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SCIENTOMETRIC PORTRAIT OF P.K. IYENGAR

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P.K. Iyengar, the well known nuclear physicist is widely recognised as a very successful scientist. His publications were analysed by year, domain, collaboration pattern, channels of communications used, keywords etc. The results indicate that the temporal variation of his productivity and of the types of papers published by him are of such a nature that he is eminently qualified to be a *role model* for the younger generation to emulate. By the end of 1992, he has to his credit 74 papers in *Neutron and Solid State Physics*; 26 papers in *Mossbauer Spectroscopy*, 34 papers in *Reactor Physics, Fusion, and Cold Fusion*; 21 papers in *Nuclear Power*, and 27 papers of general popular interest. The period 1972-76, when Iyengar was 41-45 years age, was his most productive period with highest publication activity. Publication density was 1.9 and publication concentration was 21.87. Bibliograph of individual scientist does not follow Bradford's law. Productivity exceeds the conventional expectations of 80/20 rule.

KEYWORDS/DESCRIPTORS : Bibliometrics; Scientometrics; Collaboration; Publication density; Publication concentration; Research group interaction; History of Science; Sociology of Science; Individual scientist; Scientometric Portrait.

1 INTRODUCTION

Padmanabha Krishnagopala Iyengar was born on 29th June 1931 at Thiruvananthapuram (Trivandrum) in Kerala. He started his scientific career at Tata Institute of Fundamental Research in 1952. He joined Bhabha Atomic Research Centre (BARC) – the then Atomic Energy Establishment Trombay (AEET) in 1955. He worked with B.N. Brockhouse at Chalk River Nuclear Laboratories in Canada for 15 months during 1956-1957, where he made measurements of phonons in germanium; these measurements added a new chapter to all books on solid state physics. He measured and interpreted phonon dispersion curves in hexagonal metals, semiconductors and insulators. He has studied a number of metallic, ionic and molecular crystals using inelastic scattering technique. Measurements and interpretation of dispersion relations leading to determining of inter-atomic forces in solids using the technique of neutron inelastic scattering has been one of his achieve- ments. He has also developed very sophisticated instrumentations for such studies and other spectroscopic techniques. Iyengar is the pioneer of *Neutron Scattering Research* for the study of condensed matter in India. He has introduced new ideas and adapted and modified earlier concepts in experimental neutron physics. The APSARA reactor, first neutron diffractometer, inelastic scattering spectrometer, CIRUS reactor, PURNIMA reactor, and the window filter spectrometers are examples of his work. These led to the development in physics of fast chain reacting systems.

He went to Manila in 1965 and 1969 as an IAEA expert to set up experimental facilities for neutron spectrometry in Philippines. He has received several awards for his contribution.

* Ph.D. of Bombay University in 1963.

* The Shanti Swaroop Bhatnagar Prize for his outstanding contribution to Physics in the year 1971.
* Padma Bhushan award in 1975 for his key role in the *Peaceful Nuclear Experiment* at Pokharan on May 18, 1974.
* Science and Technology prize of the Kerala Government in 1978.
* Foreign fellow of the Roland Eotvos Physical Society, Hungary in 1980.
* Raman Centenary Medal by the Indian Association for the Cultivation of Science in 1988.
* Homi Bhabha Medal, by the Indian National Science Academy in 1990.
* FICCI award for Physical Science in 1990.
* Recipient of Jawaharlal Nehru Birth Centenary Award for the year 1993-94 instituted by the Indian Congress Association.

He is also an elected fellow of the Indian Academy of Science, Bangalore, Indian National Science Academy, Delhi and Academy of Science, Allahabad. There are several other awards/honours bestowed on him in recognition of his outstanding contributions to the field of nuclear science and technology.

He worked in several national and international committees. He shouldered leadership and administrative responsibility in several capacities as Head, Nuclear Physics Division, 1965; Director, Physics Group, 1972; Director BARC, 1984; Chairman AEC, 1990 till his retirement in January 1993; and as a Member of the Atomic Energy Commission from February 1993. During all these years he has published a number of papers on a variety of topics. He has guided the scientific career of many scientists as 'mentor' and has written a number of papers in collaboration with them. An analysis of his productivity of the subjects he has worked in and of the scientists with whom he has worked is highlighted quantitatively in this paper.

2 METHODOLOGY

Scientometrics is a branch of the science of science (Consciousness of Science). Scientometricians deal with:

1) explaining output in terms of organizational structure and resource inputs;
2) developing benchmarks to evaluate the quality of information sources;
3) packaging of information for science policy decision making;
4) defining appropriate data aggregation procedures and methods for diachronic analysis;
5) empirically describing the constantly changing relationships between science, technology and the market; and
6) forecasting productivity of scientists, so that dynamics of scientific research and technological development can be understood.

Scientific publication, seems to provide the best available basis for measuring research output. One of the first writers to suggest scientific publication as a measure of research productivity was William Shockley, a Nobel laureate who was interested in measuring research productivity among individuals within a group by analysing their publications.

The informing activities of a core research group can be evaluated quantitatively (how many publications) and qualitatively (where they are published). The informing activities of P.K. Iyengar's [1] research group were considered for the present study. The entries in the bibliography were arranged in a classified order under the following domains:

A. Neutron and Solid State Physics
B. Mossbauer Spectroscopy
C. Reactor Physics, Fusion, and ColdFusion
D. Nuclear Power
E. General

Normal count procedure [2] was followed. Full credit was given to each author regardless of whether he happens to be the first or the last author. It is widely recognised that scientists all over the world look at their own papers exclusively in that way. Similarly titles of the articles were analysed and one score was allotted for each keyword, subject, journal etc.

The degree of collaboration [3] in a discipline was defined as the ratio of the number of collaborative research papers to the total number of research papers published in the discipline during a certain period of time.

Vinkler [4] defined publication density as the *ratio of the total number of papers published to the total number of journals in which the papers were published*, and publication concentration as *the ratio in percentage of the journals containing half of the papers published to the total number of journals in which those papers were published* during the period under study.

3 RESULTS AND DISCUSSIONS

During 1955-91, P.K. Iyengar has published 182 papers out of which single authorship papers were 79 (43.4%). Two authorship papers were 38 (20.88%), three authorship papers were 15 (8.24%), four authorship papers were 18 (9.89%), five authorship papers were 15 (8.24%), and six and seven authorship papers were five (2.75%) each. He has published only one paper having eight authors (0.55%). Nine authorship papers were six (3.30%).

Domainwise contributions indicate that he has published 74 papers in 'Neutron and Solid State Physics' (40.66%); 26 papers in 'Mossbauer Spectroscopy' (14.29%); 34 papers in 'Reactor Physics, Fusion, and Cold Fusion' (18.68%); 21 papers in 'Nuclear Power' (11.54%); and 27 papers in the 'General' category (14.83%).

When his contributions as main author and as co-author were analysed, it was found that in the domain 'A' he had 31 papers (41.89%) as main author and 43 papers (58.11%) as co-author. In the domain 'B' he had five papers (19.23%) as main author and 21 papers (80.77%) as co-author. In the domain 'C' he had 20 papers (58.82%) as main author and 14 papers (41.18%) as co-author. He had only single authorship papers in domains 'D' and 'E'.

His yearwise contributions as single author, multiple author, cumulative total papers and collaboration coefficient are shown in Figure 1. He has published a maximum of 15 papers in the year 1973 at the age of 42 years. He had a peak of 12 multiple authorship papers in the year 1972 when he became Director, Physics Group. He had a maximum of eight single authorship papers in the year 1973. Second peak of multiple authorship papers having nine papers was in the year 1976. It has clearly indicated that the period 1972-76 had highest productivity when he was 41-45 years old. This agrees with various scholars who have noted a growing trend toward multiple authorship of scientific papers [5, 6, 7, 8]. Later studies [9] found, instead of one peak the productivity of researchers was shown to have two modes. One before the age of 40 and second around the age of 50. Researchers, it was suggested, may reach one type of plateau for innovative work and then, at a later age, a second plateau for integrative work. In case of P.K. Iyengar second peak was observed during 1988-90 at the age of 57-59. The veteran R&D professionals will consist of those who devote most of their time to administration and those who are still active in technical work. The two mature types are basically similar in academic background and in their readiness to develop products, but they differ in their commitments to the scientific community and in the desire for greater extrinsic rewards [10].

