Reflections on science in service of a symbiotic society

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Gadgil's[1] call for Indian science to rise and contribute towards building a symbiotic society is a step forward to initiate the debate on 'why we are, where we are?'. This questions the basic scientific temperament of Indian educational institutions, which are said to be the reflection of society at large. But, if, educational institutions are buying this argument, then they do not stand the ground to serve as a moral force of change to create a better society of tomorrow, which is the motto of almost all educational institutions. Definitely, a paradox to explore and explain. However, it would be good to contemplate Mahatma Gandhi's view on role of machinery – science and technology – to further discuss this issue. What Gadgil[1] had said about Kumarappa's fear of lop-sided development was discussed by Mahatma Gandhi in his 'Village Swaraj' (village self-rule) on the issue of industrialization and development. On being asked about the role of machinery, Gandhi stated, 'I am aiming, not at eradication of all machinery, but limitation'. Further, he defined this limitation in terms of developing a healthy and moral relation between cities (modern life based on science and technology) and villages. Gandhi states that 'if the city children are to play their part in this great and noble work of social construction, the vocations through which they are to receive their education ought to be directly related to the requirements of the villages'[2]. This line provides a possible space for correcting the defects that have permeated into the Indian educational system, which can be put in terms like production of redundant workforce, poor quality or lack of high quality research, to mention a few. Within the boundaries of educational institutions, continuation of these shortcomings can be explained by two factors. First, the role played by the individuals who are acting as gatekeepers of the educational institutions. And secondly, the very culture that has been built into our educational institutions in order to nurture creativity. Indian institutions produce best and hardworking students who can compete anywhere in the world, but the very same institutions are not able to build a culture that can provide a world-class research environment and produce best of researchers. Why is this so?

For the first issue, we can discuss one probable explanation through the way our society has created the relation between student and teacher in educational institutions. Knowledge is transferred as gospels (the dominant approach in our educational institutions) rather than in question and answer mode; what Freire[3] called dialogue. This dialogue approach has remained as an island, rather than a dominant force to guide students in general in our educational institutions[4]. So, we become good at obeying rather than good at questioning. In this background, it is worth exploring what happens when a questioning mind tries to get space in [Indian] educational institution, whose gatekeepers have always shunned the questioning approach. Unlike American and European educational institutions, which do provide space to questioning mavericks, the Indian institutions either keep them aside or if they come in, the internal structure makes sure that they get isolated and do not disturb the status quo. This happens everywhere, but what makes India different is that we have been dominated by the status quo approach. Over a period, this has created a spiral of comfort zone for the research community which walks at its own administrative pace at usual walking hours of dusk and dawn. Russell[5,6] has eloquently explained how this idleness in public institutions leads to deterioration of creativity and merit over time.

To get a probable explanation for second issue, we have to question the very link that needs to be established among the research communities to address social problems. It is the present status of engagement of the educated elites in understanding the problems faced by India's downtrodden people. Educational institutions by and large do not engage with social issues, while the political and administrative apparatus has its own interest in maintaining this status quo and control[7,8]. Whenever we face any social, economic, technological, health and environmental issues, we as a state/society still have to wait for suggestion/solution/consultancy/support from overseas counterparts. This was also accepted by Gadgil[1] in his editorial. The best example of this insensitive approach and apathy by educational institutions, state, administration and research community is towards poor children (age 0 to 5 years), who are either dying or suffering permanent brain damage from regular annual recurrence of Japanese encephalitis (JE). JE has been occurring for the last three decades in northern India. We can endlessly debate about the role that has to be played by the political establishment, administration and civil society. Dwelling on this only means we – educational institutions – do not want to see our own face in mirror. Still educators and educational institutions want to act as torch-bearers of society, carrying the moral high ground to be followed at large. If this is the approach, I would not hesitate to call this a dangerous path that we are taking. This is where we have to ask – what are we doing, how are we doing, for whom are we doing and are there any other ways to create the culture of dialogue?

