Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

If you can measure that of which you speak, and can express it by a number, you know something of your subject but if you cannot measure it, your knowledge is meager and unsatisfactory

- Lord Kelvin

Measurement is the main tool of science. Methods of measurement were perhaps invented as civilizations developed. In the beginning, measurement was related mainly to length, breadth, weight and volume. As civilization progressed, need was felt to measure number of other phenomena. For a long time measurement was the field of study of physical scientists and mathematicians alone. Gradually, other areas of science and social science also started adopting it. Interdisciplinary subjects like econometrics and sociometrics have come into existence wherein mathematics and statistics have been applied to study the problems in the respective fields of economics and sociology. However, in recent times, measurement has started being used to measure science itself as the volume of scientific research has expanded exponentially. Science research is now such a large enterprise and so specialized and complex that personal knowledge and experience are no longer sufficient for understanding trends or for making decisions. On the other hand there is a need to highlight the promising areas of research and to manage better investments in science.

The fund allocation in government, industry and education has not grown as fast as 'Science'. Those in industry, government offices, laboratories and universities are being told to justify what should be supported and what should not, which research projects should receive more support than others. Achievements in industry can be measured by number of patents or sales revenue – the commercial success of discoveries as they move

from the laboratory to the marketplace. But the achievements and trends in science are not so easily counted. And so until recently peer review has been the main route by which science policy makers and research funders have coped with decisions to set the path of progress.

Growing demand to quantify the research output from public funding has compelled funding agencies and employers to treat numerical indices of research output more seriously. Thus increasingly, quantitative methods are being used to supplement the standard approach of peer review to evaluate research (Kelly, 2006).

One such method is bibliometrics. Etymologically bibliometrics is composed of two distinct parts - biblio and metrics. The prefix biblio is a Greek word meaning books and metrics means measurement. So 'bibliometrics' connotes the science of measurement pertaining to books or documents. Gradually it started being used to measure research itself. At the most basic level, quantitative approach to research evaluation is simply counting. The complexity is in the analysis and use of numbers, for, the data obtained can be understood as indicators of achievement or lack of it. There are many activities and outcomes of research that can be counted. The most basic and common is number of publications and citations received by them. Citations, the references researchers append to their papers to show explicitly earlier works which they have used or referred in their present study, indicate how a work is used in subsequent research. The citations thus act as signboards on the highway which lead the researchers to the destination. Citation Analysis is one of the main tools used to measure the research output. Following the citations and understanding their trends is a key to evaluating the influence of research.

Historical Development

Roots of bibliometrics can be traced back to 1917 wherein Cole & Eales analyzed publications in comparative anatomy published between 1543 and 1860 by simply counting number of titles, both books and journal articles and grouping them by country. In 1923

Hulme published an analysis of the international catalogue of scientific literature for the year 1901 through 1913. Subsequently, Lotka (1926) analyzed the frequency distribution of scientific productivity and his work led to the development of Lotka's Law. This law assesses the patterns in author productivity. Following the above works, Gross & Gross (1927) took the next step in the analysis of literature when they tabulated citations for the Journal of Chemical Society. This study aimed to identify journals with a high impact in their own field – Chemistry. Another pioneering study was carried out by Bradford (1934), who considered the frequency distribution of papers across journals. This work also led to formulation of Bradford's law, which is now very widely used in bibliometrics. This was followed by a study made by Zipf (1935). He studied the frequency of words in a text. Bibliometrics took a quantum jump through the works of Garfield (1955) and Price (1963). However, it was not until 1969 that the term bibliometrics first appeared in print (Pritchard, 1969). Pritchard defined it as "application of mathematical and statistical methods to books and other media of communication".

Gradually, the practical value of bibliometric studies started attracting many researchers' attention. More and more people started taking up such studies which resulted in more publications in this area. In 1980s the interest in bibliometrics took a nose dive due to lack of availability of documents, the manual collection of data and the license fee charged for obtaining documents. The breakthrough came as a result of new technological developments during 1990s in the form of availability of online data regarding publications (Glanzel, 2003).

Citation Index

As mentioned earlier, a citation is a reference to a published or unpublished source. Citations are formal, explicit linkages between papers that have particular points in common. A citation index is built around these linkages (citations). It lists publications that have been cited and identifies the sources of the citations. Anyone conducting a

literature search can find additional papers on a subject just by knowing one that has been cited.

A citation database for science was first described in 1955 by Eugene Garfield, the founder and chairman emeritus of ISI (Institute of Scientific Information, Philadelphia) in the journal 'Science'. He realized his vision a few years later with the production of the 1961 Science Citation Index (SCI). The main purpose of Garfield's citation database is improved or expanded information retrieval. By recording not only bibliographic information of the journal articles, but also the cited references in these journal articles, Garfield offered researchers a way to find articles relevant to their work that they would not otherwise turn up searching author names, title words or subject headings alone. Garfield was aware that such a database could serve other purposes as well, such as monitoring and analyzing the structure and growth of science. Others too saw this possibility. Among them two prominent ones are Derek J de Solla Price, author of the 1963 classic 'Little Science Big Science' and Francis Narin of CHI Research, USA who was pioneer in using the citation data to analyze science, particularly through his influential 'Evaluative Bibliometrics' of 1976. The combination of an ever growing corpus of publication and citation data compiled by ISI over the 1960s and 1970s and the simultaneous increase in computing power and software applications, especially those developed in the 1980s and 1990s, has made bibliometrics a very useful pursuit (Pendlebury, 2008) .

The advent of SCI and electronic access to the ISI's massive datasets has had a catalytic effect on the popularity, scope and ambition of bibliometric research. SCI grew out of specialty index to the literature of genetics and was inspired by Shephard's legal citation index which was created almost a century earlier (Cronin, 2001). However, Weinberg (1997) was of the opinion that true conceptual origins of citation indexing are to be found in the fourteenth century Hebrew literature.

Scientometrics and Informetrics

Statistical analysis when applied to a field of activity generates a new field derived out of fusion, e.g., when it is applied to information systems and services, it becomes Informetrics. The organization of science and its productivity analysis gives rise to Scientometrics. All these techniques give rise to statistical models in a particular context. Such models help in utilization of information in a productive manner and also help in identifying areas of further research.

Since Vassily V. Nalimov coined the term 'Scientometrics' in the 1960s, this term has grown in popularity and is used to describe the study of science: growth, structure, productivity and inter-relationships. Scientometrics is related to and has overlapping areas with bibliometrics and informetrics. All the three terms refer to component fields related to the study of the dynamics of disciplines as reflected in the production of their literature. Hood & Wilson (2001) carried out a study pertaining to the literature of bibliometrics, scientometrics and informetrics. Studying the frequency distribution of the metric terms, they found 7750 bibliometric documents followed by 1878 scientometric documents and 615 informetric documents. Thus, over time, the popularity of the terms has changed, with the older term – bibliometrics, fairly stable and newer terms – scientometrics and informetrics gaining in usage.

A study was carried out by Chubin (1987) wherein he has divided the evolution of bibliometrics as a subject specialty into two generations. The first generation marked by Garfield's founding of the Science Citation Index and Price's visionary thought and experimentation, explored the feasibility of understanding science through its literature alone instead of through one's participatory role in its creation. The second generation sought to develop and exploit publication and citation data as a tool for informing decision makers, especially in federal agencies and universities. This generation thus has all the features of an institutionalized scientific specialty – multidisciplinary journals and practitioners, a clientele (both consumers and patrons) and its increasing use as a policy tool. The paper assesses the most promising approaches and methods that have been

employed and suggests how quantitative data and model could be refined to augment decision making processes in science.