The general finding [11, 12, 13, 14] was that scientists publish most frequently in their fourth decade of life and there after publication rate drops. Zuckerman [15] compared age distribution of American Nobel laureates in science with the age distribution of american scientists in general. The majority of the Nobel laureates were relatively young when they had made their prize winning discovery, but the majority of American scientists also were relatively young. Since the age distribution for Nobel laureates matched that for scientists in general, he concluded that when allowance is made for the number of scientists at different ages, younger scientists are not more likely to be creative. However, due to their greater numerical representation, younger scientists are responsible for substantially more important contributions than older scientists.

Lehman [16] found that the majority of discoveries in science have come from individuals below the age of 40. The peak age for achievement differed betweeen disciplines, ranging from 26-30 for Chemistry to 36-40 for Genetics, Geology, Physiology, and Psychology. Scientists remain productive in the sense of publishing

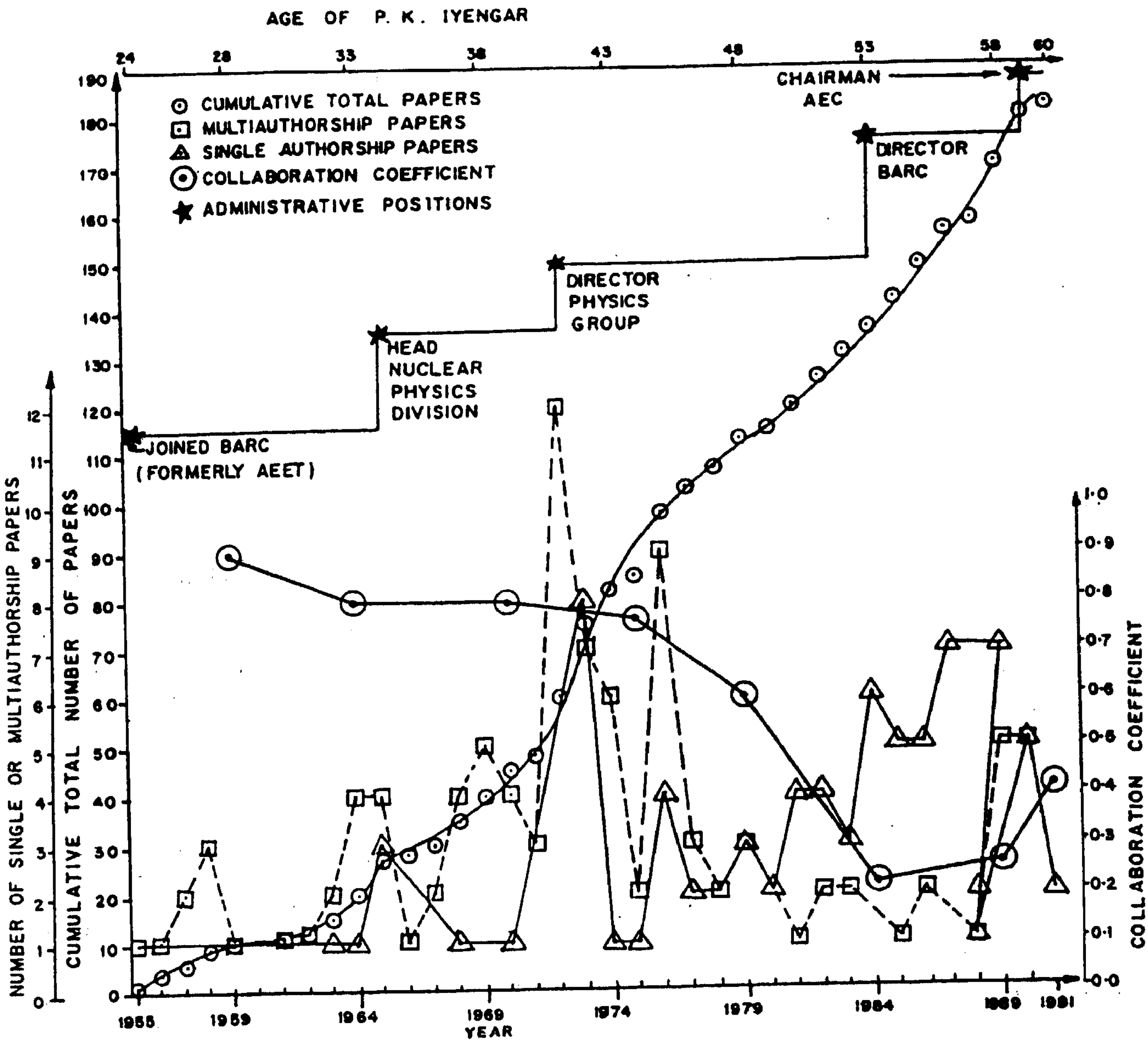

FIGURE 1
Yearwise Contributions of P.K. Iyengar

frequently, beyond 40, but what they then generate was less likely to have impact. His general conclusion was that genius does not function equally well throughout the years of adulthood. Superior creativity rises rapidly to a maximum which occurs usually in the thirties and then falls of slowly. Einstein was reported [17] to have said of scientists that *a person who has not made his great contribution to science by the age of thirty will never do so.*

The *success breeds success* phenomenon has its limits [18], a saturation takes place and instead of accelerating of a production rate, prolific authors are satisfied with their position and produce less than could be expected from Lotka's law; whereas Allison and Stewart [19] stated that among highly skewed distribution of productivity among scientists could be partly explained by a process of accumulative advantage. The publication productivity was found to be increasingly unequal as the career age increased.

Collaboration coefficient for his publications during 1955-59 was 0.89. Collaboration coefficient was stable during 1961-64 and 1965-69 at 0.8. During 1972-74 collaboration coefficient was 0.76. After this period there was a decline in collaboration coefficient during 1975-79 at 0.61, 1980-84 at 0.22, and during 1985-89 at 0.26.

Heads of departments seem to be the most productive researchers. First, it may be assured that the most productive scientists become heads, second, heads are *owners* of almost all scientific results scored in the department headed by them [20].

Studies of stratification in science have increasingly accepted the idea that science is a highly stratified and elitist system with skewed distributions. Attempts to explain the higher productivity of higher status scientists by pointing to their greater ease of publication as far as acceptance of their work by journals and publishers is concerned were not supported by the data in some recent studies. If status in general does not confer greater ease of publication in the paper [21] position within a research organization does confer greater ease of author or co-authorship and this was the major explanatory variable accounting for productivity difference within research laboratories as far as quantity of articles was concerned. Upward moves in laboratory's formal or informal position heirarchy were associated with a change of a scientist's reseach involvement from goal executing to goal setting functions as well as with an increasing access to scientific manpower and project money. Goal setting tasks provided for a significant reduction of time expenditures in research necessary to assure that the scientist was identified with the research results; consequently, they allowed for an involvement in more research tasks than originally. Equivalently, resources in scientific manpower and project money act as a multiplying element as far as quantity of output was concerned.

Domainwise productivity of cumulative number of papers depicted in Figure 2 clearly indicates that he had highest productivity of 74 papers in the domain of 'Neutron and Solid State Physics' which was his main area of interest from the very beginning of the career. His first paper on 'Mossbauer Spectroscopy' was published in 1967 and he produced 26 papers on this subject during the period 1967-86.

