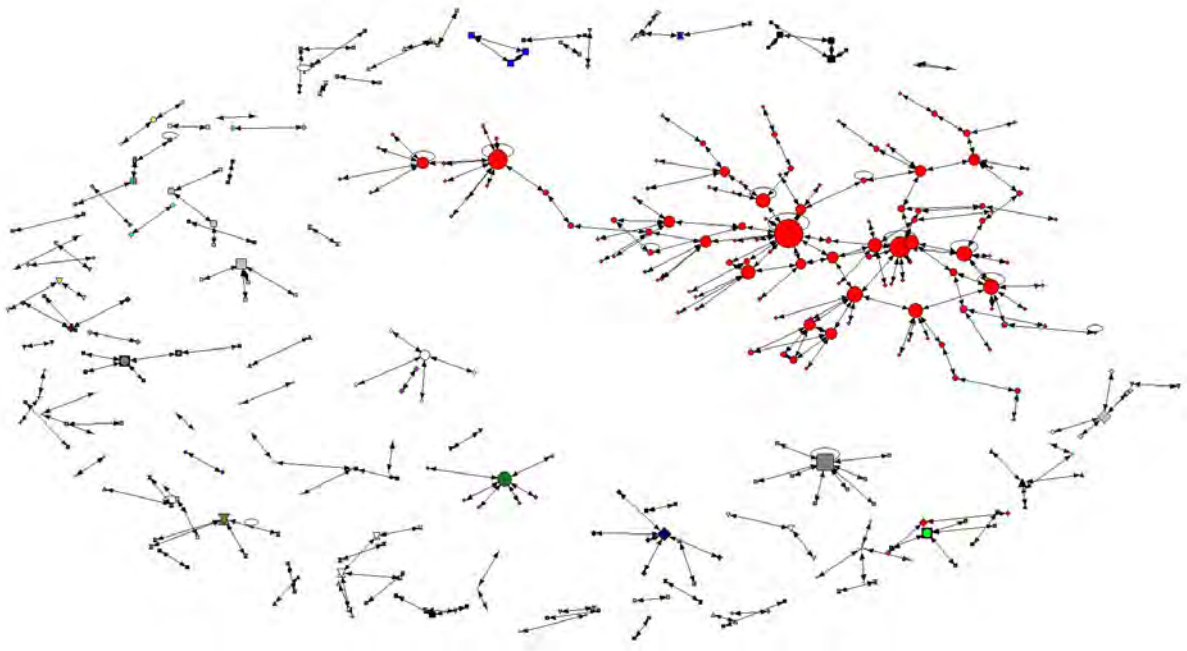

Fig. 4—Institutional collaboration network

J. J. Hospital; Bombay (7) and Government College; Lahore (7). The higher betweenness centrality score of IISc Bangalore shows that it was the centre of collaboration. It was also the most prominent actor in the largest component that consists of 123 actors. The institutions with higher betweeness are: University College; London, Andhra University, Presidency College; Madras and J. J. Hospital, Bombay. This collaboration network is not connected as a whole, so the distance between nodes in disconnected components of a network is infinite. It has been mentioned earlier that the closeness measure cannot be applied to networks with disconnected components[34,37]. The institutions with high eigenvector centrality are as follows Indian Institute of Science, University College; London, Central College; Bangalore, University of Mysore, Allahabad University and Punjab University; Lahore (Table 5).

Conclusion

Pre-independent Indian science saw the contribution of many seminal works by renowned scientists. Beside the state initiatives, there were many private initiatives both from the individual and political leaders of that time that had a 'nationalistic' zeal. The institutions like Indian Institute of Science, Indian Institute for Cultivation of Science, Bose Institute and so on were formed. These institutions were very productive in terms of scientific productivity and also prominent in scientific collaboration. These establishments of colonial period still hold the pillars of modern science in India[8, 40, 41].

The result of the present study shows that S&T publication activities in undivided India thrived during the mid-1930s. This period is associated with the creation of a series of support structures in S&T and can be considered as consolidation and institutionalization of colonial science. Parallel to colonial science, there emerged a stream of early science policy efforts in nation-building through a number of private initiatives which placed Indian science in the international scientific domain[7, 8].

The maximum research activity was observed in the area of chemistry followed by agricultural and biological science. Indian scientists preferred to publish their research output in Indian journals. The *Proceedings of the Indian Academy of Sciences* published by the Indian Academy of Science since 1934 were the most preferred journals of publication. Also, prominent Indian scientists of the time preferred Indian journals as their medium of publication of their research outputs.

