

P. C. Vaidya's contributions to mathematics and physics

A. A. Shashikumara* and Rashmi Kumbar

Prahalad Chunnilal Vaidya was an eminent general relativist, gravitation theorist, physicist, mathematician, educationist and a follower of Gandhian philosophy in post-independence India. Apart from his scientific career, Vaidya is renowned for his Vaidya metric. Though he has contributed significantly to the scientific community, very few people are aware about him or his contributions. As 23 May 2019 was the 101st birth anniversary of Vaidya, here we present his contributions and their impact through a bibliometric study. This study presents an analysis of published research works of Vaidya. During his active career, he had contributed 102 publications, including 90 journal articles, 5 conference papers, 4 book chapters, 2 review articles and 1 report. His publications have received 2004 citations, h-index of 18 and i10-index of 29 from 1979 to 2018. We analysed Vaidya's publications by type, country, journals, publishers, citations, year-wise growth, collaborated authors, top cited papers, etc. This bibliometric study is an effort to draw the attention of the younger generation of scientists to Vaidya and his contributions.

Keywords. Bibliometric analysis, citations, mathematics, physics.

Early life

PRAHALAD CHUNNILAL VAIDYA was born on 23 May 1918 at Shahpur, Junagadh district, Gujarat, India¹. He lost his father when he was only 13-years-old. Vaidya, as inspired by his father continued his education and mathematics was a subject of great interest to him².

Vaidya completed his primary education in Bhavnagar, Gujarat. There after he went to Bombay (now Mumbai) for higher studies and joined Ismail Yusuf College, Mumbai. After two years, he joined the Institute of Science, Mumbai where he received his B Sc degree with majors in mathematics and physics and later on, M Sc degree in applied mathematics. Vaidya started his first teaching job in 1940 at the Dharmendra Singhji College in Rajkot, Gujarat.

Love for freedom

Along with passion for physics and mathematics, Vaidya had great concern for the society and country. He read Gandhi and Marx, and developed a realistic view of life and explored opportunities as to how to use them to the advantage of people rather than his own advantage.

A. A. Shashikumara and Rashmi Kumbar are in the SLIS, Central University of Gujarat, Gandhinagar 382 030, India and A. A. Shashikumara is also in the Dhirubhai Ambani Institute of Information and Communication Technology, Gandhinagar 382 007, India

*For correspondence. (e-mail: aashashi@gmail.com)

Vaidya joined Ahimsak Vyayam Sangh (AVS), which started with Gandhiji's blessing as an institute for physical education by Prithvi Singh Azad³. During World War II Azad did not want to take lead in the struggle; so AVS was closed. This association of Vaidya with AVS came to an end².

March towards Banaras

In 1937, V. V. Narlikar delivered a lecture on general theory of relativity of Einstein at the University of Mumbai, which inspired Vaidya to write a letter to Narlikar expressing his interest to work with him. Immediately he got a positive reply and he moved with his family to Banaras Hindu University (BHU)³. Vaidya was in Kashi during August 1942 to March 1943, where Narlikar was a Professor at the Mathematics Department of BHU.

Vaidya was a private student of Narlikar and twice in a week he rode a bicycle to BHU to meet and consult Narlikar at his residence. Within 10 months, good friendship had developed between them.

He spent most of his evenings on the banks of river Ganga with his wife. Besides his routine life, Vaidya was busy in research work and developing new mathematical concepts.

Meanwhile struggle for freedom was gathering support and Vaidya found himself getting involved in the events of the freedom movement².

Professional career

After returning from Banaras, Vaidya got the post of a lecturer at MTB College in Surat, and worked there for three years. An opportunity arrived in the form of an invitation from Homi Bhabha, to join his handpicked team at the newly set-up Tata Institute of Fundamental Research (TIFR) in Mumbai, which Vaidya promptly accepted. Vaidya's first year was spent closely interacting with colleagues and Bhabha himself. Due to accommodation constraints, he left Mumbai, and continued the rest of his academic career in Gujarat. In 1948 he joined Vitthalbhai Mahavidyalaya in Vallabh Vidyanagar. Vaidya being a natural teacher and leader worked closely with the students; also trained them in physical education. He also restarted his research work and gained a lot as far as mathematical research and teaching was concerned².