Mossbauer effect was first reported in 1958 [22]. Bibliometric analysis of papers in Mossbauer effect as covered in the physics abstracts has been carried out by Rangarajan and Bhatnagar indicating the growth curves of papers published in the branches of physics, chemistry, metallurgy and instrumentation tending to saturation level. But activity in the new branches of biology and archeology was expected to pick up. USA followed by USSR tops the countries publishing in this field. India occupied the 7th rank. Major

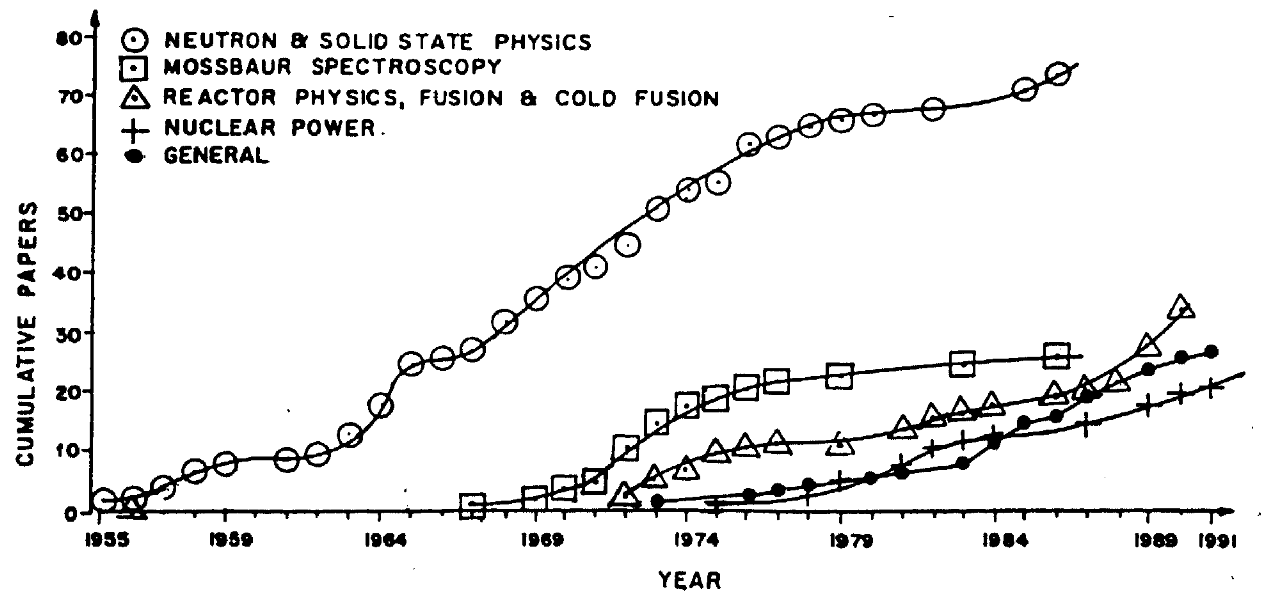

FIGURE 2
Domainwise productivity of P.K. Iyengar

portion of the contributions from India was from the universities and academic institutions. Research in this field was not initiated for nearly a decade after its discovery in the national laboratories of India and the contribution from the Defence research establishments was almost nil.

Iyengar's interest in the domain of 'Reactor Physics, Fusion, and Cold Fusion' although started by publishing the first paper in 1956 it remained latent till 1971. From 1972 onwards he has continuously published papers in this field numbering 29.

His first paper in the domain 'Nuclear Power' was published in 1975 and he has published 21 papers till 1991. The analysis of Indian journals covering nuclear physics literature reviewed from different institutions reveals that BARC is the major contributor in this area [23].

He started taking interest in 'popularization of science' and general writings since 1973 in the middle of his research career and contributed 27 papers which shows his concern for science literacy [24]. It looks he has followed the words of J. Bronowski: *We must be democracy of the intellect. We must not perish by the distance between people and power that destroyed Nineveh and Alexandria and Rome... that distance can be closed only if knowledge sits in the homes and heads of people and not up in the isolated seats of power* [25].

The researchers' association with P.K. Iyengar in chronological order of occurance and their authorship is shown in Figure 3 . Total group had 89 researchers including P.K. Iyengar. His active researchers group included B.A. Dasannacharya with 22 papers, P.R. Vijayaraghavan with 19 papers, C.L. Thaper with 18 papers, M. Srinivasan with 16 papers, A.P. Roy and G. Venkataraman with 14 papers, S.C. Bhargava

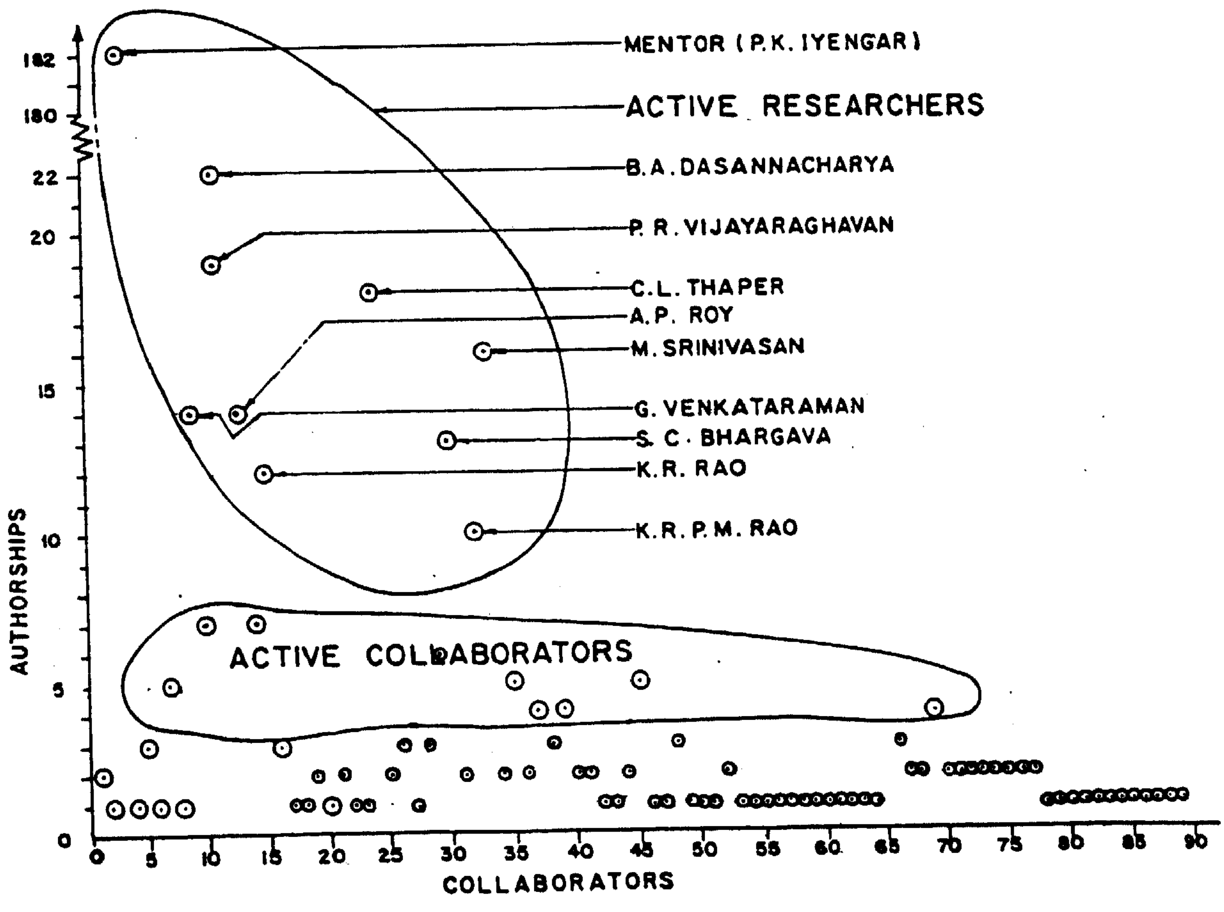

FIGURE 3
Researchers Association in Chronological Order of Occurrence

with 13 papers, K.R.Rao with 12 papers, and K.R.P.M. Rao having 10 papers.

Like many natural phenomenon, the growth of scientific knowledge appears to be cluster like. This seems to be true in physical sense. On a special scale scientific discussion mainly cluster around important universities, governmental and research institutions. On temporal scale, scientific discoveries often occur in a relatively short period of time since an important breakthrough makes new advancement possible.

Domainwise author productivity in collaboration with P.K. Iyengar is provided in Table 1. Forty five scientists have produced a single paper each, and 21 scientists have contributed two papers each in collaboration with him. Seven scientists have contributed three papers each. One group of three scientists has contributed four papers each and another group of three scientists has contributed five papers each. One scientist has contributed to six papers. Two scientists have contributed seven papers each. The low productivity group having below 4 papers constituted 120 authorships (25%) only. Total authorships were 474. Among the domains 51.48 percent contributions were from domain 'A' which forms the major interest of P.K. Iyengar.

