teaching, development work, sponsored funded research, mentoring the research scholars and their placement. Current bias tilts in favour of counting the visible tip and discounting the invisible base. My charge is that journals are not objective players in this mission of researcher performance evaluation; they have a vested interest of plugging their citation indices. My appeal is that the academic community cannot shirk the responsibility of objectively evaluating the effectiveness of teachers/researchers. This job cannot be outsourced to professional journals whose interests lie elsewhere. Let us build and strengthen the foundations; the structure will eventually rise; the flagpoles will follow; the flags will flutter in good time.

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The challenges of building the human resource pipeline in research intensive organizations*

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We are on the threshold of a new era in the history of human civilization, an era dominated and often driven by knowledge. Access to knowledge and an ability to use it for one's own advantage have become more important than access to natural resources and capital. India is one of the few countries in the world that recognized early in its history, the importance of scientific, technological and even managerial knowledge in its development strategies. Some of the premier educational and research institutions in the country and their alumni across the globe are indeed standing testimonies to this conviction. Did this early conviction deliver? There is no doubt that the answer is an emphatic 'yes'. The green revolution that turned a hungry India (ship to mouth existence) into a self-sufficient nation in food, the reverse engineering strategies of the early decades of free India that turned the country from a net importer of bulk drugs into a net exporter, etc. can directly be linked to the newly built capabilities in science, technology and management. The opening up of the Indian economy in the nineties pushed the country into a new phase where Indian scientists, technologists and the industries have to compete globally. Are we geared? Let us look around. There is no doubt that some of our institutions of higher education have demonstrated that they impart education at globally competitive levels and their students are in great demand in the global marketplace. There is no doubt that some of our R&D institutions in areas of high technology like space technology, nuclear technology and defence technologies have demonstrated that they can perform at globally competitive levels under very adverse circumstances. There is no doubt that some of the Indian industries have demonstrated that they can compete globally purely on the basis of quality and price. While the country looks to the future with confidence, can we say with confidence that the educational and the R&D systems in the country are geared to cater to the needs of the coming years? While everyone agrees that science and technology hold the key for the competitive edge in the global market place, one also hears about the poor quality enrolment in some of the traditional science streams in our educational institutions, lack of interest among students for a career in scientific research, shortage of competent scientists in our R&D institutions and our weak ranking in commonly accepted science and technology performance indicators. These will certainly compromise our position in the competitive world in the coming years. But how far are these perceptions realistic?

Let us look at the apparent lack of interest in basic sciences among the young students. India has been participating in the International Mathematics and Science Olympiads open for young students for more than two decades. Not only our students have been doing creditably well year after year but our country is also ranked among the top 10% of all the participating countries. The enthusiastic participation of a large number of students across the country in the national level selection processes and their performance levels in similar national level science events do not indeed suggest any lack of interest in basic sciences among the student community. On the other hand, it is true that many of these students opt for higher studies in streams other than basic sciences. Among the various reasons that have been cited for this large scale exodus out of the science streams, the poor inspirational quality of teaching in majority of our undergraduate educational institutions stands out.

Apart from the poor educational infrastructure such as the library and the laboratory facilities in these institutions, one of the prime reasons for the poor inspirational quality of undergraduate education is the existing disconnect between these institutions and the R&D institutions and the university departments having a research ambience. Consequently, while we see an upsurge of enthusiasm for science among the young students whenever a major scientific or technological event such as the *Chandrayaan* mission takes place in the country or even outside, the enthusiasm is rarely sustained. There have been initiatives in the past to engage the students and the teachers in major scientific activities such as the UPROBE Project (participation of youth in real-time/field observations to benefit education) or the Mapping the Neighbourhood Project by Department of Science and Technology (DST) with very visible impact on students and teachers. Unfortunately, these projects have neither been up-scaled nor sustained.

One should also recognize that a research profession is very much different from many other professions that call for similar education and expertise. First and foremost, research, defined as generation

