

## Science, technology, art: Their new place in the emerging India

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The 10 November issue of *Current Science* carried, by coincidence, a succession of three articles<sup>1</sup>, each of which caught my attention. The tribute to Gene Garfield by Arunachalam; the Guest Editorial by Ganeshaiah; and the letter by Tiwari.

As another friend and admirer of Garfield's major contribution to the metrics of science, I found Arunachalam's collection of first rate articles a worthy tribute, indeed. That said, I believe it would have been very valuable to have had a paper in this set on the very considerable dangers associated with the very frequently improper use of such *SCI* (*Science Citation Index*) data. Comparisons of simple 'numbers of citations' are made all the time, even though in a good proportion of such cases they are highly misleading. One cannot compare citations in biochemistry with astrophysics because the citing universes differ by over an order of magnitude. The scientific merit of a paper published in *Current Science*, cannot be compared with the one published in *Science* by comparing the citations. The quality of a candidate for an assistant professorship in a standard teaching and research university cannot be well defined by citation counts. Yet we all know that this is what happens daily in a substantial percentage of cases. The selection of journals used by *SCI* or *WOS* (*Web of Science*) is skewed (albeit getting less so) against older literature – and against the more 'foreign' literature and the more 'applied' literature. In other words, I am saying that the warning label on 'side-effects of citation counting' is missing from all the packaging!!! It would not get by the FDA!! But there are more technical issues.

I dealt with one 25 years ago<sup>2</sup> when we still had to add up citations manually. We showed that *SCI* quality rankings are safer for groups (like a department) than an individual. And also it appeared that just counting papers was highly correlated with citations and a lot less work (in those days). But recently it is Cardona and Marx<sup>3</sup> who have made the most detailed studies, illustrating many other interesting distortions of the typical citation process. I do not attempt to summarize their work because they must be read in the original. I refer only to one aspect which had ear-

lier caught my attention<sup>4</sup>, and then confirmed in quantitative detail by Cardona and Marx. This is the world of, what these authors call, 'Informal Citations'. This term refers to the use of a name (or a term) to refer to a procedure or method, which is so well known, that the author feels no need to give a citation, instead to simply give a label to a method or procedure. Probably the most cited paper in all of science so far will prove to be Kary Mullis 'PCR' paper (note: no reference given!). Yet tens of thousands of authors owe Mullis an enormous debt because they actually use his work, *which they acknowledge*, but do not formally cite) by saying 'using the PCR method'. This is an 'informal citation'. Yet it is not counted by *SCI*. This is a serious error which can be corrected, but not easily because of the current self-imposed procedures.

Specifically relevant and interesting to many of *Current Science* readers is Cardona and Marx's recent findings that the author most adversely affected by this 'Informal (but not yet counted as it could be by *SCI*) Citations' – is none other than C. V. Raman. The ratio of 'Informal Cites' to 'Reference Cites' is 95,669 to 1,152: that means that citation frequencies, impact factors, etc., have all been badly distorted (by a factor of nearly 100) in the case of C. V. Raman.

While Cardona and Marx also mention the matter of years of *active work* in evaluating the quality of a scientist's output, I have also raised the desirability for the *WOS* and science managers to introduce simple normalization procedures to take care of the huge population explosion in papers with time. Since the reading time of scientists is conserved, the value of a paper must be evaluated in some relationship to the total number of papers published in that citing universe. Thus we could introduce the concept of citation deflation and quote the data in (say) '2006 (or 1990) citation units'. Or normalize them routinely as we do in all economics data.

Next, I turn to the letter by Tiwari responding to my previous letter urging that India *not* copy the structure of practices in the United States research funding agencies. The use (and misuse) of citations as a major metric of quality, as

discussed above, is one of the many ways in which I urge India and the world NOT to follow simple-mindedly, certain 'developed' world practices. Tiwari has mistaken my intention by conflating all 'science' under one word.

There is and will always be the human push to 'improve' or change one's living conditions and opportunities (hopefully) for the better. This is the *technological* imperative. Its power and its dangers have been catalogued in two dozen books starting with *The Technological Society* in 1955 by Jacques Ellul. (Regrettably the extensive work of Ellul is virtually unknown in India.) The science policy issue I have raised in the United States for three decades is: should *public* funds (in large amounts) be used for the benefit of the pure pleasure and curiosity of only a tiny community (of US scientists). This is the issue that is front and centre here also. It is obvious that 99.9% of the tax-paying public receives no (in the limit) benefit whatsoever from say, radio astronomy outside the solar system, or high energy physics. There are no 'spin-offs from such fields', albeit they are not all that spectacular in most undirected basic science research. Confusing 'science' with 'technology' or applications-driven science is impermissible for serious scientists or policy analysts. A simple slogan for guiding public-science funding could well be 'Public funds for public good'. This, in no way, lessens the *value* of such interesting or fascinating basic science. Nor does it in any way restrict the access of scientists to many other kinds of resources – *private* resources.

For the record I remind the reader who is worried that the progress of science would be impaired, that from Newton and gravity, through Einstein and Bohr, and the quantum mechanics revolution, even the greatest scientists' research activities were largely self-supported by their work as professors, or patent-adjudicators in Bern! Why not revert to sweat-equity in basic science?