Types of Bibliometric studies

Depending on the use, Lancaster (1991) has classified the bibliometric studies into descriptive and evaluative studies. Descriptive bibliometric studies include the study of the number of publications in a given field, or productivity of literature in the field for the purpose of comparing the amount of research in different countries, the amount of literature produced during different time periods or the amount produced in different subdivisions of the field. This kind of study is made by count of the papers, books and other works in the field, or often by a count of those writings which have been abstracted in a specialized abstracting journal. Evaluative studies measure the literature usage by means of citations or references cited by the researchers in their papers or other documents like theses, reports, etc.

Barre (1997) carried out a descriptive bibliometric study on the European perspective on Science & Technology indicators which highlighted the outputs of various countries in Europe, the diversity of institutional settings and the growing potentials.

Bibliometric studies are also used to determine the research collaboration as it increases the research output by decreasing the redundancy of research efforts. To compare the extent of collaboration in two fields or to show the trend toward multiple authorships in a discipline, Collaborative Index or Degree of Collaboration is being used. Sangam (2001) investigated the type of collaborated research carried out in India in Psychology. He concludes that there is high degree of collaboration in Psychology in India. In another study, Rey-Rocha and Martin-Sempere (2004) studied the patterns of the foreign contributions published in six scientific journals in Earth Sciences published in different countries. The effect of geopolitical, cultural, economic and linguistic bonds amongst countries on publication and collaboration patterns have been studied.

Bibliometric Indicators

The introduction of Journal Citation Reports (JCR) as a companion volume to SCI has extended the use of citation analysis to examine relationships among journals. The journal citation data in JCR are compiled by counting the different article-to-article links. These are further used to construct journal measures (indicators) such as Impact Factor (IF), Immediacy Index (II), References per Paper (R/P), Half Life (HL), etc. Journal citation indicators are commonly used as general measures for various journal characteristics and research impact by different participants in the publication, dissemination and evaluation process of scientific knowledge. Todrov & Glanzel (1988) tried to review and comment on some citation based measures for scientific journals which are available and applied as evaluative indicators.

Impact Factor (IF)

The *JCR* provides quantitative tools for ranking, evaluating, categorizing, and comparing journals. The impact factor is one of these; it is a measure of the frequency with which the "average article" in a journal has been cited in a particular year or period. The annual *JCR* impact factor is a ratio between citations and recent citable items published. Thus, the impact factor of a journal is calculated by dividing the number of current year citations to the source items published in that journal during the previous two years. The impact factor for a journal is calculated based on a three-year period, and can be considered to be the average number of times published papers are cited up to two years after publication.

For example, the impact factor 2011 for a journal would be calculated as follows:
A = the number of times articles published in 2008-2009 were cited in indexed journals during 2010
B = the number of articles, reviews, proceedings or notes published in 2008-2009
Impact factor 2010 = A/B

Immediacy Index

This calculation, published in the JCR, is one developed by ISI as an indicator of the speed with which citations to a specific journal appear in the published literature. Such information is useful in determining which journals are publishing in emerging areas of research

Immediacy index is the average number of times that an article published in a specific year within a specific journal is cited over the course of that same year.

Cited half-life

ISI developed this calculation to provide an indicator as to the long-term value of source items in a single journal publication. The cited half life calculation appears only in the JCR.

Cited half-life is a measurement used to estimate the impact of a journal. It is the number of years, going back from the current year, that account for 50% of the total citations received by the cited journal in the current year. Say for example, Geochimica Cosmochimica et Acta (GCA) received 1000 citations in itself up till now. Number of years it took to get cited 500 times is the cited half life of GCA.

Citing half-life

ISI developed this calculation to provide an indicator of the subtle changes in scope of a publication over the course of time. Evaluation of this factor can provide information on the cross-disciplinary nature of research in a specific field of interest.
It is measured by the number of journal publication years, going back from the current year, that account for 50% of the total citations given by the citing journal in the current year. In other words, suppose Nature cites GCA 100 times up till now, then number of

years it took, going back from current year to reach 50 citations of GCA in Nature is the citing half life of GCA.

H-index

The h-index is a relatively recent bibliometric indicator for assessing the research output of scientists, based on the publications and the corresponding citations. The index was suggested by J E Hirsch, a physicist, as a tool for determining the researcher's impact (Wikipedia, 2011). Hirsch has defined h index as "A scientist has index h if h of his/her Np papers have at least h citations each and the remaining papers (Np-h) papers have <= citations each i.e. if a scientist has 30 papers to his credit and 20 of his papers have 20 or more citations, then his h-index is 20 (and remaining 10 papers will have less than 20 citations each). Thus, this index is based on the set of the scientist's most cited papers and the number of citations that they have received in other people's publications. Due to easy calculation and immediate intuitive meaning, this indicator has become very popular in the scientific community. It attempts to measure both the productivity and impact of the published work of a scientist or scholar. It gives an estimate of the importance, significance, and broad impact of a scientist's cumulative research contributions. This index may provide a useful yardstick with which to compare, in an unbiased way, different individuals competing for the same resource when an important evaluation criterion is scientific achievement. The index can also be applied to the productivity and impact of a group of scientists, such as a department or university or country (Hirsch, 2005).

A new journal indicator (SNIP - Source-Normalized Impact per Paper) of a scientific scholarly journal has been proposed by Moed (2010). It is based on a journal's subject field and takes into account the frequency and immediacy of citation and database coverage in a subject field. It is important to take into account differences in communication and citation practices between various subject fields as this affects the journal impact.

In recent years, the demand and supply of research indicators have very quickly developed both in quantitative as well as qualitative terms. These indicators are based on variety of research functions, capabilities and outcomes. In fact, nowadays, almost every research assessment decision (accepting research projects, contracting researchers, awarding scientific papers, sanctioning a grant and so on) depends to a great extent upon the scientific merits of the involved researchers.

Using these indicators, research measurement of a country or a subject field is a complex process. A number of studies have been carried out to find out India's research output in many subject fields. Next chapter on review of literature gives an overview of a few of them.

Statement of the Problem

There is a growing need to measure the impact of the research undertaken in most of the countries as lot of resources are being allocated to S & T research but the results are not tractable. The pressure is building up for research managers in the universities and research institutes to justify the money spent on research. Though it is not very easy to measure the research output of any institute, the results of bibliometric studies have proved to be a boon for the policy makers and fund managers.

The quantifying methods employed in a bibliometric study yield a fairly good idea about an institute's contribution in the national scientific output. Therefore, universities and institutes where a lot of funds are being allocated to the research activities are keen to assess the research output of their scientists. Physical Research Laboratory (henceforth mentioned as PRL) is an institute of national repute and is being funded by Department of Space (Government of India). However, a bibliometric study measuring its research output has not been carried out yet.

The present research titled "Research Undertaken in Physical Research Laboratory (PRL) : A Bibliometric study" is a step in that direction and as the title indicates is a bibliometric study of PRL which tries to find the publication pattern and thrust areas of research carried out in the institute. Physical Research Laboratory, established by Dr Vikram Sarabhai way back in 1947, is the cradle of Space Sciences in India. As a unit of the Department of Space, it carries out fundamental research in Astronomy & Astrophysics, Geosciences, Planetary Sciences, Solar Physics, Space Sciences and Theoretical Physics. A more detailed profile of PRL is given in Chapter 3.

The present study will also help in determining the usage of library collection. This quantitative study will benefit the policy makers of the institute by supplementing their qualitative tools of research evaluation.

