Evolving Corporate Education Strategies for Developing Countries:

The Role of Universities

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Chapter 9

Education and Training in Modern Biotechnology in India: Bridging the Academia–Industry Divide

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ABSTRACT

Modern biotechnology made an explosive entry about three decades ago, taking advantage of elegant and ingenious new protocols that promised very precise and highly refined products in every sector of the industry. However, the claims and hype generated were highly disproportionate to ground realities. Two fundamental errors contributed to this situation: a) treating biotechnology as single subject, to be taught from the first degree level itself, when modern biotechnology is a collaborative effort between and among experts of a dozen cognate disciplines, and b) the explosion of teaching shops pretending to impart education, without properly trained faculty and appropriate and adequate laboratory and library facilities, with the acquiescence of university administration and the governments, which created a chasm between the poor manpower generated and sophisticated needs of the industry, with an enormous campus intake compounding the damage. This resulted in an anomalous situation peculiar to India. This chapter examines the problems and possible remedial measures, in order to deliver to the society in times to come, the full benefits of the myriad developments in modern biotechnology.

1. INTRODUCTION

Amidst an array of definitions of biotechnology, a more widely adopted one is '*the use of organisms and/or their products on the large industrial scale to provide goods and services*' to the society, in the agricultural, medical, environmental and industrial fields (Kameswara Rao, 2000). Biotechnology in itself is over six millennia old with numerous and diverse uses of organisms or their products in every sphere of human life, more importantly food and medicine. Till the late 1980s biotech-

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nology has handsomely served us providing with continuously improved products. The industry drew from the innovations from the contributions of the academic and research institutions in the public sector all the time, not overly complaining about the gap between the academic training and industry's needs. This phase can be identified as 'classical biotechnology' (CBT) (Kameswara Rao, 2010a). The current phase that emerged during the 1990s uses new elegant, ingenious, sophisticated, complex and but more precise modern methods of genetic engineering for product development, biosecurity evaluation[1] and deployment, and provides an unprecedented diversity of goods and services. This phase constitutes 'modern biotechnology' (MBT) (Kameswara Rao, 2010a), which is only a small fraction of today's biotechnology industry, which is still dominated by CBT.

The application of a broad definition of biotechnology blurred the difference between CBT and MBT which is rooted in the protocols used, and this paved the way for a band wagon of players, immensely more from CBT than MBT. While the focus and benefits from the governments are rightly aimed at promoting MBT, the vast number of players in CBT hijacked the agenda and resources.

MBT's explosive entry nearly three decades ago, over-ignited the imagination of the governments, industry and the public as well. The Government of India (GoI) established the Department of Biotechnology (DBT) in 1985, almost the first such government department in the world. The industry rushed to taking advantage of ingenious new protocols that delivered refined products, in the hope of unprecedented business opportunities. The public, parents and students erroneously drew a parallel with the already booming Information Technology (IT) 'revolution' that gave India a prominent international presence and the hope of unlimited opportunities for high paying jobs and overall development from MBT as realized from the IT.

The superscripted numbers refer to the Explanatory Notes given at the end of the chapter to help those readers who are not familiar with biotechnology and related issues.

Benefitting from MBT needs competent teachers and infrastructure to produce adequate numbers of appropriately trained manpower to suit the diverse needs of the educational institutions, research and industrial establishments. MBT also requires precise and elaborate planning, enormous financial and time inputs, and purposeful and efficient management practices, to reach the goals and to realize the hope.

In the 1990s the University Grants Commission (UGC) supported vocational under graduate (UG) courses in MBT in selected institutions throughout India. The successful candidates were expected to go into business, but failing that they came back for post-graduate (PG) education, a fundamental right that could not be denied, but which defeated the purpose of a vocational program. A number of Universities and colleges soon caught up and started both UG and PG courses in MBT, some of them being supported by the DBT. Over time the DBT has also introduced several schemes to promote research, entrepreneurship, business partnering, etc., in different areas of MBT, as detailed on DBT's website. The GoI extended several benefits to encourage the MBT industry while the governments of most States have ended up in permitting a large number of glamorous teaching shops, though a few States have constituted Vision Groups and such other bodies to promote MBT.

The private educational institutions saw a great opportunity to commercialize biotech education which resulted in an explosion of colleges particularly in the private sector, pretending to impart education at enormous financial and emotional costs to students, without properly trained faculty and appropriate and adequate laboratory and library facilities, with the acquiescence of university administration and/or the government.

Though huge donations and exorbitant fees were charged, barring a few honorable exceptions, the institutions did not shoulder their responsibility of providing qualified teaching staff, well equipped laboratories and library, other infrastructural facilities, and more importantly day-to-day running expenses. The net result of over two decades of hectic activity in MBT is a chasm between the poorly trained manpower generated and sophisticated needs of the industry, with an enormous campus intake compounding the damage. We have thousands of UG, PG and doctoral candidates with the stamp of MBT, but no expertise or skills needed either for teaching, research or the industry. Three decades of effort and enormous financial inputs have not seen even a single indigenously designed and developed product in the market. We have not even conscious of the mistakes we have committed, let alone implementing remedial measures.