According to 80/20 rule, 20 percent of the authors (in this particular case, 18) are supposed to contribute 80 percent of the total number of papers (146 in this case). But in our observation for this research group, 20 percent of the scientists produced 93 percent of the total number of papers (169). Thus, the present research group is highly productive and exceeds the expectations of 80/20 rule [26].

No. of Papers	Domainwise Authorships					Total No. of Authors	No. of Authors	Prominent Collaborators
	A	B	C	D	E			
1	20	2	17	6	–	45	45	
2	12	2	28	–	–	42	21	
3	9	3	9	–	–	21	7	
4	–	–	12	–	–	12	3	
5	10	–	5	–	–	15	3	
6	6	–	–	–	–	6	1	Goyal, P.S.
7	14	–	–	–	–	14	2	Satyamurthy, N.S. & Deniz, U.K.
10	–	10	–	–	–	10	1	Rao, K.R.P.M.
12	12	–	–	–	–	12	1	Rao, K.R.
13	–	13	–	–	–	13	1	Bhargava, S.C.
14	28	–	–	–	–	28	2	Roy A.P. & Venkataraman, G.
16	–	–	15	1	–	16	1	Srinivasan, M.
18	18	–	–	–	–	18	1	Thaper, C.L.
19	19	–	–	–	–	19	1	Vijayaraghavan, P.R.
22	22	–	–	–	–	22	1	Dasannacharya, B.A.
182	74	26	34	21	27	182	1	Iyengar, P.K.
Total	**244**	**56**	**120**	**27**	**27**	**474**		
Percentage	51.48	11.81	25.31	5.70	5.70			
Cumulative percentage	51.48	63.29	88.60	94.30	100.00			

Domains : A = Neutron and Solid State Physics; B = Mossbauer Spectroscopy; C = Reactor Physics, Fusion, and Cold Fusion; D = Nuclear Power; and E = General

TABLE 1
Author Productivity and Distribution of Authors and Papers by Domains

Fortyfive scientists have published single paper each, and 44 scientists have multiple papers. The authors having more than one paper were likely to produce papers in more than one research area [27]. But in the present study, P.K. Iyengar alone has contributed to five domains, while all his collaborators have concentrated in single domain except, M. Srinivsan, who has contributed 15 papers to domain 'C' and one paper to domain 'D', and R. Ramanna who has contributed one paper each in domain 'A' and 'C'. Subba Rao, K. has contributed one paper to domain A and five papers to domain C. This clearly indicated that the group under present study is of super specialised nature.

We emphasize on human being as the most important information resource. The *social intelligence* or *collective genius* has received recent research interest as an interdisciplinary subject. Societies, organisations, individuals, and nations acquire information, process, store and use it for action.

Authorship pattern of P.K. Iyengar and his collaborators is tabulated domainwise in Tables 2, 3, 4, 5 and depicted in Figure 4. Collaborators in the domain 'A' working with P.K. Iyengar were 40. Fifty percent of the authorships were due to four authors, viz., Iyengar, Dasannacharya, Vijayaraghavan and Thaper; and 14 papers each were found in four authorship and five authorship papers.

In the domain 'B' publications, 70 percent of the authorship credit goes to Iyengar and Bhargava. 75 percent of the papers were two authorship papers.

In the domain 'C' publications 50 percent of the authorships were due to Iyengar, Srinivasan, Subba Rao, Basu and Chandramoleshwar. Five papers had nine authorship and three papers had seven authorship.

In the domain 'D' publications, 78 percent authorships belong to Iyengar, P.K. only and that too 67 percent authored by him as single author.

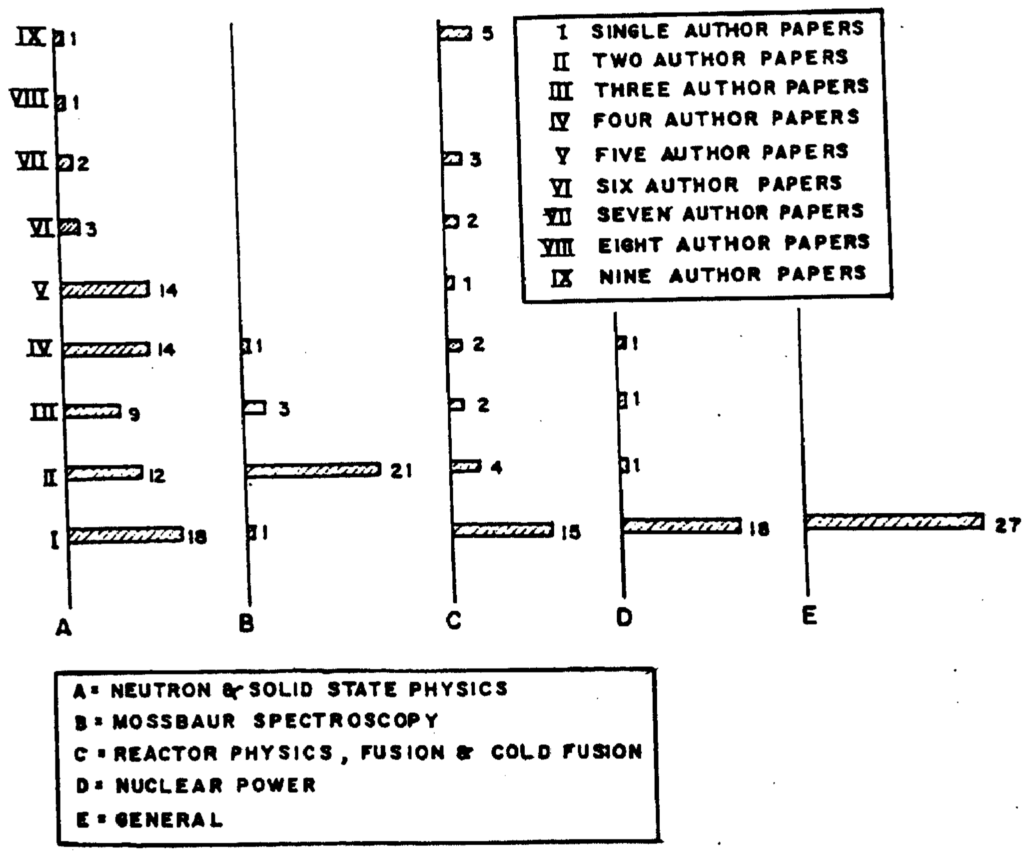

FIGURE 4
Authorship Pattern in Various Domains

Sl. No.	Author	Single author	Two author		Three author			Four author				Five author					Six author						Seven author							Eight author								Nine author									Total	Percentage	Cumulative Percentage
		a	a	b	a	b	c	a	b	c	d	a	b	c	d	e	a	b	c	d	e	f	a	b	c	d	e	f	g	a	b	c	d	e	f	g	h	a	b	c	d	e	f	g	h	i			
1.	Iyengar, P.K.	18	5	7	1	-	8	5	-	-	9	1	1	7	-	5	-	1	1	-	-	1	-	-	-	2	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	74	30.32	30.32
2.	Dasannacharya, B.A.	-	-	-	-	1	1	-	8	1	-	1	-	1	4	-	2	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	9.01	39.33
3.	Vijayaraghavan, P.R.	-	3	1	4	-	-	-	-	3	-	-	-	-	5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	7.78	47.11
4.	Thaper, C.L.	-	-	-	2	1	-	4	-	3	-	2	-	-	1	-	1	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	7.38	54.49
5.	Roy, A.P.	-	-	-	1	-	-	1	-	-	3	-	-	1	2	4	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	5.74	60.23
6.	Venkatraman, G.	-	-	-	-	1	-	-	3	2	-	4	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	5.74	65.97
7.	Rao, K.R.	-	-	1	-	-	-	-	-	-	1	3	2	1	-	-	-	1	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	4.92	70.89
8.	Satayamurthy, N.S.	-	-	-	-	1	-	-	1	1	-	1	-	2	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	2.87	73.76
9.	Deniz Usha, K.	-	-	-	-	-	-	-	-	-	1	1	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	2.87	76.63
10.	Goyal, P.S.	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	2.46	79.09
11.	Brockhouse, B.N.	-	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	2.05	81.14
12.	Venkatesh, A.H.	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	2.05	83.19
13.	Madhav, Rao L.	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1.23	84.42
14.	Sequeira, A.	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1.23	85.65
15.	Soni, J.N.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	3	1.23	86.88
16.	Chandra, P.P.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.82	87.70
17.	Chaplot, S.L.	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.82	88.52
18.	Marsongkohadi,	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	0.82	89.34
19.	Nandedkar, R.V.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.82	90.16
20.	Natera, M.G.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	0.82	90.98
21.	Sinha, S.K.	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.82	91.80
22.	Betigiri, M.G.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	92.21
23.	Dande, Y.D.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	92.62
24.	David, T.P.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	93.03
25.	Deshpande, A.S.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	93.44