In 1955, Vaidya moved to Ahmedabad, Gujarat as a professor in Gujarat College. Within three years, the Director of Education appointed him as principal of M. N. College, Visnagar. Within a year, he moved back to Ahmedabad and joined the newly set-up Department of Mathematics at Gujarat University, and with his leadership qualities, he rose to the position of Vice-Chancellor⁴. Despite the responsibilities of the post, Vaidya always made time to continue his research and later founded the 'Indian Association of General Relativity and Gravitation'.

Soon, Vaidya's primary focus shifted to mathematics education. After joining the University he started to improve the level of postgraduate education. He was of the view that teachers must be trained before they improve the curriculum at any level of education. So he started various teacher training programmes.

Gujarat Ganit Mandal, the Mathematical Society of Gujarat was initiated by Vaidya in 1963. Its first conference in 1964 was held in Bhavnagar and since then, it has been established as the most dynamic mathematical society in India. In 1960, a summer school for college teachers was initiated and by 2004 there were programmes for primary school teachers as well.

In 1963, Vikram Sarabhai met Vaidya to discuss how Mathematics and Science could be made more popular; this meeting led to the establishment of the Community Science Centre in Ahmedabad.

Between 1964 and 1973, Vaidya served as a Visiting Professor of Mathematics at Washington State University, USA; London University (Queen Elizabeth College), York University and Newcastle University in the UK. He was a visiting scientist at Dublin Institute of Advanced Studies, Ireland, and International Centre for Theoretical Physics at Trieste, Italy. In June 1971, he delivered an informative series of lectures at the Institute Henri Poincaré, Paris. Vaidya also attended the 6th International Conference on General Relativity and Gravitation at Copenhagen.

Aparajith Ramnath in his recent article says that, 'I am a historian of science by training and profession – I had never heard of Vaidya until a couple of months ago, when a colleague mentioned his name during the course of a public lecture on the life and work of Hawking'⁵.

During the later stages of his life, Vaidya had confined himself to his Ahmedabad house due to deteriorating health. He passed away on 12 March 2010.

With this background understanding of Vaidya to create awareness among the current generation of science enthusiasts, the present bibliometric study was undertaken.

Major contributions

Vaidya has contributed a great deal to the literature of physics and mathematics. Some of his notable contributions are identified and compiled systematically in this article.

Vaidya metric

In 1942, Vaidya solved Einstein's equations and his solution is known as the Vaidya metric, which may be used to model astrophysical stars. Vaidya metric describes the non-empty external space-time of a spherically symmetric and nonrotating star which is either emitting or absorbing null dusts².

Objectives

The present study was conducted to understand and present Vaidya's invaluable research contributions and their impact. The major objectives of the study are:

- To identify, locate and list all publications of Vaidya, which otherwise are dispersed.
- To determine the number of journal articles and other types of documents published by him.
- To analyse all publications of Vaidya using a bibliometric method for identifying the co-authors, journals that published his papers, their geographic spread and the decadal rate of his scientific publications.
- To identify the citation impact and top cited publications of Vaidya.

Methodology

We used only Google Scholar as Scopus and Web of Science (WoS) have not indexed any of Vaidya's publications. The bibliography was prepared by creating a Google Scholar profile to gather all publications in a single place. We used Microsoft Excel to analyse the publications by type, country, journal titles and number of

articles published, major publishers. Further, all the citations received for his publications were also analysed. This bibliography lists 102 publications, including 90 journal articles, 5 conference papers, 04 book chapters, 2 book reviews and 1 report.

Scope and limitations of the study

The study covers only 102 publications of Vaidya retrieved through Google Scholar and analysed citations received from 1979 to 2018. Since these publications were not indexed by any other databases, we had to limit the study to only one source.