Though there are a few marketed MBT products largely based on imported technology, the hype created overshadowed the huge mismatch of aspirations, abilities and opportunities, which has hurt almost all stakeholders in a couple of decades. Students, their parents, educational institutions, government, and industrial establishments, all have their share in this misadventure. The importance of education in MBT was rightly recognized, but the academic institutions treated the issue as a business opportunity. MBT probably caused more business for the educational institutions than for the industry. The situation was worsened by the unprecedented opposition to the new technology from the political and other vested interests that hindered entrepreneur and employment opportunities which can accrue only from encouragement from the governments and acceptance of the technology by the society.

The state of biotechnology education in India was reviewed in detail (Kameswara Rao, 2005), but this was largely ignored by all the concerned. Lakhotia (2008) discussed diverse issues and questioned the relevance of biotechnology degree courses. Narasimha Rao (2009) examined the situation of biotechnology education and training and suggested the adoption of tertiary education models, such as open distance learning, internet, virtual Universities, franchise Universities, academic brokering, collaboration of Universities, consortiums and clusters and University outreach programs. While these suggestions are novel and quite useful, the paper did not focus on the peculiar Indian situation. Besides, even in district centers, adequate facilities for tertiary education models, which would involve heavy financial inputs and expertise, are largely absent.

The immediate need for India is to take stock of the situation and put in place appropriate remedial measures, which is no mean task.

2. STATE OF EDUCATION IN MODERN BIOTECHNOLOGY

Basing on the inputs from students and teachers of biotechnology at a focused workshop, Kameswara Rao (2005) reviewed the state of biotechnology education and training in detail, pointing out the inappropriate conceptualization and imperfect execution of both the UG and PG courses, and the lack of opportunities for hands-on experience and post-degree training. Instead of remedying the deficiencies pointed out in the review to improve the situation, both the teachers and the managements of colleges were enraged. The following are the more serious constraints that stymied the development of MBT education and training in India:

MBT is rooted in several different protocols, more particularly genetic engineering (GE), such as recombinant (rDNA or transgenic) technology[2], cisgenics[2], gene silencing[3],, and others. The development of a product involves several protocols. For example, Golden Rice with transgenes (genes introduced from another organism) to synthesize β-carotene in the grain involved 71 patented protocols from about a dozen institutions and over 30 scientists. What was ignored is that MBT is essentially a collaborative effort from diverse experts such as botanists, zoologists, breeders, pathologists, entomologists, physiologists, agronomists, microbiologists, biochemists, molecular biologists, geneticists, pharmaceutical scientists, nutritionists, software engineers, and regulatory and legal experts. All these experts are integral contributors from the genesis of ideas to product development to regulatory evaluation to commercialization. The needs of agricultural, medical, environmental and industrial technologies are different and specific, though with a baseline overlap.

Over reach by some people with elementary exposure to areas biological sciences, such as basic training in tissue culture, a tool often indispensible in genetic engineering but which does not in itself constitute MBT itself, or those who have extracted DNA from tissues, led to making implausible claims to expertise in MBT.

Application of complex algorithms to analyze genomes[4] and other cell components opened up the area of bioinformatics, an extension of IT, which is an essential tool in analyzing, recombining, predicting *in silico*[5] and designing new products based on new gene technologies. The major utility of bioinformatics is in data mining and in the '-omic' series[6] of analysis such as genomics, proteomics, glycomics, metabolomics, transcriptomics and others, which contribute to more precise analysis, designing of new products and to establish substantial equivalence[7] between isogenics and their GE variants. Bioinformatics, an indispensible tool though, cannot be operative without enormous amounts of diverse basic biological data that often need to be generated contextually. Many run of the mill computer shops offer training in bioinformatics, based on free trial software that stops short of the essentials of effective training.

Products of MBT are subject to a severe regulatory regime[8] to ensure biosafety and environmental safety of the processes and products, which has now become a contentious issue. MBT has also brought to the forefront controversial and legal issues such as Intellectual Property Rights (IPR). An agribiotech crop requires about US$ 136 million and takes about 12 to 15 years, from the idea to commercialization (James, 2011), and this estimate applies equally well to the products in the other streams. The financial and time costs of the regulatory regime are often more than the costs of development of a prototype product.

Since several experts in diverse areas contribute to the development of products in MBT, and as none can function in isolation, MBT research teams are often comprised of over two dozen scientists of diverse expertise. In the context of teaching and research in MBT, a department/institution of biotechnology constituted of experts in different areas is understandable but not any single teacher/scientist claiming to be a biotechnologist *per se*. Treating MBT as a single course subject to be taught from the first degree level itself, not as a collaborative effort among competent teachers from diverse disciplines, was the most serious error that hampered MBT education and training.

The second major issue of mismanagement is the enormous intake flouting all norms in place for science subjects for decades. The clamor to make money in the name of MBT education led to mushrooming of private institutions offering UG and PG courses in MBT at enormous costs to the students. The Bangalore University alone has an annual intake capacity of 3,000 students in UG and 2000 in PG courses and added some 2,500 biotech seats out of 80,000 engineering seats in Karnataka, with a fair share for the Bangalore University area. The lecture classes have over 100 students, with over 40 students in the practical batches, not conducive to science teaching that needs individual attention to the students.