Objectives of the study

Several investigators have conducted bibliometric analysis of research productivity of different countries in the world. Comparisons between research outputs in different subject fields are limited because of the different methodologies used and the impact of geographic and population characteristics on the research output. A few studies have also been carried out to assess the productivity and impact of a single institute. As no bibliometric study on PRL has been done before, the researcher thought it appropriate to carry out the above study for her doctoral research with the following objectives:

1. To study the publication pattern of PRL research publications
2. To study the research trends in PRL
3. To determine the usage of library collection
4. To find the usage of electronic vs. print resources in the theses of the Ph. D. students
5. To find out how far research carried out at PRL is being cited by its Ph. D. students

Significance of the study

More than ever before, governments around the world are acknowledging the role of Science and Technology (S & T) in generating new jobs, economic prosperity, response to national issues and global challenges and global competitiveness. There has been a steady increase in the country's S & T budget from the first five year plan to the twelfth five year plan. The S & T activities in India are undertaken by institutions, units and government departments – central as well as state. Other stakeholders are public sector industry, private sector industry, non-profit institutions and associations. In these sectors, the extent of Research & Development (R & D) efforts vary according to the resources deployed and types of activities undertaken. A study was carried out by Chetal & Raj (1998) to determine the trends in country's R & D domain. From the viewpoint of S & T management in the country, sponsored R & D has remained the least understood area. In spite of the extensive flow of funds from the central S & T sector to the benefiting institutes, not much is known about the basic issues like the nature of distribution of R & D funding among various institutes, short-term and long-term impact of R & D in terms of development of research capabilities of the institutions, generation of Ph. Ds, generation of patents, generation of technologies and its usage, etc. One of the major findings of this study was that the percentage of projects resulting in published research papers was the highest for CSIR followed by ICAR, DoE, DST and ISRO.

The knowledge and processing of research results regarding any scientific area are a basic input to the evaluation of the research activities. Increasingly universities and research institutes are adopting the procedures for regular monitoring of research activities. Not only the government policymakers but scientists themselves are users of such kind of studies with which they assess their own research output. Using the Science Citation Index, Virk (2004) has surveyed the scientific research in India viz-a-viz global trends. This study reveals that during the 1980s, India occupied the 8^{th} position among top 20 nations of the world, in scientific research and during the 1990s, India came down in rank to the 12^{th} position, after Italy, Holland, Spain and Australia with only one tenth of the scientific manpower available to them compared to that in India. It clearly shows that our

per capita productivity is much lower compared with that of Europeans, not to mention that of Americans and Japanese who are far ahead. With continuing decline in scientific research, India is now out of top 20 nations. Compared to India, scientific productivity of China and South Korea has increased immensely.

Another study was carried out by Dhavan & Gupta (2007) which examined the broad characteristics of India's publication output in Physics, its subject areas of strength and also the extent to which the research pursuits have technological orientation. The study finds that India's physics related contribution is significantly high (86 per cent) in SCI covered journals of which 26.4 percent were in high impact journals (IF = 1.5). Its contributions in condensed matter physics and materials science are significantly strong. R & D sector exceeds all other sectors in publications output per institute.

China and India are seen as emerging world leaders, so a lot of curiosity exists as regards what happens in the area of S & T in these two countries. Madhan, et al (2010) have analyzed research papers published by Chinese and Indian researchers during 1998-2007 which were cited at least 100 times by end of 2009. The authors have identified prominent authors and institutions, journals used and fields of research. They found that Chinese authors have been able to place their papers in high impact journals such as Nature and Science far more often than Indian authors. The Indian Institute of Science, Bangalore, Tata Institute of Fundamental Research, Mumbai and Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore are the prominent Indian institutions.

The above studies clearly suggest that bibliometrics is increasingly being used as a tool for a critical assessment of research output. All significant compilations of research indicators depend heavily on publication and citation statistics. Other aspects normally considered for research evaluation are patents, organization of meetings and lectures, teaching assignments, conference participation, awards and editorial activities.

As no bibliometric study of PRL has been carried out till now, the researcher thought it appropriate to undertake the present study for her doctoral research. Research output of PRL is mainly available in two forms – research publications of the scientists and doctoral

theses of the Ph. D. students. The record of papers - published in journals and conference proceedings - and invited talks delivered will be used to study the publication pattern. Content analysis of papers published in journals will be done to identify the active areas of research. Bibliographies of theses submitted by doctoral students of PRL will be studied to determine the citing pattern which throws light on the use of the library resources. The findings of the study will help in identifying the future direction of research. It will be useful and relevant to the S & T policy makers in general and PRL Management in particular. The improved understanding will help in consolidating lines of research, exploring new approaches or beginning collaboration on a national or international scale. It will also reveal preferences and gaps in collection development and management of information resources.

This thesis report is organized into seven chapters as mentioned below.

Present chapter (Chapter 1) elaborates different aspects of bibliometric studies, its genesis and historical development, objectives and significance of the present study. Chapter 2 presents a review of selected literature where studies are briefly summarised to get an overview of what kind of bibliometric studies have been carried out by other researchers.

Chapter 3 on 'Research Methods and Techniques Used in the Study' presents the scope, operational definitions, data collection, techniques used for analysis and limitations of the study. Chapter 4 on 'Publication Pattern in PRL' covers the authorship pattern, collaboration pattern, number of publications in international journals, and conference proceedings, Invited talks delivered – national and international and most preferred journals for publication.

Chapter 5 on 'Research Trends at PRL' throws light on division wise output, thrust areas of research under broad subject headings and most prolific authors. It helps to identify those areas of research, which are very active and the ones, which are not. All the articles published in journals during the study period are analysed to give keywords. Physics and Astronomy Classification Scheme (PACS) devised by American Institute of Physics (AIP) is used to arrive at the subject headings.

Chapter 6 is on 'Citation Pattern of theses submitted to PRL'. It gives the usage of library collection like the type of documents preferred i.e. books, journals, reports, proceedings, etc., print vs. electronic resources used and subscribed vs. non-subscribed journals referred by the students. It helps in identifying how far Ph D students cite the research carried out in PRL. Most used journals have also been identified using the same data. Chapter 7 concludes the present study with major conclusions and suggestions for future research.

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Chapter 2

Review of Related Literature

CHAPTER 2

REVIEW OF RELATED LITERATURE

Any study to be undertaken requires a survey of the literature published in that subject area as a prerequisite so as to give insights into the research which has been carried out in the past and also to give a perspective to the researcher as regards the different methodologies employed, results found and conclusions drawn thereof. Hence the review of the literature was carried out for the present study too.

Since 1955, many bibliometric studies were undertaken which resulted in a flood of publications in this area. During 1980s, the interest in these kinds of studies dwindled due to lack of availability of documents, the manual collection of data and the license fees charged for obtaining documents. However, the emergence of online databases in 1990s proved to be blessing for such studies (Glanzel, 2003).

For the present study, preliminary literature survey of these studies was done using LISA database. Full-text on-line databases of Springer-link, Sage Journals, Emerald Publishing and ScienceDirect were also searched using the keywords – bibliometric analysis, bibliometric studies, scientometric analysis, scientometric studies, research performance and research evaluation.

The survey of literature yielded many interesting studies, collected from various sources. A few of them were evaluating a subject field, a few were limited to journals' impact in a subject field and some of them studied the research output of countries. For ease of comprehension, the researcher thought it appropriate to group the studies in different categories. An overview of 35 studies is presented in the ensuing pages grouped under six categories mentioned below. Within the categories, the studies are placed in chronological order.

A Studies pertaining to a specific subject field (7)

B Studies pertaining to particular journal/s of a subject field (7)

C Studies evaluating a country's output in a particular field (6)

D Studies evaluating India's output in a particular field (6)

E Studies evaluating a particular institute (4)

F Studies pertaining to the bibliographies of theses/dissertations (5)

A Studies pertaining to a specific subject field

1. Sujit Bhattacharya, S. P. Singh and P. Sudhakar (1997)

This paper attempts to monitor the changes in research priorities in physics by analyzing the research profile of thirty-three countries in major fields of physics as classified under PACS (Physics & Astronomy Classification Scheme). Data is taken from INSPEC (CD-ROM version) under two different time periods – 1990 and 1995. Priority Index (PI) is used to understand the priorities of countries in major fields and shifts in their priorities during these two time periods. Correspondence analysis is applied to the matrices of research priorities to understand the multivariate relationships between countries and fields and reveal the dynamics of changes taking place in two time periods.

The publication profile of a country can be visualized as an indicator of its research priorities. Tracking changes in the publication profile of a country can lead to identification of thrusts and areas of weakness in different macro-fields and micro-fields of research.