Vaidya's research contributions have been cited by many researchers around the world. As mentioned earlier, we have created a Google Scholar profile and added available citations to it. The available data were collected as on 6 July 2018. Table 1, shows the Google Scholar citations of Vaidya's publications. These publications have received 2004 citations, with *h*-index of 18 and *i10*-index of 29. Though, Vaidya had started publishing his works from 1941, this study tracked the citations going back up to 1979.

Scholarly activities and publications

Vaidya has published his scholarly works in many national and international journals, conferences, books, reports, etc. His contributions in the area of general relativity and astrophysics have been recognized across the world. He worked on topics like supermassive objects and black holes. Vaidya's first paper was published in *Physical Review* in 1951. Most of his works are published in high impact journals in physics and mathematics such as *Nature*, *Physical Review*, *Astrophysical Journal*, *Current Science*, *General Relativity and Gravitation*, *Pramana*, *Proceedings of the National Academy of Sciences*, etc. Vaidya was the founder editor and also regular writer of *Suganitam*, a Gujarati magazine which started publication in March 1963.

Year-wise citations

Vaidya's publications have been cited by professionals around the world. Interestingly, the citations have increased since the last decade. Figure 1 represents the year-wise citation received for Vaidya's publications on Google Scholar. From 1979 to 6 July 2018, totally 1705 citations

Table 1. Google scholar citations

Citations	1705
<i>h</i> -index	18
<i>i10</i> -index	29

were received. The year 2017 has got the highest citations, i.e. 98, followed by 2014 with 92 citations and 2015 with 89 citations, while the years 2005, 2011 and 2012 have got 76 citations each. The lowest citations were in 1982, i.e. 8 followed by 1983 which had 13 citations and 1980 and 1985 with 16 citations each. The results show that Vaidya's publications have been cited regularly by the researchers and found to be relevant for current research.

Type of publications

We made an effort to identify the publications in which Vaidya's works have been published. Figure 2, shows various types of publications of Vaidya's works. Most of the publications are journal articles which are 90 (88%), followed by five (5%) conference papers, four (4%) book chapters, two (2%) book reviews and one (1%) report. He has also authored several science books in Gujarati: *Akhil Brahmandman (In the Entire Universe)*; *Dashansh Paddhati Sha Mate? (Why Decimal System?)*; *Dadaji Ni Vato (Grandpa's Tales) – A Collection of Science Stories for Children*; *What is Modern Mathematics?* and *Ganit Darshan (Discourses in Mathematics)*. His work, *Ganit Darshan* had won the prize for Gujarati Scientific Literature from the Gujarat State Government in 1970–71. The study shows that Vaidya was involved in publishing his works regularly in various publications.

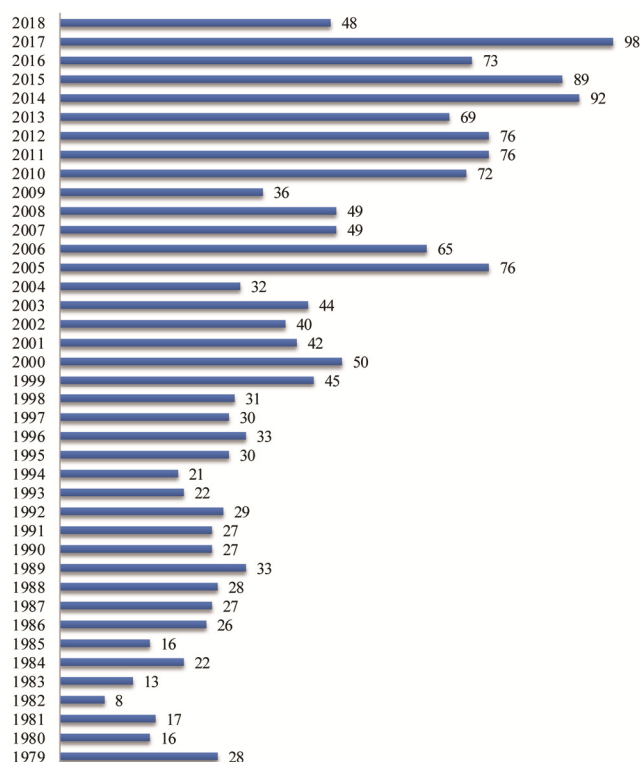


Figure 1. Year-wise citations.