TABLE 2
Authorship Pattern of P.K. Iyengar and his Collaborators in Neutron and Solid State Physics Publications

TABLE 2: Authorship Pattern of P.K. Iyengar and his Collaborators in Neutron and Solid State Physics Publications *(Contd.)*

Sl. No.	Author	Single author	Two author		Three author			Four author				Five author					Six author						Seven author							Eight author								Nine author									Total	Percent-age	Cumu-lative Percent-age
		a	a	b	a	b	c	a	b	c	d	a	b	c	d	e	a	b	c	d	e	f	a	b	c	d	e	f	g	a	b	c	d	e	f	g	h	a	b	c	d	e	f	g	h	i			
26.	Gameel, Y.H.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	93.85
27.	Hiremath, S.C.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	94.26
28.	Lee, T.C.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	0.41	94.67
29.	Mehta, M.K.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	95.08
30.	Navarro, Q.O.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	0.41	95.49
31.	Nimwanadon, T.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	0.41	95.90
32.	Pineda, V.M.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	0.41	96.31
33.	Rajput, V.S.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	0.41	96.72
34.	Ramanna, R.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	97.13
35.	Rama Rao, P.N.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	97.54
36.	Singh, P.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	0.41	97.95
37.	Song, J.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	0.41	98.36
38.	Srinivasan, T.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	98.77
39.	Subba Rao, K.	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	99.18
40.	Trevino, S.T.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	99.59
41.	Veeraraghavan,	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.41	100.00
	Total	18	12	12	9	9	9	14	14	14	14	14	14	14	14	14	3	3	3	3	3	3	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	244		
	Percentage	7.38	9.83		11.06			22.95				28.69					7.38						5.74							3.28								3.69											
	Cumulative percentage	7.38	17.21		28.27			51.22				79.91					87.29						93.03							96.31								100.0											

Position of author: a = First author; b = Second author; c = Third author; d = Fourth author; e = Fifth author; f = Sixth author; g = Seventh author; h = Eighth author; and i = Nineth author

Author	I	II		III			IV				Total	Percentage	Cumulative percentage
	a	a	b	a	b	c	a	b	c	d			
Iyengar, P.K.	1	4	17	-	-	3	-	-	1	-	26	46.42	46.42
Bhargava, S.C.	-	10	2	-	-	-	-	1	-	-	13	23.21	69.63
Rao, K.R.P.M.	-	7	-	-	3	-	-	-	-	-	10	17.85	87.48
Jaggi, N.K.	-	-	-	3	-	-	-	-	-	-	3	5.36	92.84
Parvathanathan, P.S	-	-	2	-	-	-	-	-	-	-	2	3.58	96.42
Srivastava, J.K.	-	-	-	-	-	-	1	-	-	-	1	1.79	98.21
Thosar, B.V.	-	-	-	-	-	-	-	-	-	1	1	1.79	100.00
Total	**1**	**21**	**21**	**3**	**3**	**3**	**1**	**1**	**1**	**1**	**56**		
Percentage	1.79	75.00		16.07			7.14						
Cumulative %	1.79	76.79		92.86			100.00						

Note : I = Single author paper, II = Two author papers, III = Three author papers, & IV = Four author papers
a = First author, b = Second author, c = Third author and d = Fourth author

TABLE 3
Authorship Pattern of P.K. Iyengar and his Collaborators in Mossbauer Spectroscopy Publications

In this domain collaboration was found to be very low and up to four authorship level papers only.

The 'General' popular 27 articles, lectures, radio talks etc. given by P.K. Iyengar were all single authored. (Figure 4)

Generally positive relationship exists between collaboration and quality [28]. Gains from collaboration may be apparent by more productive quantitative output of scientific knowledge, more efficient use of scientific technology and more subjective positive involvement of individuals in the research output process.

Articles in journals are the most used vehicles in contemporary science and reflect a high degree of integration and evaluation done by scientific community. However, the fact that journal articles receive so much attention from the scientific community does not mean they are the only one, sometimes, even the most important source of information.

In the present case study 61 papers were published in 32 journals. Publication density was found to be 1.9, whereas publication concentration was found to be 21.87. Journalwise scattering of publications of P.K. Iyengar are provided in Table 6. 75 percent papers were published in 17 journals. Highest impact factor of 8.213 was found for the journal 'Physical Review Letters' where P.K. Iyengar has published one paper only. Next journals in order of impact factors are 'Physical Review'(2.622), and 'Solid State Communications' (2.52) where he has published two and five papers respectively.

Iyengar has published 43 papers in 18 national symposia/workshops/meetings of which 26 papers were published in 'Nuclear Physics Symposium'. The scattering of these papers is given in Table 7.

Iyengar has published 41 papers in 31 international symposia/worshops/meetings as shown in Table 8. Highest number of four papers were published in 'Symposium on Inelastic Scattering of Neutrons', IAEA, Vienna.

In the classical model of scientific communication, the interaction, or peer review begins when preliminary research is first presented at seminars, then in forums such as symposia or conferences. The scientists attending these forums not only learn what research is being done by other scientists, they provide the objective feed back pointing out the potential questions and/or modifications that are needed

Sl. No.	Author	Single author	Two author		Three author			Four author				Five author					Six author						Seven author							Nine author									Total	Percentage	Cumulative percentage
		a	a	b	a	b	c	a	b	c	d	a	b	c	d	e	a	b	c	d	e	f	a	b	c	d	e	f	g	a	b	c	d	e	f	g	h	i			
1.	Iyengar, P.K.	15	4	-	-	-	2	-	-	-	2	-	-	1	-	-	1	-	-	-	-	1	-	-	-	-	-	-	3	2	-	-	-	-	-	-	-	3	34	28.34	28.34
2.	Srinivasan, M.	-	-	3	1	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	1	1	-	2	-	-	-	1	-	15	12.51	40.85
3.	Subba Rao, K.	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	5	4.17	45.02
4.	Basu, T.K.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	4	3.33	48.35
5.	Chandramoleshwar, K.	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	4	3.33	51.68
6.	Shyam, A.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	2	-	-	-	4	3.33	55.01
7.	Das, S.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	3	2.50	57.51
8.	Krishnan, M.S.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	3	2.50	60.01
9.	Malhotra, S.K.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	3	2.50	62.51
10.	Arunachalam, T.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1.67	64.80
11.	Chitra, V.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	1.67	65.85
12.	Gangadharan, S.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	1.67	67.52
13.	Gaonkar, D.G.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	1.67	69.19
14.	Iyengar, T.S.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	1.67	70.86
15.	Job, P.K.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	2	1.67	72.53
16.	Kalyanaraman, R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2	1.67	74.20
17.	Nargundkar, V.R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	2	1.67	75.87
18.	Pashupathy, C.S.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2	1.67	77.54
19.	Radhakrishnan, T.P.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1.67	79.21
20.	Raju, V.S.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	1.67	80.88
21.	Rout, R.K.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	1.67	82.55
22.	Sikka, S.K.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	1.67	84.22
23.	Sundaresan, R.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1.67	85.89
24.	Digamkar,	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	86.72
25.	Iyengar, S.B.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	87.55

TABLE 4

Authorship Pattern of P.K. Iyengar and his Collaborators in in Reactor Physics, Fusion, and Cold Fusion Publications

