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EDITORIAL

Innocence and Sophistication: Users and Equipment

About twenty years ago, as the era of the tightly controlled economy began to slowly fade away, universities and research laboratories in India were poorly equipped. Major facilities for research were to be found in very few national institutions. Even the best of our laboratories could only boast of equipment which were far from being comparable to that available in most laboratories in the West. Changes have happened rather dramatically in the last fifteen years. Science funding has grown steadily, foreign exchange is not a limiting factor and customs duty exemptions and clearances for publicly funded institutions are available. Most importantly, aspirations amongst a new generation of scientists are significantly higher than those of their predecessors; an inevitable corollary of globalization and liberalization. A host of government schemes now provide grants to equip laboratories in universities and national institutions. Internal funding, in the laboratories supported by large organizations like the Department of Atomic Energy (DAE) and the Council of Scientific and Industrial Research (CSIR), has grown substantially. In the last twenty years, government departments, originally conceived as funding agencies promoting research, have created and acquired institutions of their own, which then receive significant core funding. Both the Department of Science and Technology (DST) and the Department of Biotechnology (DBT) oversee a growing number of dedicated research laboratories, which proudly display state-of-the-art facilities. Once impoverished University science departments are now in the fortunate, but unfamiliar, position of being able to seek support for major equipment from a multiplicity of agencies. New schemes introduced by the University Grants Commission (UGC) are available to equip research laboratories, even in colleges. UGC's new initiatives have been characterized by a departure from the traditionally slow decision making process; an empowered committee cuts through many of the delays in fund disbursement. The drive to infuse more money into research has not always been accompanied by the creation of new administrative and financial mechanisms, both at the funding agencies and the recipient institutions. Grants may be sanctioned and received, but utilization can be a bottleneck as many institutions struggle with non-functional administrative structures. The first instalment of grants is usually received. Subsequent instalments are uncertain, as finance department at institutions and the agencies engage in a war of attrition. The situation is compounded by financial rules written for another day and age. The sudden spurt in the number of grants and grantees strains administrative structures, which were created long ago in a more leisurely era.

A consequence of the rapid increase in funding levels is that India has quickly become an important market for manufacturers of sophisticated scientific equipment. Institutions, old and new, acquire major research facilities with a frequency that was unheard of some years ago. Instrumentation centers and centers of 'excellence', a much abused word, are emerging across the country. Many years ago when a 'sophisticated instruments facility' was set up at the Indian Institute of Science in the late 1970s, it boasted of a single NMR spectrometer operating at 270 MHz. Upgradation and expansion was a very slow and arduous process until the late 1990s. In the 1970s, biochemistry and biology departments used relatively few pieces of major equipment. Even spectrophotometers and refrigerated centrifuges were prized departmental possessions, to be used in a disciplined manner. Ultracentrifuges were looked upon with respect, rotors jealously guarded and users carefully instructed before they were permitted to begin their work. Money was scarce, equipment scarcer and spares and services were difficult to obtain. The revolutions in biology and materials characterization occurred in the late 1970s and throughout the 1980s, leading to an explosion in the range of techniques used to characterize and analyse molecules, materials, cells and tissues. Microscopy suddenly transformed our view of materials and biology. Electron microscopes of ever increasing resolution, with accessories that probe chemical composition raised the bar on materials characterization. Confocal microscopes, exploiting the remarkable power of lasers and the ability of molecular biologists to introduce optical probes into cells, quickly became indispensable tools in cell biology. The human genome project spawned a host of new technologies. DNA sequencing is being achieved in ever shorter times at rapidly falling costs, with a reliability that was hardly anticipated in the days when the genome appeared an almost impossible goal. The 'omics' revolution in biology has been fuelled by the ever increasing resolution and sensitivity of mass spectrometers. It is hard to believe that mass spectrometers capable of analysing biological macromolecules were unavailable in our laboratories even in the late 1990s. In the span of less than a decade Indian institutions, public and private, have become major buyers of mass spectrometers. High performance computing is another area which has exploded, with 'clusters' proliferating in many institutions; a dramatic change from the past when computing was always centralised in the 'computer centre'. Every area of science has seen an explosive growth in the sophisticated tools necessary for modern day research. Unsurprisingly, the many new institutions that are being set up begin with formidable shopping lists for equipment, even as they struggle to recruit competent faculty to exploit the facilities being created. Older institutions replace and upgrade instrumentation with a frequency that was unimaginable a decade ago. Individual laboratories now possess equipment which not too long ago were prized as central facilities. Despite this sudden improvement in the facilities available for research, it is hard to visit an institution without hearing complaints about inadequate supporting infrastructure, which limits efficient utilization of the available equipment. Complaints about uncertain power supply are commonplace. A more disturbing grouse is the absence of trained technicians, with a high level of competence in operating and maintaining facilities.