Country-wise publications

We also traced the countries of origin of these publications. Figure 3, shows details of the countries of origin of Vaidya's publications. These publications are published by national as well as international publishers around the world. Most of them (over 55%) are published in Indian publications and the remaining are from USA (16%), UK (12%), Japan (7%), France (6%), Singapore (1%) and Moscow (1%). The origin of some of the publications (6%) could not be traced.

Journal titles and number of articles published

Figure 4 show that Vaidya published most of his works in Indian journals, besides a few in international journals. Among the Indian journals, *Current Science*, seems to have published maximum number of his papers. During

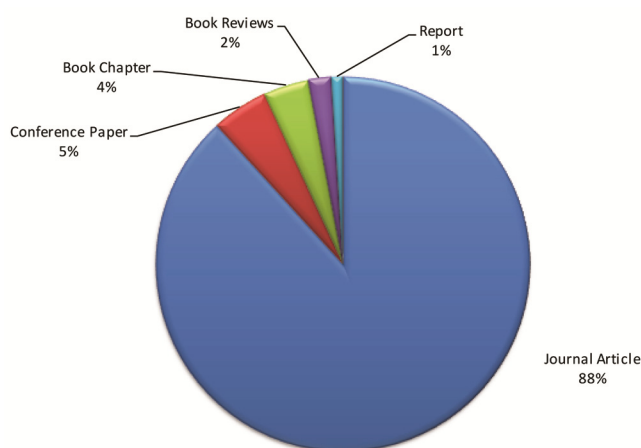


Figure 2. Type of publications.

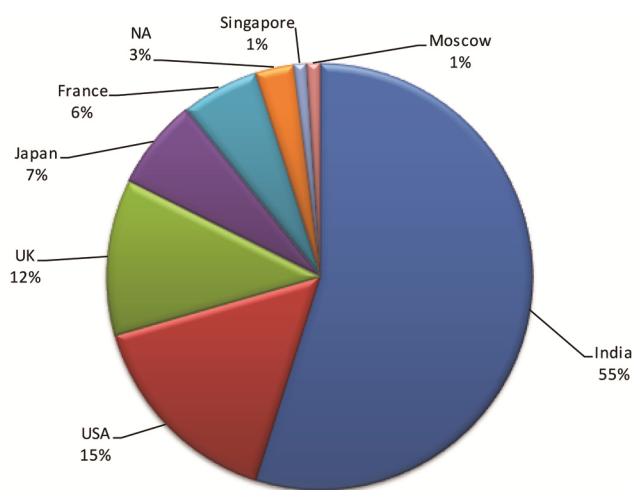


Figure 3. Country-wise publications.

the period, 1942–1999 he published 19 articles in *Current Science*. Vaidya published eight articles each in *General Relativity and Gravitation* and *Pramana – Journal of Physics*. Vaidya also published 5 articles each in *Physical Review*, *Nature* and *Bulletin of the Astronomical Society of India*, all being high impact factor journals. He has published his works mainly in subjects related to physics and mathematics, and in reputed journals and of high impact factor.

Major publishers and publications

Vaidya's works have been published by many national and international publishers, professional associations, societies and university presses. Figure 5 illustrates the major publishers of Vaidya's works. His works were published in journals and conferences by 25 publishers and associations. Current Science Association, Bengaluru published 19 articles and Springer, an international publisher published 15 articles in *General Relativity and Gravitation*, *Annales de l'Institut Henri Poincaré*, *Gravitation*, *Gauge Theories and the Early Universe*, *Gravitation and Cosmology*, *Acta Physica Academiae Scientiarum Hungaricae*, *Journal of Astrophysics and Astronomy and the Universe*. Among others, the Indian Academy of Sciences published 11 articles in *Pramana* and *Proceedings of the Indian Academy of Science, Section A*. Similarly, his works were also published by the Indian Mathematical Society, American Physical Society, Indian National Science Academy, Nature Publishing Group and Astronomical Society of India, etc.