TABLE 4
Authorship Pattern of P.K. Iyengar and his Collaborators in in Reactor Physics, Fusion, and Cold Fusion Publications *(Contd.)*

Sl. No.	Author	Single author	Two author		Three author			Four author				Five author					Six author						Seven author							Nine author									Total	Percentage	Cumulative percentage
		a	a	b	a	b	c	a	b	c	d	a	b	c	d	e	a	b	c	d	e	f	a	b	c	d	e	f	g	a	b	c	d	e	f	g	h	i			
26.	Joshi, B.V.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	88.38
27.	Kalyana Sundaram,	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	8.83	89.21
28.	Kaushik, T.C.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	0.83	90.04
29.	Kulkarni, L.V.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	0.83	90.87
30.	Lal, M.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	91.70
31.	Maglich, B.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	92.53
32.	Mani, G.S.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	93.36
33.	Mishra, S.C.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	94.19
34.	Nagvenkar, V.G.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	0.83	95.02
35.	Nering, J.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	95.85
36.	Powell, C.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	96.68
37.	Ramanna, R.	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	97.51
38.	Rao, P.S.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	0.83	98.34
39.	Sood, D.D.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	99.17
40.	Wilmerding, A.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.83	100.00
	Total	15	4	4	2	2	2	2	2	2	2	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	5	5	5	5	5	5	5	5	5	120		
	Percentage	12.51	6.66		5.00			6.66				4.15					10.00						17.50							37.52											
	Cumulative percentage	12.51	19.17		24.17			30.83				31.98					44.98						62.48							100.00											

Position of author: a= First author; b = Second author; c = Third author; d = Fourth author; e = Fifth author; f = Sixth author; g = Seventh author; h = Eighth author; and i = Nineth author

Author	I	II		III			IV				Total	Percentage	Cumulative percentage
	a	a	b	a	b	c	a	b	c	d			
Iyengar, P.K.	18	1	-	1	-	-	1	-	-	-	21	77.80	77.80
Damodaran, K.K.	-	-	-	-	-	-	-	1	-	-	1	3.70	81.5
Mukhopadhyay, P.	-	-	-	-	-	1	-	-	-	-	1	3.70	85.2
Srinivasan, M.	-	-	1	-	-	-	-	-	-	-	1	3.70	88.9
Sarma, M.S.R.	-	-	-	-	-	-	-	-	1	-	1	3.70	92.6
Sundaram, C.V.	-	-	-	-	1	-	-	-	-	-	1	3.70	96.3
Wagadharikar, V.K.	-	-	-	-	-	-	-	-	-	1	1	3.70	100.00
Total	**18**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**27**		
Percentage	66.67	7.41		11.11			14.81						
Cumulative %	66.67	74.08		85.19			100.00						

Note : I = Single author paper, II = Two author paper, III = Three author paper, and IV = Four author paper
a = First author, b = Second author, c = Third author, and d = Fourth author

TABLE 5
Authorship Pattern of P.K. Iyengar and his Collaborators in Nuclear Power Publications

to advance the research to the point of publishing an article in refereed journals. Conference literature forms a vital communication link in many fields of science and engineering. Quite often the first public disclosure of important science and technology developments or discoveries occurs at conferences, symposia or meetings having similar designations. Conference materials constitute a significant portion of the scientific literature and frequently contain information not available elsewhere or early results presented ahead of more formal scientific publications.

Physics information is also communicated in popular journals [29]. Publications in this category often take journalistic approach to science, rather than a primary reporting of refereed research results. These might be informal magazines intended for light reading about physics or physicist or they might be interdisciplinary scientific magazines containing physics as part of their subject matter. In the present case study popular journals wherein P.K. Iyengar has published two articles was 'Bhavan's Journal'. He has contributed one article each in 'Computer Age', 'Free Press Journal', 'Science and Culture', and 'Science Today'.

A bibliograph for channels of communications and cumulative number of papers in various journals, national and international meetings is depicted in Figure 5.

Since the present study deals with the micro-theme about the profile of a single researcher, the curves have not followed the Bradford's law of scattering of articles in channels of communication indicating at the tail end *Groos Droop* [30]. Our present study also supports the views of Bonitz [31] who found that in the transition from a macroscopic into a microscopic field scientific communication invalidates the Bradford's law in case of single scientist. The effect seems to confirm a fundamental qualitative difference of both fields of scientific communication. Bradford's law applies for macrotheme like research output of an institute [32]. Output based studies seem appropriate for studies of the sociology of knowledge because they begin with corpus of written knowledge.

Path analysis was done to know factors that foster productivity among national scientists in a large research laboratory [33]. In general, educational level of the scientists has an important, positive impact on productivity. Years of service has a varying and more modest positive effect. Rank

Journal	No. of papers	Percentage	Cumulative percentage	Period of journal usage			IF	II
				FPY	LPY	Total		
Physica Status Solidi	6	9.84	9.84	1969	1976	8	0.642	0.137
Pramana	6	9.84	19.68	1973	1985	13	0.521	0.277
Fusion Technology	5	8.20	27.88	1990	1990	1	0.597	0.496
Solid State Communications	5	8.20	36.08	1964	1977	14	2.520	0.707
Nuclear Instruments & Methods	4	6.55	42.63	1964	1979	16	1.078	0.371
Bulletin of American Physical Society Sr.II	3	4.91	47.54	1958	1959	2	–	–
Physics Letters A	3	4.91	52.45	1968	1986	19	1.364	0.313
Physics News	3	4.91	57.36	1976	1978	3	–	–
Bhavan's Journal	2	3.28	60.64	1985	1991	7	–	–
Physical Review	2	3.28	63.92	1957	1958	2	2.622	0.600
American Journal of Physics	1	1.64	65.56	1969	1969	1	0.452	0.131
Atomkernenergie	1	1.64	67.20	1976	1976	1	0.300	–
Computer Age	1	1.64	68.84	1984	1984	1	–	–
Current Science	1	1.64	70.48	1990	1990	1	0.164	0.025
Free Press Journal	1	1.64	72.12	1987	1987	1	-	-
IL Nuovo Cimento	1	1.64	73.76	1955	1955	1	0.494	0.071
INCAS Special Bulletin	1	1.64	75.40	1989	1989	1	–	–
Indian Journal of Physics	1	1.64	77.04	1979	1979	1	–	–
Indo-American Business Times	1	1.64	78.68	1989	1989	1	–	–
Instruments & Electronics Development	1	1.64	80.32	1986	1986	1	–	–
Journal of Nuclear Energy	1	1.64	81.96	1956	1956	1	–	–
Journal of Physics & Chemistry of Solids	1	1.64	83.60	1966	1966	1	0.916	0.223
Journal of Physical Society of Japan	1	1.64	85.24	1962	1962	1	1.798	0.822
Journal de physique	1	1.64	86.88	1974	1974	1	0.924	0.207
Journal of Scientific & Industrial Research	1	1.64	88.52	1956	1956	1	0.248	0.058
Nuclear Science & Engg	1	1.64	90.16	1979	1979	1	0.582	0.058
Physica	1	1.64	91.80	1967	1967	1	0.834	0.462
Physical Review Letters	1	1.64	93.44	1973	1973	1	8.213	2.102
Proceedings of Indian Academy of Science	1	1.64	95.08	1957	1957	1	–	–
Science Age	1	1.64	96.72	1984	1984	1	–	–
Science and Culture	1	1.64	98.36	1972	1972	1	–	–
Science Today	1	1.64	100.00	1987	1987	1	–	–
Total	**61**							

Note: FPY = First paper publishing year, LPY = Last paper publishing year, IF = Impact factor, II = Immediacy Index
IF and II values taken from SCI Journal citation reports 1988.