The study found that general physics, classical phenomenology, condensed matter I & II and cross-disciplinary physics account for more than two third of total output in each time

period (73.11 % in 1990 and 76.34% in 1995). All these fields have more number of research papers in 1995 than in 1990.

The paper gives graphical representation of subject fields for all the countries in the two time frames. The data reveals that South Korea has shown a remarkable increase in rank. Spain, Mexico, Finland, Italy and Greece have also improved their ranks by more than one. Netherlands, Poland, Hungary and Czech Republic had a steep decline in their ranks. India and Denmark have lost their position by more than one. USA, Japan, China, Argentina, Egypt and New Zealand have remained in the same position.

The top five countries in respect to the physics output are USA, Japan, Russia, Germany and UK in 1990. In 1995, this order changes in the third position i.e. Germany is in third and Russia is in fourth position. France jumps by one position and comes at fifth position.

2. Sujit Bhattacharya, Chandra Pal and Jagdish Arora (2000)

In this study, the authors have attempted to reveal the active research topics/themes within the frontier areas of physics during 1990 and 1995.

The active research topics are classified as frontier topics. Countries active in these frontier topics are distinguished in each time period. Association among countries and frontier topics are observed using the multi-variate technique of correspondence analysis. Dynamics are observed by analyzing the changes in the profiles of the countries in the two time periods.

Earlier study had identified the high activity areas (macro-fields), while actual research is conducted in micro-fields. Hence the present study was undertaken.

The same timeframe is used to arrive at precise findings. The total research contribution in 1990 and 1995 were collected in the 20 frontier areas using the PACS. This classification has a hierarchical structure, with a maximum of five digits. The first two digits classify the

area and first four digits together indicate a topic/theme of the article. In some cases an additional alphabetic character is used to classify a sub-topic.

A threshold of 200% increase in the research output in 1995 within the frontier areas was taken as significant. A high threshold was chosen to ensure that this increase cannot be attributed to chance.

Data was collected for fifteen countries in topics which were identified as frontier topics. These frontier topics were divided into two groups – topics which appeared in 1995 only (A) and topics which had significant presence in 1995 in comparison to 1990 (B). 33 topics were in group A and 29 topics in group B. Thus under 20 main frontier areas there were 62 frontier topics. Maximum numbers of topics were found in Physical Chemistry (82). USA was the lead country followed by Japan, Germany & U K.

This type of study provides the decision-maker a method for keeping abreast of scientific developments in a field. However, it can only act as a supplement to the decision-making in a research field and should not be used singularly for research assessment or resource funding.

3. Ed J. Rinia, et. al. (2002)

In this paper the researchers report the results of an exploratory study of knowledge exchange between disciplines and subfields of science, based on bibliometric methods. First the knowledge exchange between disciplines at a global level is considered by analyzing cross-disciplinary citations in journal articles, based on the world publication output in 1999. Second topic is a discussion of measures which may be used to quantify the rate of knowledge transfer between fields and the importance of work in a given field or for other disciplines. Two measures are applied which appear to be proper indicators of impact of research on other fields. These indicators of interdisciplinary impact may be applied at other institutional levels too. The results show that Basic Life Sciences have the

maximum impact within the Life Sciences and Physics diffuses maximum into the Exact Sciences.

4. Basu, A. and Lewison, G. (2005)

Performance evaluation of scientific units (from university departments to nations) requires analysis of research outputs in a given subject. For an evaluation of national performance, reliance is usually placed on an analysis of papers selected from large database like SCI as it covers all scientific fields and includes all authors' addresses.

This paper sought to characterize world astronomy research by an analysis of papers in the SCI identified with a special filter and to study Indian output in order to identify the leading institutions and authors. Lists of specialist journals and title words of papers were selected to create a filter giving high precision and recall for astronomy papers.

The filter developed by the authors was designed to capture ASTRO papers (including ones on the solar system) and was calibrated through partnership between a subject expert and a bibliometrician. The sample of the study thus comprised of 95186 papers, of which 73019 appeared in ASTRO journals. The outputs of 16 countries accounted for 99% of ASTRO papers in 1994-2003. Leading countries are US, UK and Germany. The highest growth rates were achieved by China and Spain. Countries with less ASTRO research effort were Japan and Sweden. Countries where the relative research effort in astronomy increased were Italy, The Netherlands, UK and Switzerland.

5. B. S. Kademani, Vijai Kumar, Anil Sagar, Anil Kumar (2006)

This paper attempts to highlight quantitatively the growth and development of world literature on thorium in terms of publication output as per SCI (1982-2004). During this period a total of 3987 papers were published by the scientists in the field 'thorium'. The

average number of publications published per year was 173. Highest number of papers (249) was published in 2001. The spurt in the literature output was reported during 1991-2004. There were 94 countries involved in the research in this field. USA is the most prolific country with 1000 authorships followed by India with 498 authorships. Intensive collaboration was found during 1990-2004. There were 586 international collaborative papers. BARC topped the list with 153 authorships, followed by Los Almos National Laboratory (LANL), USA with 105 authorships. The most preferred journal was Journal of Radioanalytical Nuclear Chemistry.

6. Gian Singh, Rekha Mittal & Moin Ahmad (2007)

The study has been undertaken with the purpose of finding out the growth and characteristics of digital library literature. Over 1,000 articles for the period 1998-2004 were collected from LISA Plus and were analyzed to study authorship patterns, authors' productivity and prominent contributors, language-wise and year-wise distribution of articles, country-wise distribution of journals, core journals in the subject area, and indexing term frequency. Some of the important findings are that most articles (61 percent) are single-authored; author productivity is not in agreement with Lotka's Law, except in one case where number of articles is three; the maximum number of articles were published in 2003 with English being the most productive language; maximum articles were published in the journal D-lib Magazine; distribution of articles nearly follows Bradford's Law; and USA is ranked first for maximum number of journals. The paper is relevant to those interested in bibliometrics and provides a comprehensive overview of authorship in the library and information science community.

7. Jayant M Modak and Giridhar Madras (2008)

The objectives of this study was to compare the number of journal publications and analysis of the citations to measure the quality of research in chemical engineering and its impact, published by various countries and institutions.

The publication record in terms of quantitative aspects of the number of publications from China has increased exponentially over the last decade and has overtaken USA. However, the citation analysis indicates that there is ample scope for improvement. Analysis of the output of selected Indian universities/organizations against that of the top universities in the world indicated that these are not comparable to the best universities in USA but are comparable to the best in Asia and are significantly better than the best universities in China.

The number of publications in the field of chemical engineering has increased by a ratio of 2.08 between the time periods 1990-94 and 2000-04. During these time periods USA has maintained its top position. During the same period South Korea and China have significantly increased their number of publications. India has nearly doubled its number of publications during these time periods. Among the institutes in India, IISc tops the list followed by IIT M and IIT K.

In the ranking of top 100 universities, the first four slots are occupied by the Chinese universities. However top 20 had only three Asian universities in 1990-94 which increased to nine in 2000-04.

It was also found from the citation analysis of the papers published, that average citations per paper published from USA is nearly twice that of China or India. The publication from India though smaller in number had higher number of citations per paper compared to China. However the h-index of China is higher than that of India. The number of publications in top journals as well as citation analysis indicates the clear dominance of USA.

B Studies pertaining to particular journal/s of a subject field

8. Arthur Lifshin (1993)

Geochemical publications have been found in a wide range of journals. Although primarily geological in nature, a wide range of geochemical data and information may be found in the chemistry and physics literature. In 1923, the field generated it's first and for 37 years its only journal – Chemie der Erde. In 1950, the journal Geochimica et Cosmochimica Acta began publication and rapidly became an important journal in the field of geochemistry.