The authorship collaborations were mainly restricted among the Indian authors with very little or

Table 5—Centrality measures of institutional actors

Institute	Degree	Institute	Betweenness	Institute	Closeness	Institute	Eigenvector
Indian Institute of Science	14	Indian Institute of Science	4717.216	Hislop College, Nagpur, C.P.	98775	Indian Institute of Science	0.541
Allahabad University	10	University College London	2797.239	Hope Tea Estate, North Bengal	98775	University College London	0.288
Calcutta Medical College & Hospitals	9	Andhra University	2094	Malaria Survey of India, United States	98775	Central College, Bangalore	0.263
Samaritan Free Hospital, UK	8	Presidency College, Madras	1711	D. J. Sind College, Karachi	98709	University of Mysore	0.26
Benares Hindu University	7	J. J. Hospital, Bombay	1674.691	Lahore Maternity Hospital, Lahore	98705	Allahabad University	0.235
J. J. Hospital, Bombay	7	University of London	1512	Brahmachari Research Institute, Calcutta	98662	Punjab University, Lahore	0.201
Government College, Lahore	7	Punjab University, Lahore	1501.714	Eden Hospital for Women, Calcutta	98662	Imperial Institute of Sugar Technology, Cawnpore	0.182
Haffkine Institute, Bombay	6	University of Calcutta	1417	London School of Tropical Medicine, UK	98662	Science College, Patna	0.175
Central College, Bangalore	6	Calcutta Medical College & Hospitals	1376	Chittaranjan Hospital, Calcutta	98662	University of Madras	0.167
University of Lucknow	6	University of Madras	1263	Bacteriologist to the Government of Bengal	98662	Andhra University	0.155
Punjab University, Lahore	6	Allahabad University	1154.095	Chemical Examiner to the Government, Bengal	98662	University of Lucknow	0.149
University of Madras	6	Government College, Lahore	1054.452	Government of Bengal	98662	Government College, Lahore	0.146
University of Bath, UK	6	University of Bombay	1019.667	School of Tropical Medicine, Calcutta	98654	Muslim University, Aligarh	0.146
University of Bombay	5	Haffkine Institute, Bombay	1019.357	Karnatak College, Dharwar	98590	University of Edinburgh	0.14
Royal Institute of Science, Bombay	5	Muslim University, Aligarh	928.834	Elphinstone College, Bombay	98588	Bose Institute, Calcutta	0.129
King Edward Memorial Hospital, Bombay	5	Benares Hindu University	900.667	Mayo Hospital, Lahore	98584	University of Mysore	0.122
School of Tropical Medicine, Calcutta	5	Royal Institute of Science, Bombay	739	Institute of Science, Bangalore	98542	D.A.V. College, Cawnpore	0.122
Grant Medical College	5	University of Edinburgh	698	Calcutta Medical College & Hospitals	98541	Fergusson College, Poona	0.122
Andhra University	5	Science College, Patna	650.595	King Institute	98538	Christi College, Oxford, UK	0.122
Middlesex Hospital, London	5	St.Xavier's College, Bombay	650.333	Madras Christian College	98509	J.J. Hospital, Bombay	0.122
University College London	5	Christian College, Lahore	638.333	Bombay University, Medical School, Poona	98507	Panjab University Institute of Chemistry, Lahore	0.098
Department of Public Health, Cairo	5	University of Lucknow	637.167	Ismail College, Bombay	98475	Benares Hindu University	0.077
Botany School, Cambridge	5	University of Cambridge	498.691	Plymouth Laboratory, United States	98475	University of Cambridge	0.067

most no collaborations with the scientists from the Great Britain. The similar trends have also been seen in the institutional collaboration patters. It shows the strength of Indian scientists and institutes in doing independent research at that time.

