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ETHICS OF HAVING ACCESS TO INFORMATION AND THE SCIENTIFIC OUTPUT OF DEVELOPING COUNTRIES: A CASE STUDY OF INDIA

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Abstract

Although scientific and technological research is universal, its actual distribution among different nations is rather skewed, with a small number of countries producing much of mainstream research being at the centre and a very large number of countries in the periphery contributing very little to the generation of new knowledge. We examine here the scientific output of India, the Third World's largest performer of science, the journals in which Indian scientists publish their work and how well Indian work is cited in the international literature. Comparing India's publication output and citation impact with those of several other countries, both developing and developed, we show that although India publishes a lot in the whole of science as well as in almost all the disciplinary categories, by and large the impact of Indian work is rather meagre. From an analysis of citation cluster data and peer evaluation carried out by an NSF panel, we identify areas of strength in Indian science. Looking at the citation profiles of many Indian journals, we infer that they are rather low in internationality, interdisciplinarity and current relevance. There are many reasons for the observed state of affairs. However, we discuss only a few, viz. inequities in opportunities to have access to current information, inadequate exposure of Third World work, and the neglect of Western scientists to take note of good work done outside their limited circle. We conclude that the skewed distribution of world science has an ethical dimension as well, beyond cognitive and social dimensions.

Both the creation of new knowledge in the sciences and the application of this knowledge to find solutions to problems are worldwide enterprises. Scientific and technological research is thus 'universal'. However, its distribution is highly skewed. In fact, as pointed out by Davidson Frame et al.[1], it is more skewed than the distribution of wealth among nations. Less than ten countries account for more than 75% of the journal literature of the world as seen from Science Citation Index.[2]. The membership of the international community of science is very unevenly distributed over the earth's surface. Despite the fact that a large part of the cognitive content of science is context free and despite the consensual unity of each of the various specialised fields of the community of science, there is a high degree of inequality in the community in general and in each of the specialised subcommunities.[3] Countries differ widely in the amount of money ivnested in science, in the number and size of laboratories, number of researchers employed, and investment on training, equipment and instruments, library and information resources, etc. One could understand the skewed nature of science and the creation and dissemination of scientific knowledge on the basis of a centre-periphery model[4,5] wherein a few locations account for much of the activity that counts (the centre) and very little of value happens in the rest of the world (the periphery).

In this paper, we examine the scientific output of India, the Third World's largest performer of science. We will also examine where Indian scientists publish their work and how well it is cited in the international literature. We will, in order to place India's publication output and citation impact in perspective, compare them with those of several other countries - both developed and developing. There are several reasons for the poor citation record of science done in India and other Third World countries. Some of them, especially those related to inequal access to information, will be discussed.

Indian Science : Publication & Citation Data

In spite of the large volume of work published by Indian scientists their impact on world science, on the whole, is negligible. Let us first look at some estimates of India's share of world's literature of science. And before that, let us look at the S&T manpower of a few countries. The following data were taken from the Current Contents Address Directory 1985, and the numbers given are the numbers of authors who have published at least one article in any one of the several thousands of journals covered by Current Contents:

USA	224953	Brazil	4025
USSR	66601	Argentina	2929
UK	51008	Egypt	1793
Japan	46951	Mexico	1502
France	37966	Chile	1397
FRG	37069	Nigeria	1172
Canada	25872	Taiwan	1076
Italy	19870	Saudi Arabia	864
India	17222	South Korea	767
Australia	12566	Thailand	635
Spain	11789	Turkey	626
The Netherlands	11184	Hong Kong	587
Israel	5516	Venezuela	581
P R China	5137	Singapore	430

India occupies the ninth position; till a few years ago India held the eighth rank, but Italy has now overtaken her. One reason for this sliding could be that now Current Contents (as well as Science Citation Index) covers fewer Indian journals than before.

In Table 1 are given data on the number of published papers as seen from Science Citation Index 1978 and their citations in the five-year period 1978-1982. India occupies the eighth rank in this list for all of science and is the only Third World country to find a place in the top twelve. In fact, with about 2.39% of the world's literature of science coming out of her laboratories, India is ahead of some of the advanced countries of the West such as the Scandinavian countires. However, her citation impact is among the lowest. For instance, USA the world's leading publisher of scientific papers, was responsible for about 44% of the papers which in turn had won more than 52% of all citations. In contrast, India's share of 2.39% of published papers could win only 0.81% of the citations. Among the countries which had won a higher percentage of citations than their share of the world's publications are Sweden, Switzerland, the Netherlands and Denmark. Israel is one of them too. Canada, whose scientific enterprise is comparable in many respects with that of India[6], is another.