The bigger question that needs investigation at present is whether India's present approach to higher education provides a fertile ground and culture for cross-breeding of ideas. Especially, when the institutions of excellence stand in isolation among their own tribes like in science, social science, technology, medicine, management and agriculture, to count a few. And the place – the Indian university system – where all have to get space for interaction, creation and co-creation for learning from each other has been left out. The universities still stand as traditional silos of academic discipline created centuries ago. These silos of the basic foundational courses are so outdated that they barely help students explore the possible avenues for applied research. In addition, when these islands of excellence strive away from university boundaries, young students do not get to know what changes are happening at the frontiers of knowledge. Over the period this has prevented the students from acquiring knowledge and skills required to address the future problems and look across disciplinary boundaries for possible solutions. Recent efforts of the Knowledge Commission to address these issues still have not found any space[9]. The social, political, industrial and economic reality have seen a sea change, but our university establishment has remained brittle, baring few exceptions[8,10]. The culture of creating centres of excellence (for every field outside the ambit of university sphere) is like the formation of a closed glacier lake, which has no connections with the flowing rivers (universities) to turn the barren land fertile. It is high time to question the culture of creating separate islands of excellence outside university boundaries. Bohm and Peat[11] have aptly put this as 'the potential for creativity is natural but that an excessively rigid attachment to fixed "program" in the tacit infrastructure of consciousness is primarily what prevents this creativity from acting'.

There is no dearth of examples (below I share a few) to show that the interface of science and technology with society is not a weak link. Rather, it provides a fertile ground for great changes in theoretical and empirical space of knowledge [re]creation. In addition, this has been done without compromising the ethos of knowledge creation for sake of knowledge and providing valuable practical services to society. In a way, society and science run in tandem to reinforce and push their limits, to the best of their ability and potential. In 1880s, it was the simple zeal of developing an efficient electric bulb that led to the discovery of the quantum and development of quantum science. At that time, the German companies were trying hard to compete with their counterparts from Britain and America, to build better electric bulbs. To be the first in this industrial race of capturing the market and providing an efficient bulb, in 1887 the German government founded Physikalisch-Technische Reichsanstalt – PTR (The Imperial Institute of Physics and Technology)[12,13], on the land donated by the German inventor and industrialist Werner von Siemens. What came with the establishment of PTR and the spin-off it created in developing new frontiers of knowledge is history worth reading. The case of totally preventable anaemia death of mothers at the time of child birth has been hindered by the very nature of technology for blood test, which is costly and requires a skilled hand. However, to question these two established actors – technology and skill – in medical field and providing an alternative requires astute thinking and space which can support this type of work. This is what Myshkin Ingawale (Massachusetts Institute of Technology), the co-founder of Biosense Technologies has done. The device is called 'ToucHb', based on the principle of photoplethysmogram. By simply putting the knob of the machine around the finger, it is now possible to tell the haemoglobin count within 20 sec. ToucHb is simple and durable enough to be carried to any remote location by a village health worker. Another better known example in India is the development of technology for converting buffalo milk to powder, by the team of managers and technical experts headed by Verghese Kurien. In 1950s, when Kurien's team proposed to tweak technology to suit the Indian milk market, experts from all over the world considered it to be impossible[14]. However, Kurien's team developed indigenous technology to change buffalo milk to powder. It is this technology which paved the way for 'white revolution' in India. On the other side, development of science and technology has influenced the domain of social knowledge production. One interesting example of this is the upheaval seen in mid-19th century European Arts. In early days artists were given the responsibility of reproducing replica of chosen objects. However, development of the Kodak camera challenged the artists with easy reproducibility of objects. In response to this technological advancement, artists asserted themselves with alternative, non-representational approach of artistic form. Secondly, the breakthrough in industrial chemistry, the most successful industry in late 19th century, made painting material cheaper. This led to the creation of an entirely new breed of independent painters to express themselves in a creative way, who otherwise had to depend on princely patronage[15].