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of new knowledge is uniquely human. Facilities and equipments are important but they cannot substitute the human brain in research. Consequently, neither is knowledge something that can be quantified easily nor can the research effort to generate new knowledge, the significance of the new research findings themselves, their impact on society, etc. be quantified easily. We all routinely use parameters such as the cost of research, the number of publications, patents, etc. but we also know that all these parameters are subject to large errors of judgment. A research organization has no alternative but to bet on its people, enable them to perform at their best and hope for the best. But, one presumes that the organization inducts the right people into its fold. How does one identify the potential workers, the scientists, at an early age, train them and empower them to perform at their best? Most organizations therefore tend to hire people with proven track record – a Ph D, few years of post-doctoral experience, a portfolio of publications and patents, etc., thus making a research career a late entry proposition. On the other hand, a youngster of today has a much wider range of career options as compared to, let us say, 50 years ago. More importantly, some of these careers offer financial incentives and social visibilities far more than what is offered in a research career. Mature areas of research and technologies while being relevant also lack the glamour of new and emerging areas. It should also be recognized that research by definition is a risky effort. Efforts are as important as successes. One who has never failed has perhaps never tried. Individuals and institutions must be flexible and respond to changes. Life-long learning is a necessity, more so in multidisciplinary environments. A bureaucratic organizational structure as in most of our research institutions is a clear disincentive. Increasing bureaucratization and hierarchical structures in the research organizations also lead to poor recognition of performance and stunt motivation. Lack of discrimination between performers and non-performers is a clear disincentive for the scientists.

Knowledge intensive institutions have also to put in place effective knowledge management strategies. In fact, human resource planning and knowledge management strategies are tightly coupled, their relative emphasis depending only on the state of development of the area of research itself. For example, in the early years of development, the emphasis is clearly on human resource development. While the enthusiasm for the emerging subject may be very high and the student response is very encouraging, the shortage of competent teachers and teaching infrastructure is real. As the area of research matures, not only there is an accumulation of knowledge but also it is spread out across people. It is a challenge to retain knowledge and make it available to the right people, at the right place, at the right time. Human attrition due to death, retirement or resignation is a major challenge to knowledge management. It could seriously disrupt the knowledge chain. Secrecy and information on need-to-know basis are not healthy for research organizations. On the other hand, how does one protect intellectual property (IP) in an open environment? Clearly, effective knowledge management strategies including knowledge protection demand effective human resource planning.

India is one of those few countries in the world who made an early decision to opt for nuclear power for national development and put in place a well-structured human resource development plan. Let me recall Bhabha's letter to the Tata Trust in 1944 – 'when nuclear energy has been successfully applied for power production, in say a couple of decades from now, India will not have to look abroad for its experts but will find them ready at home' – full one year before the world came to know the power of the atom, full three years before India became free from colonial rule, full 10 years before the production of commercial electricity from nuclear energy. What were the salient features of the Bhabha model? Recognizing that trained human resource holds the key for venturing into a new technology domain, Bhabha's first initiative was the establishment of the Tata Institute of Fundamental Research as the cradle of nuclear research in the country. Once the decision to launch a national nuclear programme was made and the Atomic Energy Establishment, Trombay (AEET) came into existence, Bhabha put in place the AEET Training School that imparted pre-induction training in a broad range of nuclear science and technology to all new entrants into the system. The training school has been in existence without a break for more than five decades now and its products have been the backbone of the Indian nuclear programme that has survived the brain drain of the 60s and the 70s, poaching by the industries, the large scale retirements of the first generation professionals in the 90s and beyond and above all the technology denials following the Pokhran I and II nuclear tests. Some of the other unique features of the nuclear establishment were placement in consultation with the scientists, opportunities for further studies, merit-based promotions, and last but not least, some free space for everyone to pursue their special interests in addition to their assigned responsibilities. If today, while the rest of the world is struggling to cope with serious disruptions in the human resource pipeline and knowledge management in the nuclear sector arising out of the anti-nuclear sentiments of the last few decades and the unavoidable renaissance of nuclear power in the coming decades, India is comfortably placed in its three stage nuclear power strategy chartered by Bhabha nearly six decades ago. Although the positive impacts of the strategy have been well recognized, a few negative impacts have also been seen. For example, the near-total dependence on in-house training of its personnel had to some extent stunted the growth of nuclear education in the universities and other educational institutions. A number of steps have also been taken to offset this lacuna. The Board of Research in Nuclear Sciences encourages students and teachers in universities to undertake research in nuclear sciences not only with funding support but also often with technical support from the scientists and technologists in nuclear establishments. The establishment of the Inter-University Consortium for using Department of Atomic Energy (DAE) facilities like the reactors and accelerators, the Inter-University Accelerator Centre, university participation in international mega-science projects along with the DAE scientists, etc. are also efforts to introduce nuclear education at the cutting edge into the university system. India is stepping into the 21st century with major ambitions. The Indian fast reactor programme is surging ahead keeping in mind the country's major stake in thorium utilization. India is also looking into the accelerator driven systems as an alternative to fast reactors. India is also keeping the fusion option open and is a participant in the International Thermonuclear Experimental Reactor (ITER) project. These ambitions obviously call for major initiatives in human resource development at all levels. Simultaneously, the demand for trained personnel in sectors other than nuclear power is also increasing steadily. The increasing career options available for promising young students in areas other than nuclear science and technology is also a matter of increasing concern and calls for innovative out-reach programmes. One of the unintended consequences of the Bhabha model for nuclear education has been the near disconnect between the nuclear establishment and the educational institutions. Very few universities and institutions in the country offer specialized courses on nuclear science and engineering today. Trained manpower in these institutions in these areas has also dwindled substantially. On the other hand, the need for trained human resource in this sector is expected to increase in a big way in the coming years both within and outside the nuclear establishment. The success of the Inter-University Accelerator Centre, New Delhi in the design, fabrication and commissioning of a state-of-art superconducting linear accelerator (LINAC) booster is yet another indicator of the untapped strengths of our educational institutions. The recent initiative of the DAE and DST to encourage participation of the university faculty and students in major international accelerator based research initiatives such as the large hadron collider (LHC), facility for antiproton and ion research (FAIR), ITER, etc. is indeed a recognition that the nuclear establishment must engage the education sector deeply if it has to maintain a robust human resource pipeline. In short, India recognizes that nuclear education in the coming decades calls for very innovative initiatives so that the best of students opt for a career in the nuclear field. The volume and diversity of nuclear knowledge are also increasing steadily and call for new strategies in nuclear knowledge management. The nuclear establishments across the country have taken some unique initiatives in this direction also. The success story of the Indian space programme involves a very similar strategy and owes itself to the very same man. It is somewhat unfortunate that the model is not being emulated by other sectors.