Year-wise growth of publications

We have identified a total of 102 publications of Vaidya published between 1942 and 2010. Figure 6 shows the yearly growth of publications decade-wise. As shown in Figure 6, around 11 publications appeared in the first decade of his professional life. The highest number of publications (26) was published during 1962–1971 followed by 18 publications in 1972–1981, 17 in 1952–1961 and 14 publications in 1982–1991 and 1992–2001 respectively. Around two articles were also published towards the end of his life.

Author collaboration

Vaidya had a wide professional network around the world. Figure 7 shows the author collaboration network. Over 15 authors have collaborated with Vaidya and this fact endorses that he had worked with many eminent academicians and researchers. Of the 102 publications, 58 were authored by himself while 14 were published in collaboration with Patel, LK, and 4 publications each in collaboration with Raval, H. M.; Shah, K. B.; Narlikar,



Figure 4. Journal titles and number of articles published.

V. V. and Pandya, I. M.; Shah, Yashodhara P. had collaborated with three articles.

Top-cited papers

Table 2 shows Vaidya's top-cited articles which have more than 100 citations. The journal article 'The gravitational field of a radiating star' published in *Proceedings of the Indian Academy of Science, Section A* got 616 citations, highest among all his journal articles followed by 'Newtonian' 'Time in General Relativity' published in *Nature* which has got 242, and 'Exact relativistic model for a superdense star' published in *Journal of Astrophysics and Astronomy* got 148 citations. These citations indicate the importance of Vaidya's publications.

Summary

Vaidya has made phenomenal contributions in the field of mathematics and physics. His major achievements are general relativity, equations, gravitation theory and metric solution (Vaidya metric), which have been playing

a significant role in the state-of-the-art research in mathematics and physics.

Vaidya has 102 publications of various types during his research period; his first paper was published in *Current Science* in 1942; his 90 journal articles have been published in 30 different journals, including, *Current Science*, *General Relativity, Gravitation, Pramana* and *Nature*, etc. and these are published by 24 different publishers such as Springer, Current Science Association, Indian Academy of Sciences, American Physical Society, Indian National Science Academy, Indian Mathematical Society, Astronomical Society of India, Nature Publishing Group, etc. The most cited works of Vaidya are articles from these journals. The journal articles are highly cited compared to conference papers, as is the trend in most pure science subjects. As there is no mention of projects undertaken by Vaidya, the possibilities of publication of reports may be less. Five of Vaidya's journals articles have received more than 100 citations. Geographically, seven countries, namely, India, USA, UK, France, Japan, Moscow and Singapore have published his works. These countries belong to three continents, namely Europe, North America and Asia, where prominent research work has taken place in the fields of mathematics and physics.