In Table 2, we give data on the world distribution of journal papers of all science fields combined as seen from SCI tapes for the five years 1981-1985 and citations to these papers in the same five-year period. We also give the expected and relative citation rates[2]. In Tables 3-7, we give similar data for the journal literatures of physics, mathematics, chemistry, life sciences and engineering. These data were taken from two papers of Braun et al.[7,8]. To arrive at subject-wise distribution of papers, Braun et al. assigned whole journals to chemistry, life sciences, physics, etc. Also, life sciences here include clinical medicine, biomedical research and biology. Physics includes earth and space sciences. For definitions of observed, expected and relative citation rates, please refer to Braun et al.[2]

Not only does the United States publish the largest percentage of papers, but also her papers are quoted more often than would be expected from the impact factors of the journals in which these papers have appeared. The United Kingdom, Federal Republic of Germany, the Netherlands, Sweden and Switzerland also have better observed citation rates than the ones indicated by the impact factors of journals where their papers have appeared. In contrast, papers published from India, Egypt, People's Republic of China, Nigeria, Taiwan and almost all other Third World countries have a relative citation rate far below unity. India has the advantage of publishing almost all her papers in English and hence does not suffer discrimination due to language barrier, a factor to be considered when dealing with the citation records of Soviet Union, France, Germany, etc. as well as those of many Latin American countries which publish mostly in non-English language jouals. Despite this advantage, India's citation record is poor.

Another fact deserves mention here. SCI, published by the Institute of Scientific Information, Philadelphia, covers only a small fraction of Indian journals. As, except for an occassional error of judgement, ISI usually covers the better cited journals, the poor citation record of India will be even poorer if SCI were to cover a larger number of Indian journals than it does now!

Except in life sciences where she occupies the twelfth position, India occupies the eighth, seventh or sixth position in all other fields in the number of papers published, and hence deservedly earns the title of 'the giant of Third World science'. However, in each one of these areas we se that her observed citation rate is very low. In fact, the observed citation rates of Chile, Mexico, Argentina and Brazil are considerably higher than that of India for all science fields combined as well as for individual fields. And papers published from the USA, the UK, the Netherlands, Sweden and Switzerland are quoted on an average 4-5 times more often than papers from Indian laboratories (Table 2).

We also notice that in all these Tables (Tables 2-7), India's expected citation rate is higher than her observed citation rate. This means that Indian authors, on the whole, publish their papers in journals of higher impact factors than the actual number of citations won by them would indicate. There are two ways of looking at it: one, Indian scientists are able to place their work in and meet the stiffer standards of refereeing set by these journals, but their papers are not quoted as often as they deserve to be perhaps because of extra-scientific reasons. Many senior Indian scientists who are members of international invisible colleges and who usually publish their best work in reputed international journals feel that often work published subsequent to their own by scientists in the West are given credit and quoted and their own 'original' work is ignored in the literature.[9] Two, much of Indian work appearing in better-impact journals just qualifies to pass the minimum threshold levels of acceptability in these journals, and in fact helps to bring down the impact factors of these journals. In our view, both these mechanisms are in operation .

The United States is the world leader in physics research and accounts for over 34% of papers in this field. However, Switzerland has a better observed citation rate than the USA. Other countries which have recorded an observed citation rate of over 3.0 are the UK, FRG, France, the

Netherlands, Israel and Chile, the only developing country. That Israel's record in physics is excellent has been documented earlier[10,11]. India's citation record in physics is poorer than that of many Third World countries such as Mexico, Argentina, Brazil, Venezuela, Chile, South Korea, and Hong Kong, but better than that of Nigeria and Egypt (Table 3).

Unlike physics, chemistry and life sciences, mathematics and engineering are characterised by low citation rates. Taiwan has the highest observed citation rate in mathematics, followed by the United States and the UK. Among the other better performers in mathematics are Norway, Sweden, Hong Kong, France, the Netherlands, Mexico, FRG and Israel. India has a low 0.33 for observed citation rate (Table 4). Her citation record in this field is slightly better than that of Egypt and Nigeria, but not so good as that of Brazil or the People's Republic of China.