The present study analyzes the first ten years of GCA (Vols. 1-21), 1951-1960. This decade represents the field on expansion due to new techniques. Data was collected for all articles in 21 volumes covering that period with the exception of 8 articles that were bibliographies. Data was collected for each volume and later grouped by year. Total number of articles was 515 with 10852 references. Data was then sorted and analyzed by journal title, book title, continuation title, dates, etc.

This study also confirmed the earlier studies about the journal articles being cited the most (78.3%) followed by books (11.3%), continuations (7.7%), theses (1.3%) and personal communication (1.6%). Over the years there is decrease in German language citations and increase in English language citations. An examination of the rank order listing of journals shows that American Journal of Science, American Mineralogist, Journal of Geology, Nature and Physical Review are cited at least 10 times every year. The inclusion of Physical Review in this list is due to the material on meteorites and element abundances.

Distribution of journal citations as a function of dates shows that due to the nature of the field of earth sciences, there are citations from 1800s present in almost all the years. The breakdown of citations by discipline shows that there is a significant increase in geology citations and decrease in general citations.

9. Blaise Cronin, Elisabeth Davenport and Anna Martinson (1997)

The authors have explored the social structure of the field of *Women Studies* by analyzing bibliometrically all scholarly articles and acknowledgements appearing in three pioneering journals over a twenty year period. They have analyzed the authors and the acknowledgments in terms of gender. They have also conducted content analysis of all the editorial statements published by the journals. The results demonstrated the highly gendered nature of the field and the incompatibility of its publicly stated objectives.

The journal literature of a field can furnish valuable insights into not only substantive issues addressed by a community of more or less like minded scholars but also into social relations that define a particular domain. Specifically bibliometric techniques can be used to expose the underlying social structure of a field by describing patterns of publication, co-authorship, citation and acknowledgment.

The sample of this study consisted of leading scholarly journals to analyze in detail authorship, acknowledgment and editorial patterns and practices over time. For inclusion, a journal had to meet three criteria longevity, impact and centrality. The three journals which met the criteria were Feminist Studies, Signs: Journal of Women in Culture & Society and Frontiers : A Journal of Women's Studies.

The bibliometric analysis of contributions to these three leading *Women's Studies* journals over twenty years revealed several notable patterns: a high level of sole authorship, a preponderance of female over male authors and intensive acknowledgment with higher number of credits accruing to women than men. A content analysis of editorials in the sample revealed an affirmative action agenda to give more women a voice in publications which conform to academic production protocols.

10. Sharon J Lenon, Kim K P Johnson, Ji-Hye Park (2001)

The authors of this paper thought that the end of a millennium is a good time to assess research trends in a discipline. It helps to reflect on past accomplishments, analyze the current state of research and strategize for the future.

The aim of this study was to assess trends in research, research strategies, data analysis techniques, funding sources, affiliations and the use of theoretical frameworks in *Textiles and Clothing Research.* Empirical research focused on *Textiles and Clothing* and published in three home economics related journals from 1980-1999 has been content analyzed. The three journals are – Journal of Family and Consumer Sciences, Family and Consumer Science Research Journal and Clothing & Textiles Research Journal.

The sample of the study consisted of 586 articles published in the above three journals. During the study the authors faced difficulties with coding of information and suggested researchers should strive to include research purpose, hypotheses, theoretical framework, analysis procedures used, statement of research strategy used and source of funding.

The authors found that survey method and experimentation were the first and second most used research strategies in all except one 5 year period. Data analysis techniques were primarily quantitative with increase in the use of some advanced statistical techniques. However, qualitative treatment of data had also increased during the period covered.

In addition to having familiarity with other research methods, students need knowledge of statistical tools and techniques. The authors' findings suggest that knowledge of statistics beyond basic levels will continue to be required in the future.

11. Ming-Yueh Tsay & Yi-Ling Chen (2005)

The purpose of this study is to analyze and compare journal citation data, of General & Internal Medicine and Surgery. The source items and five kinds of citation data i.e. citation counts, impact factor, immediacy index, citing half life and cited half life are examined.

The results of this work reveal that frequently published journals are cited more frequently and also have high impact factor and immediacy index. In addition they are usually accompanied with short citing half-life i.e. they usually cite current literature. A significant correlation also exists between impact factor and immediacy index. However, there is no correlation between cited half life and other citation data, except citing half life.

One obvious criterion for the evaluation of journals is that of productivity, which can be expressed as number of papers published by a journal in a specific subject field during a particular period of time.

12. John D Lee, Andrea Cassano-Pinche and Kim J Vincente (2005)

The paper here gives the result of a bibliometric analysis of 1682 papers and 2413 authors published in *Human Factors* from 1970-2000. The ISI Web of Science electronic database was used to compile the citation history of papers published in *Human Factors.* The analysis shows that Human *Factors* has substantial influence on the scientific progress in the field of human factors and ergonomics as measured by impact, immediacy and half-life.

A trend toward a greater number of authors per paper in *Human Factors* parallels that in many fields and may reflect a general trend toward increased emphasis on multidisciplinary analysis of complex systems. In other fields, the number of co-authors is associated with greater impact, and this may be the explanation for steady increase in the impact of *Human Factors*. Although, the growing number of co-authors may lead to papers with greater impact, bibliometric analysis suggest more direct ways to enhance the impact of *Human Factors.* Making the full-text of all papers available online would likely increase the

impact, immediacy and half life of the journal. A journal web site with more content tends to be more visible, as measured by the incoming links. A highly visible web site would likely increase the use of *Human Factors* by students and practitioners and might also encourage the researchers to choose it as publication venue.

This study also found that relatively few papers account for the majority of the journal's impact. And highly productive authors tend to be highly cited primarily because they write more papers, not because individual papers are cited more often.

13. Tove Faber Frandsen (2005)

Citation analysis is widely used as an evaluation method within sciences. Researchers, politicians and publishers often use citation analysis as the basis for statements on research quality or impact. The paper has not tried to argue against the strong position taken by citation analysis but rather discussed the possibilities for strengthening these analyses by ensuring a large degree of reliability and validity. This has been done by pointing out some apparent weaknesses of the simple citation analyses. These weaknesses can be partly dealt with by finding hidden structures of the science under evaluation.

The paper has investigated whether an analysis of the interaction of economics journals, where different characteristics of the journals are taken into account, can contribute to a larger insight into the science of economics and thus be used to qualify citation analyses.

The analysis indicates several underlying factors within citation patterns in economics that should be accounted for when doing citation analysis for evaluation purposes. A journal is to a large extent self-supplying with citation but when this is extracted from the data, journals are dependent on similar journals – with respect to sub-discipline, geography and journal impact factor – to supply citations. In an evaluation that takes place across a wide range of sciences, an analysis of both cited and citing journals may help to determine which factors should be taken into account for evaluation. This paper includes only a sub-set of

the journals in economics. Other sciences may exhibit other patterns and thus other underlying factors.

14. Anil Kumar, E R Prakasan, V L Kalyane & Vijai Kumar (2008)

The authors felt that as Pramana is a prominent Indian journal in physics with a current impact factor of 0.417, its evaluation in detail will give a fairly good idea about the state of physics output in terms of collaboration, organizational affiliation and preferred sub-field of physics research in the country.

The study found that during 1982-2006, Pramana has published 3976 articles with a yearly average of 159 articles. The increasing number of articles over the years shows its increasing popularity among physicists. Articles written in collaboration by two authors are found to be predominant, followed by single authors, collaboration with three authors and four authors. Among the institutes, Department of Physics, Delhi University contributes the maximum number of articles to this journal, followed by BARC and PRL. A total of 73 countries occurred in the affiliations of authors. Around three fourths of total affiliations were from India. Keyword analysis was done to examine the nature of contents of the articles. The focus areas were found to be cosmology, super symmetry, chaos, quantum chromodynamics, phase transition and quark-gluon plasma. There are 84847 references in 3976 articles of Pramana making an average of 21.34 references per article.