And that is the segue to Ganeshaiah's article on 'Asymmetry between arts and sciences'. I agree with his endorsement of various individual scientists like B. G. L. Swamy's success in India, in crossing the 'blood-brain barrier' – the divide be-

tween the arts and sciences. Under my direction Penn State's Materials Research Laboratory was the United States' national champion of advocating interdisciplinarity of all kinds throughout the University, not only in materials, for three decades. That even included having an art museum *within the laboratory*, and annual *national* 'Science in Art' awards. The conclusions from the data on our experiences across some 30 years are in. The reductionist (left brain) approach of science (not of *all* scientists, but of most) is inherently mismatched with the wholist (right brain) approach of art and the public. W. H. Auden, a rare example of a great literary figure who knew of, and appreciated, science (his brother was in the Geological Society in India-Pakistan) spoke in our lab on this topic. So did (Lord) C. P. Snow, who is increasingly being proved to be right. There really are 'Two Cultures' – distinguished most clearly as left brain or right brain dominant cultures. Only a few individuals – for example, C. F. von Weizsacker, Carl Djerassi, or Roald Hoffmann – are willing and able to tunnel through the multi-electron volt band gap.

The gap imposed by science's intrinsic reductionism is too fundamental to be erased. I taught it in my thermodynamics classes for 40 years. We preach that we *must isolate* our system from the outside world. We must be inherently reductionist *in our work*. But with some wonderful exceptions this reductionism and isolation often creeps into our personal, social and economic attitudes. In my informal surveys when giving plenary lectures at scientific meetings, I often conduct a hands-up study and find that, typically, only a few per cent of scientists in the US can even name their Senators – or what the House Science Committee is or does – thus demonstrating their 'citizenship-illiteracy'. Yet they freely criticize the public and their politicians' 'scientific illiteracy'! Very few scientists are active in social reforms, marching for/or championing causes (Linus Pauling, Bertrand Russell, Albert Einstein and Leo Szilard were rare exceptions). Gandhiji in his seven deadly sins lists 'Science without humanity'. Is the modern science establishment innocent of this charge?

But it is with Ganeshaiiah's second asymmetry that I take more serious issue. We in science are a substantial drain on the public purse. Some of it is justified and indeed pays good dividends. The en-

gineers and scientists doing *applications-driven* basic science are clearly legitimized. Such *applied* scientists can create new products and new sources of jobs/income for the nation. 'Pure' science, examples noted above, not so. Further, we have also a very oversimplified view of the economic and political value of science vs art – which in our PR goes like this: 'Science creates wealth, Art absorbs it'. It is all wrong. Barbra Streisand speaking at Harvard's Kennedy School some years ago compared the ROI (return on investment) to the US Treasury, of Science, Technology and Art. The denominator for *public* money for science and technology was probably about \$150 billion/year then. For art it was << \$1 billion/year. Yet as she pointed out, American movies and music have spread more American values (for good and ill) and they have earned as many dollars for the US also. To calibrate ourselves take this example: How many single technological products have sold over say \$1 billion. Yet Andrew Lloyd Webber's *Phantom of the Opera* – in theater and movie ticket sales alone – has grossed over \$3 billion. The short form of the equation is: Abstract pure science absorbs a substantial amount of public money; technology a modest amount; art, very little and applications-driven basic science, a good deal. Technology returns the most; art substantial amounts; 'pure'-science, very little – *to the public*.

In his closing paragraph, Ganeshaiiah strikes the note on which we deeply agree. Science as taught and practised is far too specialized and narrow and it has long since lost contact with society.

The very few leaders among research scientists and engineers, in the US, who toil in the vineyards of communicating the relevance of science to the public, including teaching it in K-12, like to show a short video of the detailed research data from a multimillion dollar research project carried out on the *graduates* of Harvard and MIT. The video provides (conclusively) the stunning evidence that *over 90%* of these *graduates* (in all fields including science and engineering) could not give the interviewer the correct answer to these three questions. (All data are available on video – *A Private Universe*, Pyramid Productions.)

- Why do we have winter and summer seasons? (*Most said it was because*

*the earth gets nearer or further from the sun!!!*)

- Where does the mass of a large tree come from? (*Many would not accept, even when prompted, the right answer of: photosynthesis from water and CO<sub>2</sub>.*)
- Can you light this bulb with a piece of copper wire and a battery (all provided)? (*One MIT chemical engineering graduate allowed as how this should be an EE major's territory!*)

I recount this story – it is stunning to an audience of scientists when shown as the video clip – to make my most important point of all. Increasingly science is tempted to offer itself as a modern theology, to the world's growing addiction to technology as its only religion.

The contemporary news media have become – not critics like Mary Shelley – but cheerleaders for the gross exaggerations emanating from unscrupulous corners, by scientists seeking funds under the latest buzzword.

Not since Jefferson and Franklin helped launch the American experiment has the top leadership of a major nation had such scientific competence right at the top – as we have in India. We need, I believe, a considerable effort to introduce the ultimate interdisciplinarity into the education of all college students. It should start with the education of our national science leadership into the now well developed realm of 'science, technology and society (STS)'. This would help them know the actual place of *science* and separately, *technology*, in our complex globalized *society*.

Finally, India could establish a paradigm unlikely to be set in any other group of scientists/technologists; where a Gandhiji 'seva' motif is brought into the education and practice of all scientists, engineers and doctors.

1. Arunachalam, S., *Curr. Sci.*, 2005, **89**, 1450; Ganeshaiiah, K. N., *ibid*, 1451–1452; Tiwari, S. C., *ibid*, 1453.
2. Roy, R., Roy, N. R. and Johnson Jr. G. G., *Scientometrics*, 1983, **5**, 117–124.
3. Cardona, M. and Marx, W., George Placzek: a bibliometric study of his scientific production and impact, ARKIV-Physics, 2006.
4. Roy, R., *Phys. Today*, 2005, pp. 12–13.

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