India's contribution to the world literature of engineering at 3.15% is substantial. But what is more noteworthy is that the observed citation rate of 0.84 is only slightly less than half that of the Netherlands, the country with the highest observed citation rate in this field. Here again, the Latin American countries, viz. Argentina and Brazil, have better observed citation rates than India. Israel and South Korea as well as Australia and Canada have better citation records than India (Table 7).

The literature of chemistry is more evenly distributed than the literatures of other fields, with the world leader's share being 22.57% and with two other countries having a share of more than 10% each. India's share of 5.06% (data from Braun et al., based on SCI tapes) seems to be too high. According to Chemical Abstracts, India's share is around 3.0%. The United States has the highest observed citation rate, followed by the Netherlands, Canada, Sweden and FRG, all of which have observed citation rates of over 3.0. India's observed citation rate of 1.07 is less than that of Mexico, Chile, Brazil, Argentina, Australia, Canada and Israel, but better than that of South Korea, Taiwan, and USSR.

The observed citation rates are more evenly distributed in life sciences than the other fields considered here. As seen from Table 6, only the USSR

Egypt and the People's Republic of China have poorer observed citation rates than India. India's share (1.76%) of publications appears to be rather low. This is so because, many journals in which Indian researchers publish their work in classical biology (botany, zoology, agricultural sciences, etc.) are not indexed in SCI.

The poor citation record of Indian scientific research calls for an explanation, particularly in view of the relatively better performance of the non-English language publications of the larger South American countries. There could be two reasons: one, much of Indian work may be of low current relevance and may be in areas which are not of mainstream interest; two, Indian researchers have a great propensity for publishing anything that will be accepted by any journal irrespective of the quality and significance of the work.

The entire analysis based on data presented in Tables 1-7 is based on Science Citation Index. Unfortunately, SCI does not cover many journals in which Third World scientists including those from India publish. As pointed out by Lea Velho[12], SCI "grasps only the contribution of these countries to internationally mainstream research, which is only a small part of their scientific output". For example, Chemical Abstracts covers more than 200 Brazilian journals out of which only six were covered in SCI in 1985.[13] As pointed out by Russel et al.[14], of the seventy-six veterinary science journals indexed by SCI only four are published in the Third World. A detailed review of the inadequate coverage of Indian journals in SCI is available.[15] This issue was also discussed in great detail at a meeting of international task force held in Philadelphia in July 1985, largely thanks to the initiative of Mike Moravcsik.[16]

However, as pointed out earlier, adding more Third World journals to SCI might lead to a more realistic estimate of the number of papers published by Third World countries, but we guess it might also lead to a lower observed citation rates for these countries.

Apart from the problem of coverage, citation analysis-based inferences are subject to criticism drawing its strength from cognitive interpretations of why people cite and whether citations can be aggregated. For a detailed review of these arguments, please see the well-written book by Blaise Cronin.[17]

To overcome these criticisms, analysts now adopt higher order citation analysis such as the one based on cocitation cluster models invented by Henry Small and Belver Griffith. In essence, cocitation analysis uses SCI data to represent research activity as a network of interacting research areas. The method produces a model of scientific activity which groups current scientific papers into discrete research areas based on their references to highly cited and highly cocited previous papers. This leads to portraying current research fronts as networks of interacting specialties. We will not go into a discussion of this, except to point out that hardly any research paper from India (or other Third World countries) turns out to be a key paper, even in areas where there is a lot of publication activity in these countries.