C Studies evaluating a country's output in a particular subject field

15. Subbiah Arunachalam, M. K. Dhirendra Rao and Praveen K. Shrivastava (1984)

The authors have tried to find the impact of physics research carried out in Israel on the international literature from the data of publication and citation counts. Authors have considered all papers published from Israel and covered under five of the ten major

sections of INSPEC's Physics abstracts – Jan-Jun 1977. These sections are *Condensed Matter Physics, Nuclear & Particle Physics, Atomic & Molecular physics, Biophysics and Physical Chemistry.* Citations to these papers as seen from five annual editions of Science Citation Index, 1977-198 were also part of source data.

In the major subject groups chosen by the authors, there were 25,593 papers world wide, out of which Israel's share was 251, amounting to a little over 0.94%. These 251 papers received 1530 citations in the five year period of 1977-1981. From this sample, 40 papers were cited between 6-10 times, 16 papers were cited more than 25 times each, out of which 3 papers received more than 85 citations each.

The journal titled 'Journal of Chemical Physics' which accounted for 14 papers received the maximum number of citations (212). Out of the eight Israeli institutes, Weizman Institute, Rehovot tops the list followed by Tel Aviv University. Israel appears to be more productive in *Nuclear Physics* and *Atomic & Molecular Physics*, areas in which her share exceeds 1.3% of the world's literature as against 0.89% in all of physics as seen from SCI 1973. There are at least 41 articles published in journals which have the words 'chemical physics' in their titles. About 35 papers were published in journals whose titles contain the 'nuclear'. These are indicative of Israel's thrust in physics research. Israel because of its close political and economic ties with the west has certain advantages. Not only does it receive all the economic benefits that such ties ensure, but its scientists get ample opportunities to collaborate with fellow researchers in very well equipped laboratories in the US and Western Europe.

16. Daisy Jacobs and Peter Ingwersen (2000)

Although many bibliometric studies have been carried out all over the world, except for a few scattered case studies in South Africa, no comprehensive study has been undertaken to understand the publication pattern of scientific research in South Africa. Hence the authors undertook the present study covering a 16 year period to analyze the publication pattern in

four science disciplines – Physics (including Mathematics & Astrophysics), Chemistry, Plant & Animal Sciences and Biochemistry (Microbiology).

The authors observed a distinct growth up to 1987-91. From then there is a gradual decrease. They also found a correlation between the research output and the status of the survey respondents. Analyses of data clearly indicate that professors published the most, followed by Associate Professors, Lecturers and Senior Lecturers in that order. Senior lecturers demonstrate a surprisingly low research activity. One of the reasons for this can be attributed to a lack of expectations for promotion in the immediate future.

This study therefore agrees with earlier similar studies which suggest that promotion was the driving force behind faculty research publications.

17. Subbiah Arunachalam and Jayshree Balaji (2001)

In this study, the authors have compared Fish & Aquaculture research in the People's Republic of China over the six years 1994-1999 with that of India, using data from six databases – three abstracting services and three citation indexes.

The authors found that during this six year period, China published 2035 papers (roughly 4.5-5 % of the world output) and India published 2454 papers. More than 95% of China's papers are journal articles compared to 82.8% of Indian papers. About 78% of China's journal paper output has appeared in 143 domestic journals compared to 70% from India in 113 Indian journals. Less than a dozen papers from each of these countries have appeared in journals of impact factor greater than 3.0. Fish research institutes and fishery colleges are the major contributors of the Chinese research output in this area. In India academic institutions are the leading contributors (61%) followed by Central Government institutions (>25%).

Although China's research output and its citation impact are less than those of India, China's fish production and export earnings are far more than those of India. Probably China is better at bridging the gap between know-how (research) and do-how (technology).

18. Mee-Jean Kim (2001)

Until the 1980s, limited R & D resources prevented Korea from promoting Big Science projects which ultimately play an important role in the development of the country. In the 1990s, the need for advanced technology development triggered a Science & Technology policy that emphasized basic research and ushered Korea towards the scientific mainstream. As evaluation of research performance in terms of research publications and the citations' impact is coming to be considered an integral part of science, the scientific community of Korea cannot avoid such scrutiny. This paper has carried out such an evaluation.

For the study, the sample comprised of 4665 papers published by the researchers affiliated with physics departments or physics associated laboratories at Korean Universities and indexed by SCI during the five year period 1994-1998. Out of 4665 papers 1488 papers were a result of collaboration with researchers from other countries. Collaboration with US researchers in 96 papers yielded the highest citation rate, an average of 15.9 citations per paper. These 4665 papers were published in 224 scientific journals from 19 countries. US and Korean journals predominated, followed by Dutch, UK and German journals. Among the 96 Korean academic institutes the top 15 each published more than 100 articles and contributed 4031 papers (86.4%) of the total number of publications. Seoul National University (SNU) took first place with 813 papers followed by Korea Advanced Institute of Science & Technology and Korea University in second and third place respectively.

19. Mario Coccia (2005)

The debate on the reform of the research sector in many European countries has recently become more important, both due to the reduction in public funding and due to the domination of US and Japan in the field of new technology. Nowadays universities and public sector research organizations account for most of the technological developments and innovations which are necessary for the competitive industrial system in a fast growing knowledge society.

In this scenario, a new model is devised by the author covering 108 public research institutes belonging to the Italian National Research Council using the data from 2003 and displays the laboratories with high flow performance. The results are substantially stronger and quicker to obtain than those calculated by using conventional indicators. This model supports the policy makers, who must decide about the level and direction of public funding for research and technology transfer.

This research confirms the concern that Italian national system of innovation is not working satisfactorily and that financial resources are insufficient to strengthen the Italian scientific network in terms of production and diffusion of scientific researches and technology in the economic system. The author suggests that one way to increase the research performance could be the relocation of researchers so that they can choose in which laboratory to work according to their scientific preference. Also, introduction of more incentives for researchers will surely improve the scientific research output of Italy.

20. Eva Isakson (2007)

The author got interested to carry out this study when at the latest research assessment evaluation done at the University of Helsinki in 2005, the panel of experts asked for citation count data for the first time. She then decided to carry out a bibliometric study of

Astronomy in Finland. The author used both ADS and ISI databases in order to find out how they compare.

The sample of the study consisted refereed papers of four institutes doing astronomical research in Finland for the period 1995-2004. The 910 papers had 1,998 authors out of which 162 were listed with affiliations from one of the four Finnish astronomy institutes. Of the most productive 50 authors (with more than 12 published papers) eight were identified as women.

Other interesting finding was that majority of the papers were stand alone in the sense that only one of the four institutes was involved in its publishing. There was not even one paper with all of the institutes co-operating. All the collaborations are directed abroad instead of with other Finnish Astronomy institutes.

D India's output in various subject fields

21. I. K. Ravichandra Rao and P. Suma (1999)

In recent years several projects were sponsored by NISSAT of the Government of India to map Indian Science. As a part of it a database in engineering field was analyzed.

For the purpose of this study COMPENDEX database for the periods 1990 and 1994 was used as source data. It was found that 3520 and 4829 articles were the research output in engineering for the years 1990 and 1994 respectively. Engineers too preferred journals for communicating their research results (88% of the total). This was followed by 11.5% in conference proceedings. Monographs and reports constituted only 0.5% of the total.

Research output in Applied Physics, Light & Optics, Bioengineering and Information Science are increasing at both levels - world and India. In the area of Energy Technology, Metallurgical Engineering and Food Technology output is decreasing at both levels. In branches of Electrical Engineering & Electronics, Computers & Communications,

Environmental Technology, Marine Engineering and Aeronautical Engineering is decreasing from 1990 to 1994. However, in Civil Engineering, Industrial Engineering and Mechanical Engineering, the world's publications are decreasing, whereas India's contributions are increasing.

The study also found that 1000 institutions contributed a total of 8349 publications for the development of the engineering field. Indian Institute of Science (IISc), Bangalore ranked first with 490 (5.87%) publications followed by IIT, Delhi and IIT, Madras with 4.86% and 4.76% of publications respectively.