2.7. The multiple streams of courses supported by the UGC, DBT, All India Council for Technical Education (B.E., in MBT), run by Central, State and Deemed Universities and Autonomous Colleges, eroded parity in course content and teaching standards, which are essential for quality teaching and mobility of students from one institution/ State/University to another.

In IT, if a department acquired a set of computers and software it serves teaching purposes for several years. In MBT, besides expensive instrumentation, heavy financial inputs are continuously needed as each UG practical class costs around Rs. 3,000 and a PG practical class about Rs. 5,000. With the managements, including those of the Universities, being reluctant to provide these inputs, practical experience is largely nominal, affecting the student's competence and employability.

Initially, when the MBT departments were started, depending upon their influence with the management, either the botany or the zoology departments became biotechnology departments overnight, the same teachers teaching all areas of MBT. This practice was inevitable in the first few formative years, but continued all along. Only in a few institutions teachers qualified to teach genetics, microbiology, biochemistry or other subjects, are also involved.

An impressive curriculum and syllabus[9] largely taken from the internet, claimed to be international were in place, but without a reasonable uniformity among the institutions. Since the teachers themselves had no exposure to the subjects they teach, translating the syllabus into knowledge was seriously affected in most of the institutions.

In many institutions including Universities, courses in MBT and other attractive areas such a molecular biology, are 'self-financed'[10] (by students). The courses are mostly run by 'guest faculty'[11], many of who teach in several institutions during the day. Almost everywhere, the deplorable practice of private coaching shops has taken ground, which do not help the students much, since the same teachers who teach in the institutions also run these tuition classes charging heavily. This situation was worsened by the numerous bazaar guides, often called text books and question banks, written by the same inadequate teachers.

There is no academic or performance audit of biotech departments. The inspection committees of the Universities themselves are suspect as most of them have approved introduction of courses or increase of intake year after year, when there are serious grounds for rejecting such applications. Even when the committees rejected proposals, the managements got what they wanted, with the connivance of the University administration and/ or the Government. The once in five year exercise of the National Assessment and Accreditation Council (NAAC) of rating the Universities and colleges is of no consequence to MBT teaching, as whole institutions are rated by NAAC, not even the departments, let alone the courses. The annual exercise of the Biospectrum magazine of ranking biotech institutions in the country often gave dismaying rankings. In a survey that includes biotech departments of both well established universities and moffusil colleges, naturally the former will stand out.

Education and training offered in MBT by most of the formal institutions is inappropriate and inadequate to serve the needs of the industry. Some courses/departments supported by the UGC and the DBT are marginally better, but acquired an air of pseudo-superiority. This does not mean that there are no competent institutions in MBT or its cognate areas, but that no single Indian teaching, training or research institution can claim to be of world class. In the recent QS World University Rankings released in September 2012 (QSWUR, 2012), the best of the Indian institutions (Indian Institute of Technology, Delhi) is found at the 212th position, although some Indian institutions may be rated higher in some specialized areas. All our institutions need to put their house in order to be globally competitive and to serve the needs of the industry and the country. In consequence of all these factors, barring a few honorable exceptions, the system became so suspect that leading biotech companies inserted riders in advertisements that candidates from particular Universities need not apply.

The other issue that seriously threatens the future of educational standards in India is related to the competence of 15 year-old students in elementary schools in mathematics and science. The Programme for International Student Assessment (PISA) is a program of the Organization for Economic Cooperation and Development, Paris (OECD), conducted by The Australian Council for Educational Research (ACER). In December 2011 the ACER released the PISA 2009+ report covering 74 countries from 10 economies (ACER, 2011).

The Government of India accepted to participate in PISA, but at the end only Tamil Nadu and Himachal Pradesh were in it. Students from both the States are at the bottom of the list of the 74 countries assessed. There are no reasons to believe that the other Indian States are much better than these two. If the school education in the country is not tightened India's global standing in higher education is bound to suffer.

Another serious consequence of the clamor for MBT education is that it has severely curtailed intake into the basic sciences of botany and zoology at both UG and PG levels. Over enthusiasm for saleable science led to such ill advised combinations as biotechnology, microbiology and genetics, at the UG level, ignoring the huge overlap of these subject areas, that gives an unfair advantage to the students over those of the other combinations. More damaging to the knowledge base of the students of this combination is the absence of chemistry from the course. Over specialization at the UG level forecloses options for the students early. They are better off with basic biological science subjects along with chemistry at the UG which provides them a choice for any biological science subject at the PG level and later on. With proficiency in any of the component areas, one can get into MBT at any time in the career.

The governments of several States have not recognized candidates with M.Sc., degree in biotechnology as qualified to teach courses in basic biological sciences. So those biotechnology PG candidates who could not get jobs to teach biotechnology or in the industry, are now doing PG courses in botany, zoology or microbiology, in the hope of enhancing their job opportunities. BE graduates in biotechnology are better off as about 40 per cent of them have been absorbed by the software industry (Suresh, 2012). Biotechnology does not seem to be a part of campus recruitment even in the engineering colleges, putting the candidates at a disadvantage.