Last year the US National Science Foundation commissioned a bibliometric assessment of Indian science based on the cocitation cluster technique and the Center for Research Planning model constructed from SCI 1984. The study carried out by Bob Coward provides valuable insights into the Indian science enterprise.[18] According to Coward, India is active in 5,419 specialty nodes as against the 28,128 nodes for the world. Activity means participation by publication of at least one paper. Although India contributed less than 2% of the papers in the model, Indian researchers were active in 19% of the specialties and 57% of the larger regions. In contrast with most developing countries, Indian activity in biomedical fields is relatively weak, while activity in chemistry is very strong. Of the top 100 strongest Indian research areas 55 are in chemistry, 16 in agronomy/ecology, 14 in biomedicine, five in mathematics and four in materials science. Of the bottom 100 (weakest) Indian research areas 68 are in biomedicine and only five are in chemistry.[18]

As in most developing countries, in India also activity tends to concentrate on older, less rapidly developing fields. However, India does maintain a presence in some rapidly developing fields such as nucleotide sequencing, monoclonal antibodies, quantum chromodynamics, superconductivity, and optical fibres. In general, mainstream research areas are not as accessible to Indian science as are more peripheral areas in world science.[18]

According to Coward, while nineteen Indian institutions participated in the intellectual base that led to developments in biotechnology, hardly any contribution was made to the intellectual base of solid state physics. The record of Indian materials scientists was, however, much better. Forty-five Indian scientists contributed to the intellectual base in this field. Also, about 10% of the areas of high activity in materials science are rapidly developing.

Among the institutions that contribute significantly to biotechnology research are the Indian Institute of Science, Bangalore; Banaras Hindu University, the Indian Institutes of Technology, the University of Delhi, and the National Chemical Laboratory. The Bhabha Atomic Research Centre, the Indian Institute of Science, Indian Institute of Technology (Kanpur), and the Tata Institute of Fundamental Research are among the major contributors to materials science research.

The US National Science Foundation conducted a questionnaire survey on India's scientific strengths and weaknesses. The respondents were scientists of repute with considerable knowledge of their chosen fields and with some experience with Indian collaborators. These experts identified the following areas, among others: thermodynamic states of liquid crystals, synthesis and characterisation of materials, organic synthesis, powder metallurgy and rapid solidification, extractive metallurgy, spectroscopy of microstructurals in colloids, Mossbauer studies in surface physics, fibre optics theory, ceramics, preparative inorganic chemistry, and synthesis of metastable materials such as metallic glasses.[19]

One area of great strength which was not identified either by Bob Coward's cocitation analysis or by the experts is electrochemical theory.

A point worth noting is an observation made by an American professor who was on NSF panel that serious and important work is being done in unlikely places. For instance, in a study we made of liquid crystals research in India we found that two papers were published in Journal of Chemical Physics of AIP. Both of them were written by researchers working at the Meerut Univeristy which is not given a high rating by academics both within and outside India. Not many Indian scientists publish in this journal.

The NSF questionnaire survey revealed that synthetic organic chemistry is an area of strength but not physical organic chemistry. However, a study conducted at the National Institute of Science, Technology and Development Studies,[20] New Delhi, based on data from Chemical Abstracts, has shown that physical organic chemistry is an area of high activity. Perhaps, its importance as well as its impact on world science is low.

We have so far seen a lot of data based on SCI and the cocitation cluster model based on SCI. We have also seen the views of US experts interviewed by NSF on the areas of strength and weakness in Indian science. Now let us see the journals where Indian scientists publish their findings.

Where do Indian scientists publish?

Arunachalam and Singh[21] have analysed data from three editions of Current Contents published in the second half of 1982. Indian scientists used 345 journals in the Physical, Chemical and Earth Sciences Edition (PCE) for 2863 articles, 350 journals in the Life Sciences edition (LS) to publish 1473 articles and 242 journals in the Engineering, Technology and Applied Sciences edition (ETAS) to publish 980 papers in these 26 weekly issues. 39 journals and 170 articles appearing in them are common to the PCE and ETAS editions. 25 journals and 298 articles appearing in them are common to the PCE and LS editions. Thusour sample consists of 2863 + 1473 + 980 - 170 - 298 = 4848 articles. Figure 1 is a plot of number of journals vs cumulative number of publications.

A very large percentage of Indian research papers appear in low impact journals. More than 50% of papers in the PCE edition, 40% of papers in the LS edition and over 54% of ETAS papers have appeared in journals whose impact factors are less than 0.5 (Table 8). In contrast, only about 9% of Australian papers and about 11% of Canadian papers covered by the PCE edition have appeared in journals with an impact factor less than 0.5. In the life sciences the contrast is even sharper, with only 1.45% of Australian papers and 3.23% of Canadian papers appearing in journals of such low impact. Also, very few Indian research papers appear in high impact journals. Only about 2% of India's PCE papers (as against 11.5% of Canadian PCE papers) and 5% of Indian LS papers (as against more than 21.5% of Canadian LS papers) appeared in journals with impact factors greater than 3.0.