A great deal of the most sophisticated analytical facilities used today can indeed be directly operated by trained users. Microscopes and spectrometers of all kinds should, in principle, be accessible to direct use by researchers, primarily students, provided they are adequately trained and supervised. In most, if not all, institutions 'operators', with a minimum knowledge of the methods that they use, stand as custodians of sophisticated facilities. Users, who often display a degree of technical innocence that is almost touching, turn to these operators for solutions to problems that occupy their attention. Very often it is a case of the 'blind leading the blind'. Few major facilities in India are staffed by technically competent professionals who can indeed address problems posed by their clients. Most major facilities are sub-optimally used and sophisticated instruments are rarely exploited to their full potential. Senior researchers who preside over large groups of students and assistants generally have a limited 'feel' for the wide range of analytical methods that are required for much of the characterization that is central to modern research in biology and materials science. Ph D students sometimes use a bewildering range of methods in their research, but profess ignorance of the principles behind the techniques used in their studies. Unfamiliarity with instrumentation results in a quick demise of user operated facilities, as a consequence of casual and cavalier treatment of spectrometers, chromatographs and other pieces of relatively widely used equipment. In the better funded institutions and laboratories replacing equipment appears more attractive than resurrecting instruments that have suffered from misuse. Poor training of students in the methods essential for their research is often the root cause of the many mishaps that occur in research laboratories. The failure to solve problems that are amenable, despite the availability of analytical facilities, is a direct result of a lack of appreciation of the intricacies of interpretation. Problem solving in many areas requires both good experiments and careful interpretation.

In thinking about the new problems created by the funding boom, I was drawn to a recent commentary in *Nature* which argues that 'over-reliance on automated tools is hurting science'. In a column entitled 'Understand how it works', the head of Vanderbilt University's core microscopy laboratory emphasizes the 'need to do a better job of teaching students how techniques work before they start using them (Piston, D. W., *Nature*, 2012, **484**, 440). He illustrates the pitfalls that may be encountered in microscopy using automated image analysis. Describing a specific example of a mis-interpretation he concludes: 'In this case it wasn't inspiration that was lacking – it was instruction. The researchers had used a proven and validated tool, but in a way inappropriate for the problem at hand.' Piston voices a concern that research supervisors might do well to heed: 'Unfortunately, this scenario is becoming all too common in many fields of science; researchers, particularly those in training, use commercial or even lab-built automated tools inappropriately because they have never been taught the details about how they work.' He notes correctly that 'the interdisciplinarity of modern biomedical research makes it almost impossible for one person to understand the subtleties of all the procedures on which they rely'. He goes on to argue for creating an instructional programme in training research students which will 'emphasize better the fundamental concepts and practice of experimental techniques. This would necessarily include hand-on-labs involving state-of-the-art equipment and instruction from experts with proven success in using these techniques'. His conclusion, that students must not only be taught 'how to formulate hypotheses, design research approaches and write manuscripts, but also how to build, implement and troubleshoot their experiments', merits the most serious attention.

Indian institutions need to enhance the level of technical competence in their core facilities, examine ways of recognizing and rewarding those who play an important role in sustaining facilities and promoting enlightened usage, and plan on organizing instructional workshops centred around major research equipment. Technical innocence, in an age when experimental facilities are rapidly expanding, may no longer be acceptable.

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