Conscious of this disturbing situation, the Foundation for Biotechnology Awareness and Education, Bangalore (FBAE), appealed to various authorities throughout the country for years, to improve the situation, but to no avail. The FBAE worked with the DBT for a National Council for Biotechnology Education and Training (NCBET), on the lines of the All India Council for Technical Education, the Medical Council of India and other such national statutory bodies. The proposal for the NCBET to formulate model UG and PG curricula in life sciences and in translational science keeping in view the future needs, was included in the 11th Five Year Plan report on Science and Technology (Government of India, 2006, p 149), but nothing further seems to have happened in this regard.

3. POST-DEGREE TRAINING IN MBT

Even in the best of times, a raw PG candidate is hardly employable by the industry. The employability of a candidate would certainly be enhanced with some hands on experience in the industry, during and after formal education. In the vocational UG courses of the UGC, a short period of mandatory training in the industry was included and the industry enthusiastically provided facilities in the initial years. With intake exploding, the industry could not entertain the vast numbers of UG and then the PG students seeking training, though some companies still provide training opportunities. Many institutions silently dropped the provision of practical training, without changing regulations first. Presently, co-curricular training is hardly the norm. Nevertheless, there are several institutions offering post-degree training courses in MBT, barely any one of them satisfactory, since the candidates are not assured of recognition, as these are outside the formal system. A few examples illustrate the general pattern:

1. Institute of Bioinformatics and Applied Biotechnology, Bangalore, offers post-degree diploma courses and training in bioinformatics and biotechnology, as well as in entrepreneurship. IBAB also offers M.Sc., degree courses recognized by the Indira Gandhi National Open University and PG degree and Ph.D., programs recognized by the University of Manipal. Supported by the State Government and recognized as a centre of excellence by the Department of Information Technology, GoI, IBAB is projected as a premier institution of its kind. The opportunities IBAB can provide for hands on practical training, after biotechnology degree courses at other institutions, are very limited.
2. The Biotech Industrial Training Program is being run by the Biotech Consortium India Limited (BCIL), New Delhi, on behalf of the DBT for over 15 years. BCIL is only a facilitator between the trainees and training institutions, and not an institution itself. The program is expected to provide ‘an opportunity to biotech industry for training and selecting suitable manpower’. The industry’s response to this program does not seem to be all that encouraging, as the industry needs are more focused than what is offered and the recruits have to be retrained to fulfill the needs of different streams of MBT industry.
3. SHRM Biotechnologies Pvt., Ltd., Kolkata, recognized by the DBT, offers training in 10 diverse areas, which are no different from those in the curriculum/syllabus of the formal degree courses.
4. Ten BT Finishing Schools are proposed by the Government of Karnataka, selected by the Association of Biotechnology Led Enterprises (ABLE), Bangalore, and the Karnataka Biotech Vision Group, constituted by the State Government. These schools require both ABLE’s recognition and accreditation from a recognized University. It is not clear why the former is needed when the latter is available. The proposal, which lacks in clarity and in the end may suffer from lack of credibility, is being widely promoted.
5. Bhat Bio-tech India (P) Ltd., Bangalore, offers training courses and projects to students in diverse, but very basic areas of MBT, which are covered under formal education system. This is a good effort by a company to utilize instrument idling time. Unless recognized under the formal system such courses deny the candidates recognition and credibility.

It would enhance their competence if the teachers of biotechnology also undergo such training. A training program started by one of us (SRA) under certification by the Wageningen University did not survive for long, as both the managements of educational institutions and the teachers were reluctant to bear the moderate participatory costs of this program.

Efforts to put in place efficient and appropriate training programs will bear fruit only if the administrative and academic management of the training institution takes up an active involved role in formulating the program and in carrying it out diligently. One such example is the Keck Graduate Institute of Applied Life Sciences, Claremont, USA, (Schuster, 2012), where about 75 members of the Board of Trustees and the Advisory Council are actively involved in different phases of the program.

4. NEEDS OF THE MBT INDUSTRY

The biotech industry needs to draw a position paper on its requirements from the educational system and on what it can do to enhance training opportunities. A proforma, suggested by Dr Shyam Suryanarayanan of ABLE (personal communication), to gather information on the industry's needs is given in Annexure I. This information will help in designing courses and training programs in different streams of MBT, which will be more purposeful because of the active participation of the industry.

5. CARRYING CAPACITY OF DIFFERENT STREAMS OF MBT

The 'carrying capacity' of an industry depends upon the quality of appropriate education and training, technological competence of the personnel employed by the industry, and the resources it has to meet with the developmental challenges, but is limited by the need and demand for products in the long term, both within the country and outside. State-of-the-art technological competence and enhanced financial and material inputs and effective management practices are all essential to enlarge the carrying capacity. Expansion of the carrying capacity is possible only when all the component factors are favorable.

Numerous reports that frequently appear indicate that biotechnology has an immense indigenous and export market potential. This is at the heart of the clamor of everyone to get into MBT, but only resulted in an enormous hype.