State wise distribution of publications indicates that Maharashtra is first with 1283 records (15.38%), West Bengal with 1007 records (12.06 %) and Delhi with 917 records.

Indian researchers have used 900 journals published from 27 countries to publish their research output. 41 % of the literature is published in journals from USA and 12% of journals are from India.

22. Subbiah Arunachalam (2001)

This study quantifies and maps mathematics research in India as reflected by papers indexed in MathSci database for period 1988-1998. *Statistics, Quantum Theory* and *General Topology* are the three sub-fields contributing the most to India's output in Mathematics research, followed by *Special Functions, Economics* and *Operations Research and Relativity and Gravitational Theory.* Indian Statistical Institute and Tata Institute of Fundamental Research are the two leading publishers of research papers.

A total of 17,308 papers were published in 11 years. About 92% of these papers have appeared in 877 journals published from 62 countries. Of the 36 journals that have published at least a hundred papers, 20 are Indian journals, of which only two are indexed in JCR. In the late years, there has been a moderate shift to non-Indian journals.

About 78% of papers have come from universities and colleges and 13% from institutions under science related departments. Almost all papers in high impact journals are physics related and most of them have come from institutions under DAE. Over 15% of the 9760 papers published during 1993-1998 are internationally co-authored. The USA, Canada and Germany are the most preferred countries for collaboration followed by France, Italy, Japan and the UK.

23. K. C. Garg and P. Padhi (2002)

Laser research in India began almost simultaneously after the demonstration of the Ruby Laser in 1960. Since then R & D programmes related to laser research have expanded considerably and today encompasses many of the important areas of laser applications. Since laser has many applications and is an increasingly growing field, authors have attempted to look at laser research in India during 1970-1994 using the publication output abstracted by the journal of Current Laser Abstracts published by Laser Focus, USA and their citations in the international literature during 1970-1999 as seen from Science Citation Index published by the ISI, Philadelphia, USA.

The sample of the study consisted of 952 publications published by Indian scientists during 1970-1994. The analysis indicates that laser research in India picked up during the 1978-1994 and reached its peak in 1980. It was also observed that publication output is concentrated among a few institutions and there is a similarity in the activity profile of highly productive institutions. Amongst the most productive institutes, IIT, Delhi, BARC, Mumbai and Hyderabad University are in the top three positions in that order.

Analysis of local, domestic and international collaboration in the papers indicates that most of the Indian collaborations are in theoretical laser research unlike international collaboration where most of the work is in experimental laser research, followed by application oriented laser research. Out of 952 papers published, only 162 were

collaborative papers. Of these 19 were local, 81 were domestic and 62 were international collaborations.

The study indicates the need to develop both domestic and international linkages. The thrust should be on collaborative programmes focusing on application oriented laser research.

24. S. Mohan, B. M. Gupta and S. M. Dhavan (2003)

This paper aims to identify the major areas, sectors and institutions involved in Indian Materials Science research that have collaborative linkages with developed and developing countries. This helped the authors to understand to what extent the collaborative research is helping to meet the national objectives, conforms to the general international trends, as well as to learn about new technological developments taking place in this area.

Publication data for the study was derived from the CD-ROM version of the Materials Science Citation Index (MSCI), brought out by ISI, Philadelphia, USA for the period of 1995-1999. The database covers around 2000 significant world journals in all fields of S & T, focusing on Materials Science research. The study was restricted to co-authored articles, arising out of India's collaborative research with all major developed and developing countries.

Total number of co-authored papers was 2587 during 1995-1999. Each paper was classified under two broad categories – Particular material (subject) and nature of work done on that material (process). There were 36 subjects in category 1 and 14 processes in category 2. Among the 36 subjects in first category, *General Organic Materials* produced the maximum number of papers (285), followed by *General Metals and Alloys* (235). Polymeric Membranes and Fullerenes, which have great potential in new technologies, are yet to take off significantly in India. Among the 14 processes in 2nd category, *Analysis & Characterization* happens to be the most important aspect of the research.

Among the bilateral collaborative papers, highest number were with European countries, while among the multilateral collaborative papers highest number were with USA followed by Germany and Japan.

A total of 154 institutions, including universities and national laboratories participated in collaborative research, with IISc, Bangalore coming on top with 286 papers followed by TIFR, IIT Bombay and BARC.

25. Swapan Kumar Patra and Partha Bhattacharya (2005)

For the purpose of this study, data has been downloaded from PubMed database using the Endnote software. A total of 6408 records were found. Each record contains English language abstract and bibliographic information.

The study shows that Cancer research is increasing, with a marginal decrease in the year 1991, 1993, 1995, 1997 and 2003. US is the largest producer of cancer related research. PubMed indexes biomedical literature published in different communication media too. Journal literature accounted for 88% of the Indian literature on oncology.

All India Institute of Medical Sciences (AIIMS), Delhi has produced the maximum papers on cancer research followed by Tata Memorial Hospital, Mumbai and Post Graduate Institute of Medical Education & Research, Chandigarh.

26. B. M. Gupta and S. M. Dhawan (2005)

This paper presents the status of Computer Science research in India in terms of publications output, its areas of strength and weakness and the leading institutions and individual scholars involved in Computer Science research in the country. The data source for this paper was INSPEC database which contains over 3500 national and international

journals and some 1500 conference/seminar proceedings and numerous other publications. INSPEC is a product of Institute of Electrical and Electronics Engineers (IEE).

The research output as per INSPEC database revealed that Indian scholars published 4690 papers in Computer Science during 1994-2001. Of these, 3143 papers (67%) had appeared in journals and the rest 1547 (33%) in conference/seminar proceedings. Of the 3143 papers published in journals, 2028 were published in JCR – covered journals and 1115 were covered in non-JCR covered journals.

The most preferred journals to publish the research results were Fuzzy Sets & Systems (93), Microelectronics & Reliability (69) and Computers & Structures (64). Highly productive subject fields were found to be *Systems & Control Theory* (1530 papers) and *Computer Applications* (1082 papers).

Most productive academic institutes were IIT, Madras (396 papers), IISc Bangalore (348 papers) and IIT Bombay (267 papers). Most productive research institutes were Indian Statistical Institute, Calcutta (258 papers), Institute of Mathematical Sciences, Chennai (73 papers) and TIFR, Mumbai (72 papers).

Thus Computer Science research in India is mainly driven by the academic sector as only one fourth contribution is made by research institutes, government institutes and industrial sector and three fourth of the output is contributed by the academic sector.

E Studies evaluating a particular institute

27. Suresh C. Sinha & Anil K. Dhiman, eds. (1994)

This bibliometric study has analyzed the research output of Central Building Research Institute (CIBRI) which is one of the engineering laboratories of CSIR.

822 research papers were published by the scientists of CIBRI during Jan 1980- Mar 1990. Each paper was categorized on the basis of journal in which it appeared and to the division to which it belonged.

Out of the 822 papers published by the scientists of CIBRI, 483 were presented in conference/symposia and 339 were published in 94 journals. The preferred Indian journals were Indian Concrete Journal, Indian Ceramics, and Research & Industry. Out of 339 papers, 278 were published in Indian journals, probably because papers in Indian journals are easily accepted because of weak refereeing system. Preferred foreign journals for publication were Building Research & Practice, Cement & Concrete Research and Durability of Building Materials.

It is observed that Engineering Sciences fare poorly from citation point of view. But it can be improved if the scientists of engineering disciplines publish qualitative work in foreign journals having high Impact Factor and Immediacy Index. It is generally seen that engineers do not cite authors whose works they refer in their own research.

28. V. K. Jeevan and B. M. Gupta (2002)

In this study, research publications in national and international journals over a three year period from 1994-95 to 1996-97 are analyzed for a few departments of IIT Kharagpur. In all, 1172 research papers were published during the three year period by the nine selected departments of IIT, Kharagpur. Of these 757 were published in SCI-covered journals. Around 75% and above of the papers from Department of Chemistry and Rubber Technology are published in SCI covered journals.