TABLE 6
Journalwise Scattering of Publications of P.K. Iyengar

Symposium/Workshop/Meeting/Seminar	No. of papers
Nuclear Physics Symposium, India	26
IEEE Annual Convension, New Delhi	1
Indian Science Congress, Mysore	1
Indo-Soviet Seminar on Fast Reactors, Kalpakkam	1
IPA Seminar on Physics of Fusion Plasma, Matheran	1
International Committee for Future Accelerators (ICFA) Meeting, TIFR, Bombay	
Meeting on Excellence in Science, Organised by Scientific Advisory Committee	1
National Conference on Nuclear Science and Technology in India-Past, Present and Future, Bombay	1
Proceedings of the Indian Science Congress	1
Proceedings of the Interdisciplinary Meeting on Hydrogen in Metals, BARC, Bombay	1
Seminar on Nation Building Development Process and Communication, New Delhi	1
Seminar on Nuclear Option for Power Development, Cochin	1
Seminar on Science and its Impact on Society – Indian Experience, INSA, New Delhi	1
Seminar on Uranium & Thorium Fuel Cycles, Bombay	1
Silver Jubliee Physics Symposium, BARC, Bombay	1
Symposium on Lattice Dynamics	1
Symposium on Reactor Physics, Bombay	1
Workshop on Materials in the Future of India	1
Total	43

TABLE 7
Scattering of Publications of P.K. Iyengar in National Symposia/Workshops/Meetings

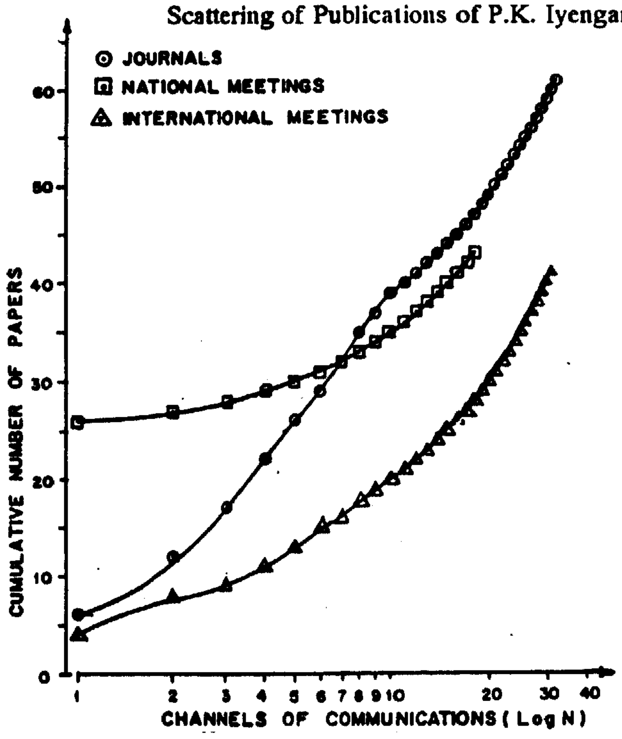

FIGURE 5
Bibliograph

of the scientist has an intermediate positive impact on productivity. Psychological factors have a negligible effect. Finally, the influence scientist has on research endeavours has a modest positive impact on productivity.

References given to the papers were counted and data is tabulated in Table 9. These citations indicate their impact on the research undertaken and the results in the paper. The statistical parameters of mean communication inputs per unit of communication outputs and range of the communications cited provides idea about the use of information and information seeking behaviour of an author in producing his paper. However, it does not fully reveal the network of influences operating during the course of writing paper.

In the present study following were the titles having maximum number of references to the papers in each domain:

Symposium/Workshop/Seminar	No. of papers
Symposium on Inelastic Scattering of Neutrons, IAEA, Vienna	4
Symposium on Inelastic Scattering of Neutrons in Solids and Liquids, IAEA, Vienna	3
International Conference on Interactions of Neutron with Nuclei, Lowell	2
International Symposium on Radiation Physics	2
Proceedings of the Symposium on Irradiation Facilities for Research Reactors IAEA, Vienna	2
Proceedings of International Conference on Lattice Dynamics	2
Workshop on Intense Neutron Sources	2
Advisory Group Meeting on the Role of Advanced Reactors in World Energy Supply, IAEA	1
Annual Meeting of American Nuclear Society	1
Asian Regional Seminar on the Contributions of Science and Technology to National Development, INSA, New Delhi	1
Conference on Neutron Scattering, Gattinburg	1
IAEA Regional Study Group Meeting on Research Reactor Utilization, Bandung, Indonesia	1
International Atomic Energy Agency, South East Asia and Far East Study Group Meeting on Problems and Experience in the Utilization of Research, Bombay	1
International Conference on Neutron Interaction with Matter, Lowell	1
International Conference on Nuclear Physics on the occasion of the Golden Jubliee of INSA	1
International Conference on Nuclear Power and its Fuel Cycle, Salzburg	1
International Course on the Theory of Condensed Matter	1
International Symposium on Process Modelling and Computer Applications in Metallurgy, IIM, Bombay	1
International Symposium on the Significance and Impact of Nuclear Research in Developing Countries, Athens, Greece	1
International Symposium on the Utilization of Multi-purpose Research Reactors and Related International Co-operation, Grenoble	1
International Workshop on Anomolus Nuclear Effects in Deuterium/Solid Systems, Provo, Utah	1
North-South Round Table on Synchroton Radiation, Third World Academy of Sciences, International Centre for Theoretical Physics, Trieste, Italy	1
Proceedings of ANS/NIST Conference, Guithersburgh, Maryland, USA	1
Proceedings of a Conference on Neutron Scattering in the Nineties, Julich	1
Proceedings of International Conference on Magnetism, Nottingham	1
Second International Symposium on Radiation Physics, Penang, Malaysia	1
Seminar on International Research Facilities, Zagreb, Yugoslovia	1
Symposium on Inelastic Scattering of Neutrons by Condensed Systems, Brookhaven National Laboratory	1
Symposium on Neutron Inelastic Scattering, Copenhagen, IAEA	1
Transactions of the Second International ANS Conference on Nuclear Technology Transfer, Buenos Aires, Argentina, ANS	1
Total	**41**

TABLE 8
Scattering of Publication of P.K.Iyengar in International Symposia/Workshops/Meetings

Domain	Number of references		Mean	Standard deviation
	Min.	Max.		
Neutron and Solid State Physics	0	84	14	16
Mossbauer Spectroscopy	0	54	9	12
Reactor Physics Fusion, and Cold Fusion	0	216	17	41
Nuclear Power	0	38	10	10

TABLE 9
Characteristics of Communication Inputs Per Unit of Communication Output in Publications of P.K. Iyengar

A. P.K. Iyengar. Crystal diffraction techiques. Chapter in *Thermal Neutron Scattering* edited by P.A. Egellstaff, Academic Press, London. 1965, pp 97-140.

B. K.R. Rao, S.L. Chaplot, P.K. Iyengar, A.H. Venkatesh, and P.R.Vijayaraghavan. Inelastic neutron scattering from and lattice dynamics of alpha-KNO_3 *Pramana*, 11(3), 1978, pp 251-288.

C. J.J. Srivastava, S.C. Bhargava, P.K. Iyengar and B.V. Thosar. Chapter in *Advances in Mossbauer Spectroscopy : Applications to Physics, Chemistry and Biology*. Elsevier Scientific Publishing Company, Amsterdam, 1983, pp 1-121.

D. P.K. Iyengar and M. Srinivasan. Overview of Inertial Confinement Fusion (ICF). *IPA Seminar on Physics of Fusion Plasmas*, Matheran. 1982, pp 1-41.

Factors increasing more number of references [34] in a paper include: review article, maturity of the field, intrinsic nature of the field, longer paper length, availability of indexes, complexity of the research, mutual courtesy citing, and fashion to cite more references.

Key words from the titles of the articles were counted and their frequencies more than two included in Table 10. Highest frequency of nine each was for the keywords 'Neutron Scattering' and 'Nuclear Power'. Next important keywords were 'Massbauer Effect', 'Lattice Dynamics', 'Neutron Spectrometry' and 'Trombay'. The results indicate that he had wide ranging interests in each microtheme and super specialisations in Nuclear Physics.

Keywords from the titles of the article used only once are presented in Table 11. These keywords indicate his wide spectrum of interest, materials, methods, instruments used and the subjects addressed to in the course of his 36 years of professional career.

Nagpaul and Gupta [35] have concluded after study of 1460 research units in six countries that professional competence is a necessary but not a sufficient condition for effective leadership; managerial competence is also required for effective leadership, but professional competence is much more important than managerial competence. This implies, inter-alia, that the quality of leadership can not be improved merely through management development programmes. It would also be essential and desirable to improve the level of expertise of the leaders through a package of incentives like sabbatical leave to enable them to work at centres of excellence within or outside the country and by inviting leading scientisits from such centres to work in the research institutions.