The blanket application of the term 'biotech industry' is misleading since it does not distinguish between the classical and modern biotechnologies. Currently biotech industry is a bandwagon pining for the incentives and concessions offered by the governments to encourage MBT. If the MBT industry has been doing as well as it is projected, it has been doing so with the existing expertise and manpower, and so its need for new contingents of skilled personnel is rather limited. It was estimated that biotech industry recruits about 4,000 freshers every year, while the national output is close to 20,000 (Suresh, 2012). While we believe that this estimate of output is fairly low, the recruitment volume is an indicator of the carrying capacity of the industry.

Girl students constitute over 60 per cent of biotech enrolment, but the majority of them opt out of a career in preference to 'home engineering' mostly under family compulsions, thus considerably reducing the pressure on the job market.

In India, agriculture and pharmaceutical sectors are more visible than industrial and environmental sectors. Of about 40 companies in agricultural biotechnology, only five or six are involved in R & D. Even these are functioning using imported gene constructs and the rest are 'back crossing artists' who use sub-licensed gene constructs and protocols to genetically transform their own varieties. In the pharmaceutical sector, not even 10 per cent of the companies are into R & D that involves modern genetic engineering protocols. Most function on the basis of imported gene constructs and protocols or age old technologies. Basically the industry's potential for innovation and product development is fairly low, but the pretentions are very high. After three decades and a lot of expenditure, there is not even a single indigenously designed and developed MBT product on the market. Such a situation indicates that importing technology is both economical and time saving in the long run. This does not mean that innovation and product development are beyond the public and private sector scientists and industry. The private biotech industry actually has more competent scientific force and infrastructural facilities, than most of the public sector establishments.

By and large, it appears that the carrying capacity of the Indian MBT industry is a matter for concern. Nevertheless, a whole lot of effort in every aspect of producing competent scientific workforce to promote industrial R & D in MBT is urgently needed to cater to the future needs. The current political climate, with an over powering anti-tech activism that politicizes scientific decisions on clinical trials, field trials and commercialization, does not augur well for MBT. The industry needs to play an active role to change this situation, but the industry has not shown itself to be a serious player, surviving on false promises and wishing the problems away. So long as this situation remains, no amount of effort and expense to improve on education, training and competence will bear results.

6. INNOVATION, ENTREPRENEURSHIP, AND MANAGEMENT

Innovation cannot be taught but case studies of technological innovation such as the transgenic technology[2], gene silencing[3], gene stacking[12],, etc., or product innovation such as human insulin produced by transgenic *E. coli* and Golden Rice with transgenes for β-carotene, and others, serve as illustrative examples and role models

The process of innovation requires an evaluation of the current situation and vision to identify the more pressing problems of the society, to design appropriate scientific solutions using improved protocols to develop better products. Innovation is what everyone clamors for but only very few can realize it.

Rwigema and Venter (2004) defined entrepreneurship as the ‘process of conceptualizing, organizing, launching and through innovation, nurturing business opportunity into a potentially high growth venture in a complex, unstable environment’. The creation of new business activities is a major driver in the economy and greatly influences economic growth, job creation and general prosperity (Nicolaides, 2011). To an extent, this enhances the national competitiveness in the global business arena. Nicolaides (2011) reviewed these issues in the context of South Africa, many of which are equally relevant to the Indian situation.

Entrepreneurship too cannot be taught, but can only be guided by molding the thought process to identify opportunities and to strive to take them to fruition. There are a handful of successful MBT companies to serve as role models in India, but by and large Indian situation does not seem to be conducive to promote entrepreneurship. The Indian academia, industry and the government need to review the position to identify negative factors and influences, to remedy the situation, and this requires an enormous effort and serious commitment on the part of all the players. The DBT has launched several programs to encourage entrepreneurial activity, but without man power with appropriate scientific and technical competence, this is putting the cart before the horse.

A successful entrepreneurship essentially needs top-notch education and training (Nicolaides, 2011), the absence of which is a serious constraint to industrial expansion. The Indian ‘revolution’ in MBT education and training failed to deliver. Since the formal educational system can no longer provide for a lifelong career, we essentially and urgently need other interventions to improve the situation.

Several websites such as the Biotech Boulevard of Genetic Engineering and Biotech News magazine (GEN, August, 2012) publicize new biotech firms developing breakthrough products around the world, which should serve as sources of inspiration.

Management skills are essential at different stages of MBT, from the genesis of an idea, through development, regulation and commercialization. A single management package for all the streams of MBT does not work. The need for different models for different streams/technologies was highlighted in the context of algal biotechnologies (Narasimha Rao *et al.*, 2012).

7. PUBLIC AND PRIVATE PARTNERSHIP IN MBT

The private sector has been playing a very crucial role in MBT throughout the world. The successes in agricultural and pharmaceutical MBT, such as bacterial human insulin, hybrids of *Bt* cotton and *Bt* brinjal, came from the private sector. If *Bt* cotton were not introduced a decade ago by the private sector, India would not have had even a single commercialized agribiotech crop even today. Development of *Bt* brinjal varieties and Golden Rice in the public sector institutions in India was made possible through international cooperation by way of cost free transfer of technology developed in the private sector. Unfortunately, by and large, the public sector failed to deliver.