There are a number of R&D institutions in the country that are relatively small in size, with limited budget and a focused mandate. The Bhabha model of human resource management is not suitable for such small organizations. They have very limited recruitment options. More importantly, their limited faculty strength is a sure damper of the intellectual vibrancy of the place. The only way to keep up the intellectual vibrancy is to involve a reasonable number of students in their programmes. Reaching out to the educational institutions, conveying the excitement of research in their area of interest and offering to the students research opportunities in their institutes can bring in good quality students some of whom may be potential employees. Involvement of some of the teachers also in the research programmes can also strengthen the overall knowledge management strategies. The recent effort by some universities and institutions to design and launch microsatellites is indeed worth emulation by other institutions and in other sectors.

Being small in size, a hierarchical staff structure can also be counterproductive. It will certainly help these institutions to de-emphasize hierarchical structures and empower individuals in project implementation. It will also help in streamlining career progression in these institutions. As mentioned earlier, professional recognitions are integral parts of a scientist's career progression. A non-hierarchical structure simplifies professional recognitions. The small institutions also benefit from networking with other institutions having an overlap of interest. In particular, mobility of scientists across such institutions is highly beneficial. Small institutions are highly vulnerable to disruptions of the human resource chain. Horizontal induction at all levels to fill gaps in expertise is unavoidable in these cases. The present recruitment procedures that are tuned to fill-up posts are to be re-structured to fill-up gaps in the knowledge chain.

It is clear that, whether a R&D institution is big or small, an effective human resource pipeline can only be built by engaging other institutions having overlapping mandates, the universities and educational institutions at all levels, that too in a sustained manner. Models of engagement do exist but they are neither in the main mandates of the science ministries nor of the education ministry. This needs to be addressed.

Before I conclude, I will like to touch upon one more aspect related to human resource, namely retirement of scientists at a fixed biological age. It is known that biological age does not decide the capacity to think. They are also major repositories of knowledge accumulated over a life time. At the time of retirement, while they may leave all documented knowledge to their successors, they do carry very valuable intangible knowledge with them. It is said that successes are well documented and disseminated but failures rarely get documented. At the same time, failures are recognized as stepping stones of success and constitute an integral part of the knowledge bank. It therefore makes sense to continue to have access to their knowledge even after their retirement. Why then not re-tyre them and use them productively as researchers and mentors, in consultancy, in human resource training, in preparation of training materials like books, etc.? It is cost-effective to use retired but competent people.

All the mentioned steps call for serious re-examination of our administrative structures. We have been talking about de-bureaucratization of science administration for a long time. Repeated recommendations have emerged from successive science advisory councils. Assurances from successive Prime Ministers have been heard in Science Congress sessions. It is unfortunate that visible follow-ups are yet to be seen.

If India has to achieve its rightful place in the comity of nations in the emerging knowledge society, serious efforts are to be made to recognize the special needs of the research community, re-igig the management strategies and evolve a robust human resource pipeline and knowledge management strategy. Then only, India can gain fully from its present demographic advantage.

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