References

1. Basalla G, The spread of western science, *Science,* 156 (1967) 611-622.
2. Kumar D, Patterns of colonial science in India, *Indian Journal of History of Science,* 15(1) (1980) 105-113.
3. Kumar D, Science and society in colonial India: Exploring an agenda, *Social Scientist, 28*(5/6) (2000) 24-46.
4. Kumar D, Science and the Raj: A study of British India, 2nd edn (Oxford University Press India; New Delhi) 2006.
5. MacLeod R M, Scientific advice for British India: Imperial perceptions and administrative goals, 1898—1923, *Modern Asian Studies, 9*(3) (1975) 343-384.
6. Raina D, From west to non-west? Basalla's three-stage model revisited, *Science as Culture, 8*(4), (1999) 497-516.
7. Krishna V V, A portrait of the scientific community in India: Historical growth and contemporary problems. In J. Gaillard, V. V. Krishna, & R. Waast (Eds.), *Scientific Communities in the Developing World*, (Sage Publications India Pvt Ltd; New Delhi), 1997, p. 236-280.
8. Krishna V V, India. In M. Scerri, & H. M. M. Lastres (Eds.), *BRICS National System of Innovation: The Role of the State*. (Routledge India; New Delhi) 2013, p.138-187.
9. Prakash, G. Science "Gone Native" in colonial India. *Representations, 40* (Special Issue: Seeing Science), (1992) 153-178.
10. Krishna V V, The Colonial "Model" and the Emergence of National Science in India: 1876–1920. In P. Petitjean, C. Jami, & A. M. Moulin (Eds.), *Science and Empires Boston Studies in the Philosophy of Science* (Vol. 136, (1992) p. 57-72).
11. Raj K, Colonial encounters and the forging of new knowledge and national identities: Great Britain and India, 1760-1850. *Osiris, 2nd Series, 15*(Nature and Empire: Science and the Colonial Enterprise), (2000) 119-134.
12. Harrison M, Science and the British Empire, *Isis,* 96(1) (2005) 56-63.
13. Needham J, Science and Civilization in China. Vol. 2 History of Scientific Thought, (1956).
14. Braun T, Bujdosó E, & Schubert A, *Literature of analytical chemistry: A Scientometric evaluation*: (CRC), 1986.
15. Glänzel W, Bibliometrics as a research field. *A course on theory and application of bibliometric indicators. (Course Handouts).* Available online at https://www.research-gate.net/publication/242406991_Bibliometrics_as_a_research_field_A_course_on_theory_and_application_of_bibliometric_indicators. (Accessed on January 30th 2017).
16. Abbasi A, Hossain L, and Leydesdorff L, Betweenness centrality as a driver of preferential attachment in the evolution of research collaboration networks, *Journal of Informetrics,* 6(3) 403-412.
17. Otte E and Rousseau R, Social network analysis: a powerful strategy, also for the information sciences. *Journal of information Science,* 28(6) (2002) 441-453.
18. Yin L -C, Kretschmer H, Hanneman R A, Liu Z –Y, Connection and stratification in research collaboration: An analysis of the COLLNET network, *Information Processing & Management,* 42 (6) (2006) 1599-1613.
19. Hanneman R, Riddle M, Introduction to social network analysis. Available at *http://faculty. ucr. edu/~ hanneman/-nettext/ (Accessed on 30th December 2016)*
20. Scopus Content coverage guide. Elsevier BV Amsterdam, Netherlands (2016).
21. Borgatti S P, Centrality and network flow, *Social Networks,* 27 (1) (2005) 55-71.
22. Borgatti S P, Everett M G, Freeman L C. Ucinet for Windows: Software for social network analysis (2002).
23. Heymann S, Gephi. In *Encyclopedia of social network analysis and mining* (Springer) (2014) 612-625.
24. Bhattacharya D, Chakravarty R and Deb R R, A survey of Bengali writings on science and technology, 1800-1950, *Indian Journal of History of Science,* 24 (1) (1989) 8-66.
25. Van Raan A, Scientometrics: State-of-the-art, *Scientometrics,* 38 (1) (1997) 205-218.
26. Patra S K, Chand P, Biotechnology research profile of India, *Scientometrics,* 63 (3) (2005) 583-597.
27. Beaver D D, Reflections on scientific collaboration (and its study): past, present, and future. *Scientometrics,* 52 (3) (2001) 365–377.
28. Ponomariov B and Boardman C, What is co-authorship? *Scientometrics*, 109 (3) (2016) 1939-1963.
29. Newman M E, Coauthorship networks and patterns of scientific collaboration, *Proceedings of the National Academy of Sciences,* 101 (suppl 1) (2004) 5200-5205.
30. Newman M E, *Networks: an introduction,* (Oxford University press; Oxford) 2010.
31. Newman M E, The structure and function of complex networks, *SIAM Review,* 45 (2) (2003) 167-256.
32. Newman M E, The structure of scientific collaboration networks, *Proceedings of the National Academy of Sciences,* 98 (2) (2001) 404-409.
33. Freeman L C, Centrality in social networks conceptual clarification, *Social Networks,* 1 (3) (1978) 215-239.
34. Wasserman S and Faust K, *Social network analysis: Methods and applications* 1st Ed (Cambridge University Press: Cambridge) 1994.
35. Everett M and Borgatti S P, Ego network betweenness, *Social Networks,* 27 (1) (2005) 31-38.
36. Leydesdorff L, Betweenness centrality as an indicator of the interdisciplinary of scientific journals, *Journal of the American Society for Information Science and Technology,* 58 (9) (2007) 1303-1319.

37. Opsahl T, Agneessens F and Skvoretz J, Node centrality in weighted networks: Generalizing degree and hortest paths. *Social networks,* 32 (3) (2010) 245-251.

38. Ilhan N, Gündüz-Ö˘güdücü S and Etaner-Uyar A S, Introduction to Social Networks: Analysis and Case Studies. In S. Gündüz-Ö˘güdücü, & A. S. Etaner-Uyar (Eds.), *Social Networks: Analysis and Case Studies* (pp. 1-19). Springer Wien Heidelberg New York Dordrecht London: Springer (2014).

39. UNESCO, *National science policy and organization of scientific research in India*. Paris, France: United Nations Educational, Scientific and Cultural Organization (1972).

40. Rao P R, India: Science and technology from ancient time to today, *Technology in Society*, 19 (3/4) (1997) 415-447.

41. Mashelkar R A, Indian science, technology, and society: The changing landscape, *Technology in Society*, 30 (2008) 299– 308.