About 45% of PCE papers, 33% of LS papers and about 18% of ETAS papers from Indian laboratories appeared in Indian journals. US and British journals were used to a large extent in all the three areas, followed by Dutch journals. Among the Indian journals used often are: Current Science, Indian Journal of Chemistry Sections A & B, Journal of the Indian Chemical Society, Indian Journal of Experimental Biology, Indian Journal of Medical Research, Indian Journal of Technology and Transactions of the Indian Institute of Metals. Among the foreign journals often used by Indian scientists are : Thermochemica Acta, Journal of Materials Science, Physica Status Solidi B, Journal of Macromolecular Chemistry, and Journal of Applied Polymer Science in PCE; Wear, Journal of Materials Science Letters, and Textile Research Journal in ETAS; and Phytochemistry, Experientia, Toxicology Letters and IRCS Medical Sciences: Biochemistry in LS. (Table 9).

India's share of the world's literature is about 4.1% in the PCE edition, about 1.4% in the LS edition and about 2.5% in the ETAS edition. The universities and other institutions of higher education account for about 73% of journal articles in the PCE edition, about 65% in the LS edition and over 60% in the ETAS edition. The Indian Institute of Science and the Indian Institutes of Technology lead the list of publishing institutions in the ETAS edition, followed by the University of Roorkee and the Banaras Hindu University. University of Delhi, Banaras Hindu University, Universities of Calcutta, Madras and Allahabad, Osmania University, University of Rajasthan, Indian Institute of Science and the Indian Institutes of Technology are the leading contributors of papers to the PCE edition. Banaras Hindu University, the Universities of Calcutta and Delhi, All India Institute of Medical Sciences, and the Postgraduate Institute of Medical Education and Research are prolific contributors of life sciences papers. Among the universities, Banaras Hindu University publishes the most number of papers, followed by the University of Delhi, University of Calcutta, University of Madras, and Osmania University, each of them having more than 100 papers. National Chemical Laboratory and the Central Drug Research Institute are the two CSIR laboratories with more than 50 papers. Bhabha Atomic Research Centre and the Tata Institute of Fundamental Research figure prominently in the PCE edition, and BARC's contribution to the LS edition is also substantial (Table 10).

From the titles of journals in which Indian papers have appeared, we can infer that India is active in experimental biology and medicine, bio-chemistry and pharmacology, materials science, electrical and electronics engineering, organic chemistry, polymers and condensed matter physics.

Not only does India publish a very large number of papers but also she publishes in a wide spectrum of fields and subfields. On the one hand there are strong Indian groups in truly international fields such as radioastronomy, particle physics, superconductivity, liquid crystals, holography and molecular biophysics. And on the other we have a large number of Indian scientists working in fields which are largely of local interest, such as Himalayan geology, natural products chemistry, indigenous medical systems, tropical diseases, agriculture, etc. Thus, in terms of both the size of the scientific enterprise and the volume and variety of publications it would not be proper to consider India as a Third World nation. However, the overall impact and significance of Indian science are indeed poor. That does not mean there is no excellence. May be the peaks of excellence are few.

Although on the whole Indian science is peripheral, there are certain areas in which India is closer to the centre than in others. To validate this hypothesis we need to compare the performance of Indian scientists with that of scientists elsewhere in different fields. That is a formidable task. But there is an easier option.

What can Indian journals tell us about Indian science?

Let us look at some of the better run Indian scientific journals and see if we can draw some inferences on the nature and characteristics of scientific research performed in India.

Indian scientific journals, for this analysis, can be classified into two groups: those covered by SCI and those which are not. For the SCI covered journals we can obtain from the Journal Citation Reports the impact factors (an index of how often articles published in a journal are quoted in the international literature), the age distribution of references cited in these journals (an index of how close to or how far away the research reported is from the currently active research fronts), the number of times (or percentage) reference is made to national and foreign journals and conversely the number of times (or percentage) articles published in a journal is quoted in national and foreign journals (an index of 'internationality), and the number of references made to a journal in journals devoted to other fields as well as the number of times a journal quotes articles published in journals outside the fields(an index of 'interdisciplinarity.