It is in this background that the role of educational and research institutions becomes crucial to support students who carry out socially relevant cross-disciplinary work. These works often do not get space for publication in high impact journals, as also shared by Gadgil[1]. Nevertheless, the spin-off from these application-oriented explorations does have place to reach a wider audience and change the face of academic disciplines over time[16,17]. This application-oriented cross-disciplinary innovation requires technological change. Historical studies have shown that changes in technology exist as dyad with changes in social, political and economic factors[18,19]. For example, changes in application-oriented technology call for new skill sets linked with educational landscape, which is constrained by economic and political realities of society. In this background the researcher and research institutions have to be sympathetic to the social, cultural and political reality of society. Einstein had once said 'nature is biggest laboratory'. If, we can find any sanity in his words, then India has to be a goldmine for any research tribe and the onus is on us to prove it. This issue of what should be the role of scholars in solving the scientific or philosophical problems is aptly put forwarded by Popper[20] in the following words:

> 'The belief that there is such a thing as physics, or biology, or archaeology, and that these "studies" or "disciplines" are distinguishable by the subject matter which they investigate, appears to me to be a residue from the time when one believed that a theory had to proceed from a definition of its own subject matter. But subject matter, or kinds of things, do not, I hold, constitute a basis for distinguishing disciplines. Disciplines are distinguished partly for historical reasons and reasons of administrative convenience (such as the organization of teaching and of appointments), and partly because the theories which we construct to solve our problems have a tendency to grow into unified systems. But all this classification and distinction is a comparatively unimportant and superficial affair. We are not students of some subject matter but students of problems. And problems may cut right across the borders of any subject matter or discipline.'

To address the requirement of dynamic social environment we are in, our educational institutions have to explore and extend new frontiers of knowledge domain. They have to give priority to build a culture where the basic human instinct of 'questioning' is given primacy; where there is ample space for [re]creation of knowledge with changing time.

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The biotechnology pyramid: basic science to application of science

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Biotechnology is the buzzword in biology, and not without reason. The apparently endless opportunities that biotechnology offers in terms of new products, processes, improved health and comfort[1], as well as job opportunities, are drawing present-day research students, who consider this to be the most important topic of biology. This leads to debates about what research topic would be important and what would not, which Ph D topics are to be selected and which are to be discarded and which laboratories and research supervisors are to be sought after and which are not. There often seems to be some confusion about what actually leads to good biotechnology research, an issue not only with research students but with senior scientists as well. Biotechnology is an important branch of science that aims to benefit human society. However, I would like to argue that high standards in biotechnology research can be achieved by asking 'what is interesting', as much as 'what is important'. While one does not doubt that science has to ultimately resolve societal problems, such ends are not achieved only by focusing on societally relevant issues, thus leading to a catch-22 situation. How does biotechnology work then?

Basic sciences to application: the biotechnology pyramid

Technology rests on a base of science, small or large. A technology emerges when the science is put to use as a product or process for the benefit of the human society, in the form of medicine, food, beverages, chemicals, textiles and others. Technology development is the end result of a process that science undergoes. I will illustrate this with a few of my favourite examples.

The green fluorescent protein (GFP) as well as other fluorescent proteins are now important molecular biology tools, being used as reporter genes in gene expression studies[2,3]. The GFP gene fused to the gene of interest lights up the cells under an epifluorescence microscope when the gene under study is expressed, thus providing important information to the researcher. The story of GFP started in the 1960s with the research interest of Osamu Shimomura on the fluorescence of the jellyfish *Aequorea aequorea*. He spent the next 20 years in basic research that led first to identifying GFP as being responsible for the fluorescence, subsequently purifying it, crystallizing it and characterizing the protein. Then Martin Chalfie successfully cloned and expressed the GFP gene in *Escherichia coli*. In the mid 1990s, Roger Tsien was responsible for developing this technology further for gene expression studies and was deservedly awarded a Nobel Prize in Chemistry in 2008. Tsien's achievement was based solidly on his own enormous expertise in the chemistry of GFP and also the foundation of GFP science that had been laid by then by a few key scientists. Understandably, therefore, Tsien was not the only recipient of the Nobel Prize. Martin Chalfie was the second recipient of the same Prize. It would be easy to state that these two were the biotechnologists who were responsible for the fluorescent protein technology. However, it is not quite so. The entire edifice of GFPs, prior to the work of Chalfie, Tsien and a number of other students and researchers, rested on the science that was built up by Shimomura, who became the third recipient of the Nobel Prize. In the words of Marc Zimmer[4], 'I hope that