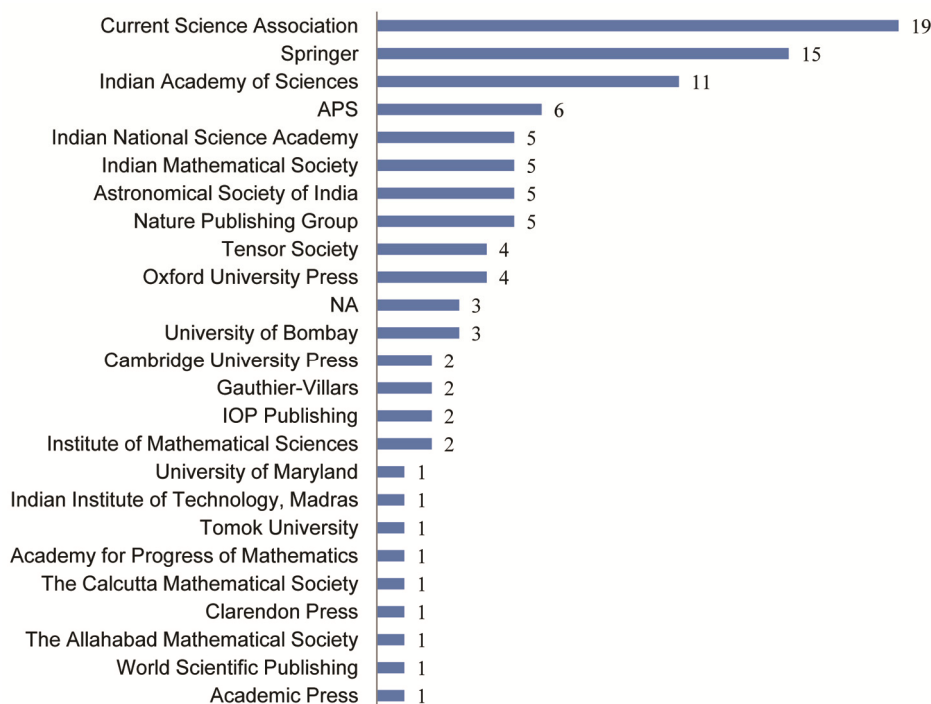


Figure 5. Publications by various publishers.

Table 2. Top-cited papers

Authors	Title	Publication source	Page nos	Year	Publisher	No. of citations
Vaidya, P. C.	The gravitational field of a radiating star	<i>Proceedings of the Indian Academy of Sciences, Section A</i>	264	1951	Indian Academy of Sciences	616
Vaidya, P. C.	‘Newtonian’ time in general relativity	<i>Nature</i>	260–261	1953	Nature Publishing Group	242
Vaidya, P. C. and Tikekar, Ramesh	Exact relativistic model for a superdense star	<i>Journal of Astrophysics and Astronomy</i>	325–334	1982	Springer	148
Bonnor, W. B. and Vaidya, P. C.	Spherically symmetric radiation of charge in Einstein–Maxwell theory	<i>General Relativity and Gravitation</i>	127–130	1970	Springer	128
Vaidya, P. C.	Nonstatic solutions of Einstein’s field equations for spheres of fluids radiating energy	<i>Physical Review</i>	10	1951	APS	104

Vaidya’s publications have been regularly cited in the current literature of physics and mathematics. Of the total citations received by Vaidya’s publications, 1705 (40%) have come since 2010, 92 citations in the year 2014, 89 citations in 2015, and 98 citations in 2017. Current Science Association is the major publisher of Vaidya’s works; the other major publisher is Springer, an international commercial publisher. This shows that Vaidya’s work is relevant even today and most valued by peers, subject professionals and also allied information professionals.

Conclusion

It is evident from the above study that Vaidya made phenomenal contributions to the field of mathematics and physics. His notable achievements were general relativity, relativistic theory for gravity and a metric solution to Einstein’s general relativity which is known as Vaidya metric. These contributions have been playing a significant role in the state-of-the-art research in mathematical and astrophysical relativity. Vaidya was a teacher, scientist, mathematician and freedom fighter. The world

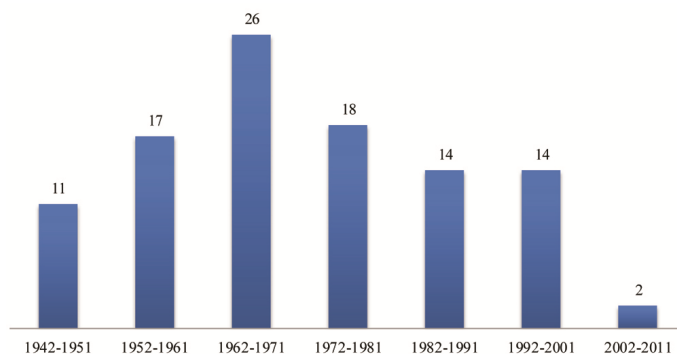


Figure 6. Year-wise growth of publications.