Using these indicators in conjunction, we can gain some insights into the nature of scientific research in India, especially if we compare Indian journals with international journals, of the same genre. Arunachalam and Manorama[22] have performed such an exercise. Arunachalam, Rao and Hirannaiah[23] have used this technique to study Indian agricultural research journals. In Table 11 we have compared the age of references in several Indian journals with those of leading international as well as Canadian and Australian journals. The international averages are obtained by considering six of the leading journals in each field. We see that Indian journals usually quote a high percentage of older references and a low percentage of recent references. For example, in physics the Indian Journal of Pure and Applied Physics differs from the international average by 27 percentile points for older references and about 20 percentile points for recent references (Table 11).

Please note that the two Indian ecology journals are not indexed in SCI, and data on them were collected manually. The intellectual base of ecology is older than all the other subjects considered here. The well-known Canadian Journal of Fisheries and Aquatic Science has an excellent age of reference profile, with fewer old references and more recent references than in most other ecology journals. In contrast, the two Indian ecology journals have an intellectual base going back to several years.

Journal of Biosciences published by the Indian Academy of Sciences has an intellectual base which is relatively younger than that of Indian Journal of Biochemistry and Biophysics. The two chemistry journals from India considered here also draw heavily upon older literature. But Journal of Astrophysics and Astronomy differs only to a very small extent from the internationl journals in the age distribution of references.

All the Indian journals except the Journal of Astrophysics and Astronomy have an impact factor lower than 0.5 (according to JCR 1986). Almost all of them are cited rarely and most of these rare citations (or at least a large part of them) occurs in Indian journals (Table 12). Like most Third World journals most Indian journals suffer from disciplinary insularity. They rarely quote journals devoted to other subjects, and they are rarely cited in journals outside the field. In short, most Indian journals have a low rating in internationality , interdisciplinarity, citation impact and current relevance. The situation is even worse with non-SCI journals.

So far, we have provided ample data to show that on the whole science done in India, as revealed by publication and citation data, is not of the same class as science performed in the advanced countries of the West. The situation is not very different in other developing countries. With rare exceptions, scientific research in developing countries is derivative and mediocre.

There has been criticism in the literature of basing one's conclusions on Third World science on citation data[12,24]. This criticism stems from the argument that a large part of science done in the Third World is locale specific and is meant to deal with problems encountered in these countries. We are fully aware of this debate, and yet we believe that citation data, if their limitations are properly understood, can be used to understand the cognitive contributions made by developing countries. For example, there is nothing locale specific or uniquely Third World about particle physics, liquid crystals and biotechnology research done in Third World laboratories and published in national and foreign journals.

In our opinion, one would be wiser to draw valid inferences from citation analytic and other accepted tecniques such as peer evaluation, and look for reasons why science in the Third World suffers from some of the lacunae that we know it suffers.

Access to Information

One can list a whole lot of causes for the poor performance of science in the Third World - some obvious and others not so obvious. Lack of adequate funding, inadequate training facilities, lack of a long-standing tradition in doing (Western) scientific research, absence of a viable 'scientific community', inadequate peer evaluation procedures, etc. are often responsible for such poor performance. But, we will talk about only one of them, viz. the lack of access to current information[25,26].

"The precise extent to which research workers are wasting energy in repeating experiments that have already been made is difficult to estimate; but those who have given much attention to the study of the literature of their special subjects are aware that the proportion of labour which is wasted for lack of information on previous work is very high. It is indeed more than possible that half the energy expended in experimental research is dissipated in useless repetition." This excerpt from Nature 60 years ago (15 December 1928) holds good even today as far as research in the Third World is concerned.

The Nature editorial went on to say: "Perhaps it is less well perceived that the same proportion of useful work is published only to be buried out of sight in masses of volumes on the library shelves. To end this extravagance would enormously increase the efficiency of scientific research and the resulting stimulus to industry would be incalculable. It is worthwhile, therefore, that attention should be concentrated on the indexing of recorded information, so that hard-won data may be found at need and play their part as a basis for further progress."

Inadequate appreciation of the usefulness of and the need for information thus leads to two consequences: useless repetition of research resulting in wastage of scarce resources, and inability to profit from knowledge lying 'buried out of sight'.