It is widely believed that a PPP would greatly help Indian MBT. Varieties of *Bt* brinjal and Golden Rice are both languishing to see the light of the day due to inept handling by the government and public sector establishments (Kameswara Rao, 2010b). If the past experience from these products is an indicator, there is little scope for PPP, which would work only when both the partners contribute adequately in terms of expertise, infrastructural facilities, time and financial inputs. The private sector, particularly the MNCs, have the state-of-the-art technological infrastructure, very competent scientific force, financial strength, sense of time, a determination to produce, and a fiscal responsibility, while the public sector largely lacks in most of these important pre-requisites for success. For PPP to be productive and benefit the private sector partner as well and just not draw from it, a lot of committed effort is needed on the part of the government and Indian public sector scientific institutions. The current political climate and attitudes in India are not conducive to successful PPP. This has a serious bearing on opening up new entrepreneurship opportunities and product development, both needing appropriate education and training.

8. CONCLUSION AND RECOMMENDATIONS

India is now a decade behind the rest of the world in deriving benefits from MBT. There is evidently an infrastructure and management crisis in education and training in MBT which endangers future growth in terms of manpower generation, industrial development and services, which need to be addressed without further delay. The following conclusions and recommendations are expected to largely remedy the situation:

The UG course in MBT should be discontinued, encouraging UG courses with botany or zoology with microbiology and chemistry. These combinations provide an adequate background in genetics, molecular biology and biochemistry, preparing the candidates for PG courses in MBT. Lakhotia (2008) also suggested that all school and UG stand-alone programs in biotechnology and bioinformatics should be stopped.

The current PG programs in a great majority of institutions are only glorified UG programs. It is necessary to realize that the PG programs are essentially specialist in nature and large numbers of institutions and huge intake in each will only undermine the quality. The PG courses in MBT should be restricted to a dozen institutions in each State.

Discontinuing UG courses and reducing intake into PG courses would not be difficult as in the face of lean job opportunities, enrolment into biotech courses already started declining during the past four or five years. There was a drop of about 11 per cent in enrolment, bringing down revenue of the educational institutions to Rs. 1,020 crore last year from Rs. 1,150 crore earlier (Suresh, 2012). This should worry only the private educational institutions which have milked the system for over one and a half decades.

Encourage PG courses in botany, zoology, microbiology, genetics and biochemistry. Lakhotia (2008) also suggested the revival of PG programs in biotechnology related disciplines and to make them integrative, to provide a more holistic biology education that stimulates the students to ask deeper questions.

The Universities and other management bodies under whose aegis educational institutions function should draw lists of mandatory equipment and library books to be provided by the institutions for each course.

Several institutions offering courses in biological sciences in a particular city/town should be networked to share teaching and training facilities in diverse areas, avoiding duplication and/or wastage of resources.

Although thousands of management graduates are turned out each year, some with a focus on biotechnology, post-degree training in management of all aspects of MBT is important to serve the needs of the diverse streams of the industry.

Entrepreneurship and management skills, for which an appropriate technological background is needed, should be a part of post-degree training programs to introduce awareness of the issues.

The curriculum and syllabus for PG courses should be drawn in consultation with the industry. As we are now uncertain of the industry's requirements, data need to be gathered as detailed in Annexure I.

Separate academic, infrastructural and performance audit, both in-house and by external agencies, is essential for all the educational institutions and training centers in MBT. The audit reports should be placed in the public domain so that the students and parents would be aware of the preferable institutions.

It is very important that an independent statutory body, such as the National Council for Biotechnology Education and Training (NCBET), which the DBT has already recommended to the government, is put in place to monitor and regulate biotechnology education and training.

A perennial complaint is the serious lack of linguistic and communication skills, more particularly when the candidates had their schooling in regional languages. It is also essential to inculcate a culture of communication, in which the country as a whole is deficient. An auxiliary course to fill this lacuna, along with the training courses, is a desideratum. An internet and computer based student specific off–the-class teaching program in communication will go a long way.

Multi-location e-learning classes could compensate for the short comings of the educational system, but computer and internet facilities need to be greatly enhanced. While e-learning is beneficial in a way, teaching science subjects particularly MBT, without personal interaction between the teachers and the taught, has its own shortcomings. It is necessary that the degree programs are well resourced and made strong to produce measurable results for the industry, before expanding online programs.

Instrumentation, computer and internet facilities are now suboptimal even in district centers. There is a great need for several central instrumentation centers in each State to provide training in instrumentation, to support project work and to provide paid facilities for research, so that work can be outsourced instead of duplicating expensive facilities whose optimal use is rarely achieved. An inventory of instrumentation facilities now available in various institutions is needed in order to put them to an efficient use and plan new instrumentation centers.

The industry should provide facilities for short co-curricular training in the PG courses.

Well structured and organized post-degree training programs are needed and these should be recognized under the formal system in the interests of the candidates. The following are some notable examples in this regard:

1. The Michigan State University and Iowa State University (USA) conduct one to two-week training programs in different aspects of agricultural biotechnology and related areas, such as biosafety[1], food safety, mo-

lecular plant breeding[13], agroecology[14] and Integrated Pest Management[15], biofuels[16] and bioenergy[17,], and science and technology of communication.