The publications of the Chemistry and Physics & Meteorology departments have received the largest impact – 2.761 and 2.058 respectively. Based on the proportion of high quality papers, the highest rank is received by Chemistry Department. It is also believed that those departments which qualitatively perform better also tend to collaborate more, both on the

national as well at the international level. In terms of co-authored papers, the largest percentage is in the Physics Department – 64.21%.

Considering the overall performance measure, departments of Chemistry, Physics and Electronics & Electrical Communication have done better than other departments.

29. Chu Keong Lee (2003)

Lee thought of measuring the research output of Institute of Molecular and Cellular Biology (IMCB) as lot of funds had gone into building up this institute. It was set up in 1987 at the National University of Singapore (NUS).

The study found that the number of research scientists and engineers (RSEs) increased from 116 in 1991 to 179 in 1996 and the recurrent budget increased from S$19.38 million to S$ 36.37 million in the same period.

In its first 10 years, the IMCB produced 395 research papers, 33 book chapters, 24 conference papers and 4 monographs. The research papers were published in journals of increasing impact factor, resulting in increased visibility for the IMCB. The articles received 25 to 35 citations per article. Four of its articles received more than 200 citations. IMCB contributed 46 PhDs and 14 MScs to the research force in Singapore.

30. B. S. Kademani, et al. (2007)

The paper analyses the citations to 1733 publications published during 1970–1999 by the Chemistry Division at Bhabha Atomic Research Centre, using Science Citation Index 1982–2003 as the source data. The extent of citations received, in terms of the number of citations per paper, year wise break up of citations, domain wise citations, self-citations and citations by others, citing authors, citing institutions, highly cited papers, the categories of

citing documents, citing journals and distribution of citations among them etc. are determined.

During 1982–2003 Chemistry Division publications have received a total of 11,041 citations. The average number of citations per year was 501.86. The average number of citations per publication was 6.37. The highest number of citations received was 877 in 2001. The citation rate was highest during 1990–2003 as maximum 9145 (82.82%) citations were received during the period. Total self-citations were 3716 (33.66%) and citations by others were 7325 (66.34%). Citation time lag was zero for 144 (15.52%) papers and one year for 350 (37.72%) papers. Single authored publications (168) have received 456 (4.13%) citations and 1565 multi-authored publications have received 10,585 (95.87%) citations. The core journals citing Chemistry Division publications were also identified as a result of the study.

F Studies evaluating the bibliographies of theses/dissertations

31. Margaret J. Sylvia (1998)

In this study the author collected the bibliographic citations for journals from research papers written by graduates and undergraduates taking classes in the Department of Psychology at St Mary's University from Fall 1994 to Fall 1995 (3 semesters). The sample of the study comprised of 157 bibliographies. For each entry journal title and citation year were recorded. The information was used to check for library holdings of the journal. The current subscription price was used to determine the cost-effectiveness of each journal by dividing the cost of the journal by the average number of times cited per year. For the analysis, total number of journal citations was 1289. The study not only identifies new journals which should be subscribed but also indicates which titles should be canceled using not only the citation data but also the re-shelving data from the stacks. The author cautions that decisions for collection development should be obtained by using convergence of data from all available sources.

32. Angela M. Gooden (2001)

A citation analysis of dissertations accepted in the Department of Chemistry at The Ohio State University between the years 1996-2000 was performed as a way to determine material use. Dissertations from this range (1996-2000) totaled 117. The author extracted 25% of the 117 dissertations to obtain a more controllable yet accurate sample. The random number generation analysis tool in Microsoft Excel created a sample of 30 viable dissertations.

Title pages and reference sections were photocopied from each of the 30 dissertations. Information extracted from each included doctoral student's name, year of graduation, year and location of cited work (SEL, other), number of citations, and total of each cited title broken into three categories: journals, monographs, and other documents. The "other" category consisted of patents, proceedings, technical reports, and unpublished papers (including dissertations and theses).

The 30 dissertations generated a total of 3,704 citations. Journal articles were cited most frequently (85.8%), followed by monographs (8.4%), dissertations, theses and proceedings, newspapers and annual reports (2.2%, referred to as "other"). Dissertations and theses comprised over half of the 'Other' category (60%).

These results corroborate past research by other authors. Knowing which resources doctoral students require should enable collection managers to more adequately serve them. The method in this study will help chemistry librarians determine which materials are being used at libraries. Ultimately, it is also assumed that an improved collection for chemistry will better support the research needs of future chemistry doctoral students.

33. Vicki L. Waytowich, et. al. (2006)

The purpose of this study was to investigate the citation error rate and quality of reference list in doctoral dissertation proposals. The study also sought relationship between perfectionism and frequency of citation errors and adherence of the reference list to the fidelity of the chosen citation style among doctoral students. Also of interest was to determine which demographic variables predict citation errors and quality of reference list.

The sample of this study consisted of 64 doctoral students from various disciplines enrolled in a graduate level dissertation preparatory course at a large South Eastern University in the USA.

The findings indicated the graduate students with relatively high levels of self oriented perfectionism tended to commit the most citation errors and construct reference lists that departed the furthest from the citation style stipulations. Every dissertation on an average contained 12 missing or inconsistent citations. This indicated that for every 3 citations included, one of them represented some type of error. Analysis revealed that students with lowest expectation levels tended to commit the highest rate of citation errors. The authors suggest that there is a need for more formal and more deliberate approaches for all instructors to instill in students the importance of avoiding citation errors.

34. R. V. Chikate and S. K. Patil (2008)

In this study authors have used 27 LIS dissertations, submitted to the University of Pune, from 1982 to 2005, as a source of data. A total of 6,257 citations were found in all 27 dissertations. Data compiled includes year of publication of article, journal subject, journal language. Publication status, place of publication and publisher of the journal is taken from the online version of Ulrich's International Periodical Directory. This data was entered in SPSS.

The study found that journal articles comprised of 42.2% of citations followed by 31.2% of citations from books. Other interesting finding was that out of 2,639 journal citations, most cited journal by LIS researchers is College & Research Libraries (141 times), Journal of American Society for Information Science (113 times), Journal of Documentation (99 times) and Aslib Proceedings (82 times).

This study confirmed the Bradford's Law of scattering. The ranked list of 351 journals from 2,639 citations reveals that most of the journals cited are from USA (131) followed by India (88) and UK (71). Nearly all citations are from English documents – 2,485 (94.2%) followed by Marathi documents – 118 (4.5 %). The study also revealed that LIS doctoral students cited journals from a multitude of disciplines including science, medicine, economics, psychology, etc.

35. Núria Vallmitjana and L. G. Sabaté (2008)

A bibliometric study was carried out on the citations within the Chemistry Ph. D. dissertations to ascertain what types of documents are the most frequently used in the research process, the most frequently consulted journals and obsolescence rate of the journals. The analysis covered 46 doctoral theses presented at the Institute Químic de Sarriá (IQS) from 1995 to 2003. The results obtained from the 4,203 citations revealed that the most frequently used documents were scientific papers, which accounted for 79 percent of the total; 33 journals met 50 percent of the informational needs; and the age of 50 percent of the citations was no older than 9 years. Finally, the results can be used as a tool for the collection management of the library.

The literature review of above 35 studies under six categories thus revealed a gap of research output evaluation of an institute in physics. Going through the above studies, the researcher felt that it would be worthwhile to undertake a bibliometirc study of one institute – Physical Research Laboratory as no such study has been carried out till now. The researcher thought of making use of immense amount of information available in the

annual reports of the institute as the base for getting the list of research documents in the form of papers published in journals, conference proceedings, invited talks and theses awarded during the 10 year period of study (1997-98 to 2006-07). This quantitative study will also benefit the policy makers of the institute as the results of the study could be used to supplement the qualitative tools of research evaluation.

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