It is clear from recent Indian experience that better access to current information leads to better performance in scientific research. To cite only one example, currently India's performance in astronomy (including astrophysics and cosmology) is much better than her performance in most other fields of science.[24] Among the factors responsible is certainly the excellent iformation back-up Indian astronomers receive from libraries such as the Raman Research Institute library in Bangalore, which should serve as a model for the rest of India and the Third World for what a dedicated librarian could do for his clientele.

Much of the scientific and technical information (STI) is produced in a few countries of the world, and are processed and made available in the form of bibliographic databases by even fewer countries, notably the United States of America, No Third World country has the resources to buy even a small fraction of the large number of primary journals, monographs, reports, books and the current awareness and abstracting services. Indian libraries in S&T institutions spend more than three-fourths of their meagre books and journals budget on imports from the West. (In fact, the literature produced within the country is precious little).

With advances in technology, the database producers have several options available to them. They now produce STI databases in the conventional print-on-paper form, computer-readable magnetic tape form and the CD-ROM form. As more and more subscribers in the advanced countries where the bulk of the subscribers is located opt for the newer forms, the database producers adopt a pricing policy which makes the print-on-paper form more expensive than the other forms! Thus the already poor ends up paying more for the same information than the rich![27] Besides, because of the enormous distances involved, most Third World countries get their print-on-paper databases several weeks later.

If we go one step further, we will see the actual cost of such information for a Third World researcher is even higher, as both the total number of users who consult these databases and the number of times these databases are actually used are relatively low in developing countries.

Thus, there is a built-in inequity in the acquiring of information, which works against the interest of the Third World.

Conferences

One way scientists keep themselves posted with the latest information is by attending conferences. A casual glance at a secondary service on conferences such as the International Scientific and Technical Proceedings will show that the really informative and useful conferences are often held in the advanced countries. Most Third World scientists do not get opportunities to attend these conferences. For one thing the enormous distance and therefore the prohibitive cost of an air ticket make it unafforadable for a scientist from a poor country. And often the enormous effort one has to mount in order to get one's application to go to such meetings cleared by the local institutional and government authorities make all but the highly motivated refrain from applying at all. Besides, because of their low visibility, most Third World scientists do not get invited to conferences abroad. Thus they lack the opportunity to meet and discuss with fellow-researchers elsewhere.

There have been attempts to meet this problem such as travel grants meant for Third World scientists, provided by international funding agencies such as IDRC and UNESCO. One of the finest initiatives meant to provide opportunities to developing country scientists to work in a first-rate institution where they can spend from a few weeks to a few months in a stimulating atmosphere and meet with fellow-reseachers from all parts of the world was the establishment of the International Centre for Theoretical Physics (ICTP) at Trieste, Italy. But ICTP is largely confined to physics, and a few more institutions of that kind devoted to other fields of research are badly needed.

Secrecy in Science

It is in this context, one regrets to see that governments of some advanced countries, notably the United States, enforce certain regulations aimed at preventing foreigners from having access to technological information.[28] Anyone other than US citizens are prevented from attending certain conferences in strategic areas - such as superconductivity, supercomputers, and strategic materials. There have been instances when even overseas members of certain professional societies were prevented from attending certain sessions of the society's meetings. At least one US university attempted to keep foreign students away from the classroom.

At diferent times the United States State Department has barred communicating information about "carbon-carbon alloys", "metal-marix composites" and other areas considered to be crucial to American security or business interests. And the US Government armed itself with the right to levy fines up to $1 million and even imprison conference organisers violating a 1980 Commerce Department directive on letting foreigners attend conference sessions discussing certain topics.

Such steps prevent non-US citizens - even the allies of the United States, let alone Third World scientists - gain knowledge vital for their work. All the talk about the Mertorian norms of free and open communication of scientific knowledge is meaningless when one is denied access to information either by a government fiat or by its prohibitive cost or because of systemic inequities. It is widely believed that at least in some cases such denial of access to foreigners is not justifiable on military grounds, but is aimed to win and retain technological and commercial edge in competitive industries. The issues involved pertain not merely to national security interests but also to ethics.