A researcher is good if he or she surpasses the expectations of what he or she might achieve. But this is only possible if the focus is on work and the problem involved, and not on competition or success. The effectiveness of research or of running an institution depends primarily on the researcher himself, on his models, and within the institute itself, on the respect he shows his staff members, which, in turn, enables him to demand that they work to capacity [36]. Scientists of all disciplines should learn from the humanities.

The duty of scientists and technologists is not only to conduct their own work at the highest possible level of quality but also to make the societies in which they live more aware of the powers and climate of science. Since by definition, scientists and technologists are the first to know of scientific advances they can be described as the cartographers of the future. They must work to ensure that the public, and especially the public's leaders, understand the

Keyword	Frequency	Keyword	Frequency	Keyword	Frequency
Neutron scattering	9	Cobolt alloys	3	Mossbauer spectrometer	2
Nuclear power	9	Crystal hydrates	3	Neutron beam research	2
Mossbauer effect	7	Fusion breeders	3	Neutron sources	2
Lattice dynamics	6	Gallium alloys	3	Neutron energy	2
Neutron spectrometry	6	Iron alloys	3	Nuclear programme	2
Neutrons	6	Magnesium alloys	3	Nuclear science and technology	2
Trombay	6	Nuclear research	3	Nuclear technology	2
Inelastic scattering	5	Nuclear science	3	Physics reactors	2
Iron	5	Palladium alloys	3	Purnima reactor	2
Basic research	4	Phonons	3	Respiratory pigments	2
Beryllium	4	Spin fluctuations	3	Rhodospirillium rubrum bacteria	2
Cold fusion	4	Water molecules	3		
Manganese alloys	4	Calcium oxide	2	Solid ammonia	2
Mossbauer spectroscopy	4	Developing countries	2	Spin glass behaviour	2
Neutron diffraction	4	Dispersion relations	2	Spin relaxation	2
Paramagnetism	4	Frequency distribution	2	Technology	2
Science and technology	4	Lattice vibration	2	Zero energy fast reactor	2
Ternary alloys	4	Manganese oxide	2	Zinc	2
Tin alloys	4	Manpower development	2		

TABLE 10
Frequencies of Keyword in the Titles of Papers by P.K. Iyengar

maps that they draw – the options which are possible and sustainable, so that wise democratic decision can be taken. [37].

Max Perutz, one of Britain's most distinguished scientists in his book "Is Science Necessary : Essays on Science and Scientists" states *In science, as in other fields of endeavour , one finds saints and charlatans, warriors and monks, geniuses and cranks, tyrants and slaves, benefactors and misers, but there is one quality that the best of them have in common, one that they share with great writers, musicians, and artists: creativity.* On the other hand there must be caution so as not to uphold orthodox scientists who are as adamant as religious fundamentalists on resisting new ideas destructive to some of their own pet theories and systems of thought. However, it takes belief in ones own ability and ideas, and courage to be a potential rising star and it takes a special kind of person like P.K. Iyengar to push out the frontiers of knowledge beyond the current state of the art.

A very few scientometric studies have been carried out on individual scientists in India [38-43]. It is felt that more studies should focus attention on the functioning of research groups and their acountability in the economic crisis that the country is facing. Already there is a decline in the support for science and technology. India was investing 1.1 percent of the GNP which was reduced to less than 0.9 percent in 1991 . As budgets for research are being restrained, a better allocation of the existing resources is necessary. A rational distribution of budgets according to the established priorities is of course needed in order to promote the desired areas of research. Nevertheless, while designing national priorities, the perception of the human scientific potential that a country has is as important as the funds for research.

Actinide waste	Fusion power reactors	Platinum alloys
Alternative nuclear energy	Germanium alloys	Plutonium oxides
Aluminium	High temperature super conductivity	Potassium nitrate
Ammonium chloride	Hydrogen	Pulsed amplitude analyser
Ammonium halides	Hyperfine field	Pulsed fast reactor
Ammonium iodide	Hyperfine interactions	Reactivity measurements
Ammonium salts	Inelastic neutron scattering	Reorientation dynamics
Anharmonicity	Inertial confinement fusion	Research and development
Antiferro magnetism	Instrumentation	Resolution function
Applied research	Intermetallic compounds	Rotational behaviour
Atomic energy	Iron-57	Science education
Atomic forces	Iron fluoride	Second order effects
Automatic operations	Iron impurities	Second order neutrons
Barium sulphate hydrated	Iron ions	Short-range interactions
Beryllium oxide	Iron oxides	Short-range magnetic ordering
Breeding feasibility	Kalpakkam pulsed fast reactor	Short-range ordered paramagnet
Breeding of nuclear fuel	Kohn anomalies	Single crystal filters
Calcium fluoride	Lead selenide	Site preferences
Central force models	Local magnetic ordering	Slow neutrons
Chromium fluoride	Magnetic disorder	Slowing down constants
Chromium halides	Magnetic materials	Solids
Cobolt	Manpower training – India	Spin-offs of nuclear energy
Combined density	Mega electron volt	Spin orientations
Concentrated binary magnetic systems	Metal lattice	Superconductivity
Control circuits	Metals	Synchrotron radiation source
Crystal diffraction techniques	Mixed salts	Terminal tandem accelerator
Crystal spectrometry	Monte-carlo study	Thermodynamic properties
Delta T-window spectrometer	Multiarm analyser	Thorium
Deuterated titanium	Multichannel analyser	Thorium fuel cycle
Diffusion constants	National development	Thorium levels
Distorted single crystals	Neutron irradiation	Thorium-Uranium fuel cycle
Elastic incoherent scattering	Neutron physics research	Time analyser
Electrolyser	Neutron radiography	Tin site
Energy levels	Neutron spectrometers	Titanium
Energy management	Nickel alloys	Torsinal oscillations
Energy spectra	Nickel-Zinc ferrites	Transuranium nuclides
Exchange integrals	Nuclear programme	Uranium-233
Exyder	Parabolic coefficients	Uranium alloys
Fast critical facility	Paramagnetic diffuse scattering	Uranium fuel cycle
Fermi surface in metals	Phonon dispersion curves	Vanadium
Ferrites	Phonon measurements	Waste management
Filter-detector spectrometer	Physics of reactors	Windo filter
Fusion neutron source	Physics research	Zinc ions
Fusion of deuterons	Plasma	

TABLE 11
Keywords Used Only Once in the Titles of Papers by P.K. Iyengar

Evaluation of research proposals and future projects should depend on the subjective/qualitative criteria such as originality and feasibility, and the quantitative analysis should serve as a background of strengths and weaknesses, state-of-the-art. Bibliometric data can be used as a *monitoring device* for science policy and research management. It can also be used to explore large scale collaboration, team work, and expertise identificiation in specific domains. Regular quinquennial reviews of scientific R & D establishments can help to strengthen the interaction of scientists at the national and international level since these highlight strong research expertise in various fields at a particular location. Scientometric tools may enable coordinating the efforts of the research institutions of the country, to converge scientific efforts and resources on a definite range of problems and avoid unnecessary duplication of projects.

4 CONCLUSION

Publications productivity analysis of the successful scientist, P.K. Iyengar, carried out here has thrown light on his pivotal contributions to science and technology. He can be considered as a 'role model' for younger researchers to follow. Knowledge is valuable for its own sake and research has cultural value. Desire of being creative is built in our genes. Who knows this effort may switch on genes for creativity in some of those who happen to read this article ! Narrating success stories always has an encouraging effect. It is also important to recognise that excellence in science is not just a matter of a few individual successes, what is required is a wide base of high quality, which would enable peaks to come up more freqently and on a more definite basis. New ways to motivate scientists seems as important to contest outcome as new sources of funds. Science policy makers interested to know about functioning of active research teams as centres of excellence and factors responsible for optimizing, maximising and enhancing outputs may find further interest in scientometrics. As per Indian Scientific Policy Resolution 1958, which our scientists regard as their charter, *to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity* all must work together with wholistic approach.

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