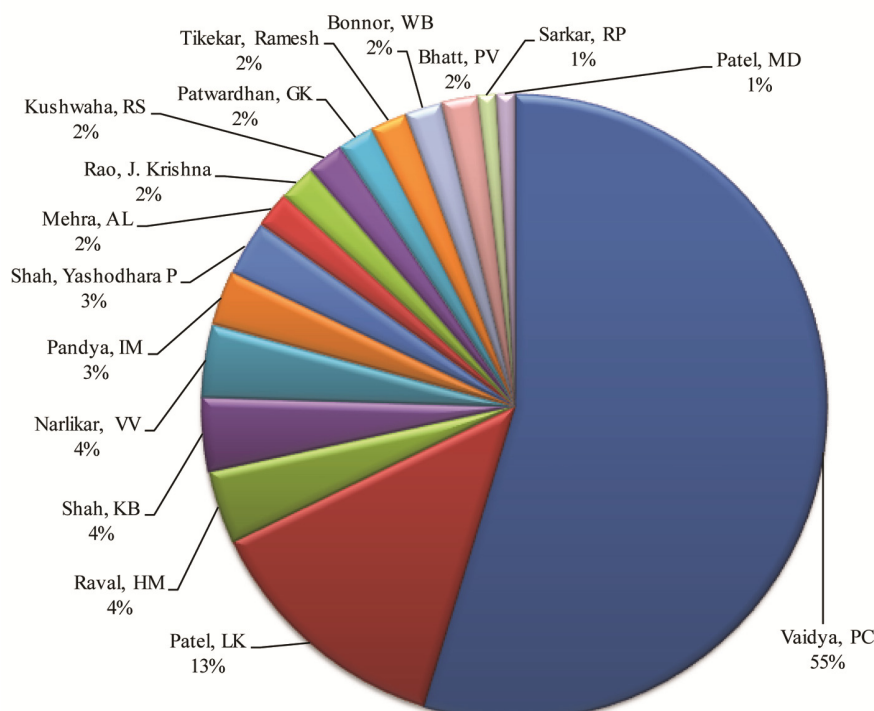


Figure 7. Author collaboration.

remembers him as a scientist, but Gujarat will always value him as a teacher more than a scientist or mathematician. During the course of evaluation of Vaidya's scholarly activities and publications, we found that he was genuinely involved in meaningful research that contributed to the knowledge base. All these demonstrates the impact of Vaidya's works on modern research. If every academic institution and library makes an effort to create awareness and popularize the works of scholars such as Vaidya, it would add great value to many ongoing research projects.

1. Prahalad Chunnilal Vaidya, Wikipedia, https://en.wikipedia.org/wiki/Prahalad_Chunnilal_Vaidya (accessed 10 August 2018).
2. Shanbag, S., Indian scientist – Prof P. C. Vaidya (motion picture); <https://www.youtube.com/watch?v=bvzV3RTEkF4> (accessed on 1 May 2019).

3. Sherrif, A., Remembering the forgotten scientist who fought for freedom and for science; <https://www.thebetterindia.com/143176/forgotten-indian-scientist-who-fought-for-freedom-and-for-science/> (accessed on 1 May 2019).
4. Shastri P., 100/100 for Gujarat's mathematics guru; <https://timesofindia.indiatimes.com/city/ahmedabad/100/100-for-gujarats-mathematics-guru/articleshow/64279402.cms> (accessed on 1 May 2019).
5. Ramnath, A., Centenary: P. C. Vaidya, a Gandhian physicist who laboured in India's shadows; <https://thewire.in/the-sciences/centenary-p-c-vaitya-a-gandhian-physicist-who-laboured-in-indias-shadows> (accessed on 1 May 2019).

Received 18 June 2019; revised accepted 14 August 2019

doi: 10.18520/cs/v117/i12/1951-1957