2. The Institute of Plant Biotechnology, Ghent University, Ghent, Belgium, offers specialized summer courses in agricultural biotechnology.
3. The Keck Graduate Institute of Applied Life Sciences, Claremont, USA, offers not only training programs, but also a post-doctoral professional Masters degree program (PPM) in bioscience management designed to educate in soft and hard skills needed in industry (Schuster, 2012).

Such courses in all streams of MBT would go a long way in bridging the gap between academic and practical training and the industry's needs. The need for technology/stream based approach was highlighted by Narasimha Rao *et al.*, (2012) in the context of algal biotechnologies.

The post-degree training programs should be run by the national research institutions such as the Indian Agricultural Research Institute, Indian Institute of Agricultural Biotechnology, the National Institute of Pharmaceutical Education and Research, Universities or other recognized centers, to ensure standards, credibility and recognition. Funding the institutions and financially supporting deserving participants is a critical issue.

The industry's contribution to improving education and training is the not so apparent component of corporate social responsibility (CRS). Credible and visible CRS programs which directly benefit communities would soften the negative public sentiment against the corporate sector.

Technology and products are developed for public use. Without public confidence in the efficacy, safety and benefits of the products to the farmers and consumers, all efforts will go a waste and the agenda would be hijacked by the activists. Though the Universities can play a role in reaching out to the society on promising technologies like algal biotechnology (Narasimha Rao *et al.,* 2012), it is for the industry and the governments to be more visible and responsible players in public outreach.

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ENDNOTES

1. Biosecurity evaluation involves assessing the safety of the new products, in addition to their projected efficacy, for a) safety in consumption as food, feed and medicine, b) safety to the environment such as non-target organisms (bees, butterflies, birds, predatory organisms, etc.), and c) safety of water and soil, for which every country, including India, has a mandatory regulatory regime (see No. 8, below).
2. Recombinant (r-DNA) or transgenic technology involves the insertion of genes from any organism into the genome (see No. 4, below) of any other organism, which was not possible earlier on account of serious genetic differences between the two organisms. Transgenic technology made it possible to insert genes for human insulin into bacteria so that the new transgenic bacteria synthesize human insulin, which is far more efficient and safer than the earlier products where insulin was extracted from cow and/or pig pancreas for injection into the human body. On account of genetic differences between the human and bovine or porcine insulin biosynthetic systems, there are frequent complications. *Bt* cotton, *Bt* corn and *Bt* brinjal are examples of transgenics developed for pest tolerance using pesticidal genes from the universally occurring soil bacterium *Bacillus thuringiensis.* Golden Rice contains genes for β-carotene which is used by our bodies to synthesize vitamin A, an ingenious means of ameliorating vitamin A deficiency which is a serious problem, more particularly in children.
   Cisgenics differ from transgenics in that the former are developed by transferring genes from a genetically related organism, such as a variety of particular crop and so are less controversial.

3. A gene is expressing when it facilitates the synthesis one of several thousands of proteins in organisms. Gene silencing involves the suppression of expression of selected genes and is a useful tool in preventing the expression of undesirable traits. Coffee without caffeine and a 'tearless' onion which does not synthesize the chemical compounds that cause the eyes to water while chopping onions, are some examples of products developed through gene silencing.

4. Deoxyribonucleic acid (DNA) is the genetic material in most organisms, and ribonucleic acid (RNA) in some viruses. Specific sequences of the components of DNA and RNA, called nucleotides, constitute and function as the genes. DNA is packaged in the chromosomes. Most organisms have two sets of genes in two identical sets of chromosomes. The genome is one set of the sum total of all nucleotides in specific sequences and so all genes, of an organism at the species level, and includes genes from all varieties of that species. The genomes in terms of a) sequence and the total number of nucleotides in the genetic material, b) the number of genes and c) the number of chromosomes, vary from organism to organism. The genomes of a number of organisms including man have been unraveled through very complex and expensive protocols. The physical size of the organism or a higher status in the evolutionary scale, is not an indication of the number of genes. The tiny water flea (*Daphnia pulex*) has the largest number of genes (31,000) so far known in any organism. Some examples of known genomes are: man (23,000 genes), mouse (23,000), dog (19,300), chicken (16.736), grapes (30,450), yeast (6,000) and the common intestinal bacterium *Escherichia coli* (3,200). Usually, related species, and sometimes even unrelated species (such as humans and their intestinal parasites), share the same genes on account of similar biological processes and/or evolutionary relationships. Genome data are a very important tool in MBT, helping the choice of genes for developing novel products.

5. Biological investigations are conventionally conducted both outside the living systems in the laboratory glassware (*in vitro)* and/or in the living systems (*in vivo)*. This involves a lot of time and money before a product design is finalized, often with high failure rates. The availability of extensive biological data and bioinformatic packages makes it now possible to conduct a lot of product design work using computers simulating living models, with high predictive value. Operations performed through computer simulation are described as '*in silico',* in reference to the silicon chips (crystals of silicon semiconductors designed to carry out electronic functions) in computer integrated circuits. This approach saves a very considerable amount of time and money during product designing, more particularly in drug design.