Such regulation of scientific exchange and restriction of the flow of scientific information are not conducive for the growth of scientific knowledge. In fact, enlightened leaders of science in the United States have strongly deplored such tendencies. "A society that would foster the most fruitful scientific enterprise must build its science policy on the open, public nature of science" says Gerard Piel of Scientific American. Columbia University sociologist Robert Merton and the British physicist-cum-science studies specialist John Ziman have written extensively on how science can grow only in a climate of full and open communication.

It will be unfair to blame the United States alone, According to (pre-glasnost) study made by Francis Narin and colleagues of Computer Horizons, Inc., the Russians might be withholding important scientific advances made by their scientists. Although funds spent on R&D by the Soviet Union are on the increase, the Soviet share of the world's published literature is on the decline, says Narin,

Both the United States and the Soviet Union recognise scientific information as a very valuable, and often strategic, resource that can help keep them one up on the other. It is but natural for them to impose control over its free flow. That is the price the world's scientists have to pay as long as the world is divided and as long as much of the funds spent on R&D is on military research!

Recognising Third World Contributions

Much has been written about the inadequate access to information and the deleterious consequences it can have on the growth of science in less developed countries. But a related and an equally important problem, viz. the inadequate exposure and recognition of work done by Third World researchers, is not well recognised.

Many Third World journals, carrying important information, are not adequately covered by the world's leading secondary services. For example, Science Citation Index (SCI), the world's leading multidisciplinary database covered less than a dozen Indian journals in 1987 as against about 800 titles covered by Indian Science Abstracts. SCI's coverage of other Third World journals is also equally poor; in all less than 50 Third World titles were indexed by SCI in 1987! Some international databases such as Chemical Abstracts and INSPEC's Physics Abstracts cover Third World journals reasonably well. Current awareness services such as Current Contents, which play a key role in alerting researchers worldwide to recent publications, cover only a small fraction of Third World titles. As Third World journals suffer from poor marketing and as they are not very well noticed by secondary services, even the good work published in these journals does not get as much recognition as it may deserve.

Neglect of Third World Work

There is yet another serious problem, which defies understanding. Even when a Third World scientist publishes his work in one of the better known international journals it is possible that it may not be noticed (or at least may not be quoted) and the credit for the same may be given to some other (usually Western) author(s) who might have published a paper on the same topic years later. Take the case of a recent paper in Science. Two New York based developmental biologists LaDonne H. Schulman and John Abelson wrote a paper entitled "Recent excitement in understanding transfer RNA identity" in Science (17 June 1988), 1591-1592. They state that the term "second genetic code" was coined by C. de Duve in Nature, Vol. 333 (1988) page 117. In fact, this term was first coined as far back as 1969 by P M Bhargava et al. in a 1970 paper in Journal of Theoretical Biology (vol. 29, pp. 447-469). What is more, Bhargava et al.'s paper stated in unambiguous terms at least two of the 'generalisations' that are implied as being new in the article by Schulman and Abelson!

All that Dr. Bhargava could do was to write a letter to Prof. Daniel Koshland, Editor of Science, drawing his attention to his earlier paper. He went on to say in his letter: "This is not the first time that the work done outside of the American continent (and, perhaps, part of Europe) has not been taken appropriate note of by the Western scientific community which, in view of its accomplishments justifiably dominates the world scene today. In fact, we can cite examples where our articles (having an Indian address) published as lead articles in important areas, in journals such as Nature and Science, have been ignored in later work done in the same areas. I believe that such situations are not conducive to progress of science."

To see one's work being cited is the supreme satisfaction a scientist can have. To be denied this satisfaction - by many people in the West quoting work by the other Westerners published subsequent to one's own - is an experience not uncommon for at least some Third World scientists.

Sociologist of science Harriet Zuckerman of Columbia University and Tibor Braun, the eminent editor-in-chief of Scientometrics, believe that such instances result from ignorance of the literature at the individual scientist level and not out of deliberate conspiracy against the Third Worlders. But, whatever be the reason, there is no denying the fact that the operation of this phenomenon affects the Third Worlders the most, and those who are at the receiving end naturally feel hurt. And to them this is an ethical issue as much as reporting fraudulent results is.

As in other social phenomena, in international science also the Mathew effect operates ruthlessly. Be it the access to information or giving credit to a good piece of work done the rich gets richer and the poor is deprived of even what is legitimately due to them!

The inequities in international science cannot be exaplined entirely on the basis of cognitive and social factors. They clearly have an ethical dimension.

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