6. The use of the suffix '*-omics'* to denote areas of study is not new (e.g. Economics), but in recent times bioinformatics and molecular biology have adopted it for a wide range of analytical methods. Some common examples are, a) Genomics (the study of genomes, with several subareas such as cognitive, comparative, functional, personal, etc.), b) Proteomics (analysis of the entire complement of proteins in an organism, with subareas of structural, functional, immunological, nutritional, etc.), c) Glycomics (study of the carbohydrate profiles), d) Metabolomics (chemical fingerprinting of residual small molecules), and e) Metabonomics (metabolic responses to pathophysiological stimuli or genetic modification). Transcriptomics, the study of the set of all RNA molecules, is actually a part of genomics.

The-omic protocols are complex and sophisticated. They require technical expertise, extensive instrumentation and heavy time and financial inputs. They are by no means routine studies. Some of them, but not all of them in any given case, are useful in establishing substantial equivalence (see No. 7, below) and safety of the new products and so should be employed on a case by case basis, if other safety evaluations warrant the need for any study in the –omic series. In general, a history of safe use of the isogenic and the absence of any adverse effects of the inserted/altered genes is adequate to consider GE products as safe as their isogenics.

The demand of the activists that every GE product should be subjected to all the different –omic analyses is in fact comic, as there is no scientific basis for doing so and it is wholly unnecessary and wasteful in terms of both time and money.

7. Substantial equivalence is a measure of identity of chemical compounds between a genetically engineered organism such as a transgenic and its parent variety (isogenic) and so is a measure of safety. Different parameters of analysis of the isogenic and its transgenic are needed to show that the transgenic is 'substantially equivalent' to its isogenic in terms of nutritional (or other) quality and safety when consumed.

8. All genetically engineered products are subject to strict regulatory regime, for product efficacy and safety, unlike the conventional products. The Indian regulatory system is elaborate and more rigid than that of most other countries. The current regulatory structure is composed of four competent authorities with the Genetic Engineering Approval Committee (GEAC) as the apex statutory body, mandated to approve GE products for field trials and commercial release. The GoI has now tabled in the Parliament a new Act to constitute the 'Biotechnology Regulatory Authority of India' (BRAI) providing for a three stream (agricultural, medical and industrial) regulatory structure, in a single window clearance mode for each. The GEAC was severely criticized by the activists who wanted a new system to replace it, but are now equally vehement against BRAI. The BRAI is aimed to smoothen some of the rough edges inherent in the present system and the draft Bill underwent a lengthy process of consultation and discussion.

9. In India very few people differentiate between curriculum and syllabus, and use the two terms interchangeably. Curriculum is a course of study in a school or college and a core curriculum is the subjects a student is obliged to study. Syllabus is the abstract program of topics and subtopics to be taught in a subject. The syllabus of a particular course may vary from institution to institution but not significantly. Our educational system is based in the concept of 'taught courses' and so a competent teacher is essential for its success.

10. Barring the students with scholarships or fee concessions, all students pay for their education, (but subsidized fee in public sector institutions) and so have been in the self financing mode all the time. With the governments becoming serious in curtailing capitation fee and heavy donations, the term 'self financing courses' has come to be used as a respectable label for the practice of students paying heavy amounts to join apparently attractive courses of study and share the costs. This unhealthy practice which makes education available only to the rich was started in the private institutions but now most Universities run self financing courses. At least 10 students are needed in a PG class to provide an atmosphere of academic and social interaction among the students. Besides, a class of less than 10 students is financially unviable. It is bet-

ter that all self financing PG courses with less than 10 students are discontinued, also because the volume of intake speaks of the popularity of the courses offered.

11. 'Guest Faculty' is a euphemism for 'hourly labor'. Teachers are paid a fixed amount per hour of teaching work they do. Some institutions pay better than many others. These teachers are not given full time work and are not paid during holidays. Such ad hoc appointments are designed to spend less on salaries and to deny the teachers any rights for regular employment after some years of service. This undesirable practice, started by the private institutions, is now adopted by many Universities as well. As the money they get from any one institution is not adequate for their survival, these teachers may teach some hours in different colleges during the same week and/or work for the tuition shops. Inspection committees often discovered the same teachers listed in the attendance registers of more than one college. On the average three out of five teachers serve as guest faculty. Without full time and/or permanent appointments, the institutions lose on commitment and loyalty from the majority of the teachers.

    The 'Guest' practice does not end with the faculty. With the connivance of suppliers (for a consideration) there have been instances of 'guest equipment' and 'guest books' brought to impress the inspection committees and removed after the inspection, to some other college on similar terms and for the same purpose.

12. Most products of GE on the market contain only one transgene, for pest tolerance or herbicide tolerance or other traits. In India Bollgard I *Bt* cotton and *Bt* brinjal contain only one *Bt* gene, the *Cry 1Ac*. Gene stacking (gene pyramiding) involves transferring two or more genes into the same variety. Bollgard II of *Bt* cotton, that contains two genes, *Cry 1 Ac* and *Cry 2 Ab*, is more popular with the Indian farmers as it offers far greater pest tolerance. A transgenic corn developed for nutritional enhancement contains five genes to provide for vitamins A, C and B9, in a single product. GenuitySmartStax corn containing eight stacked genes, six for pest tolerance and two for herbicide tolerance, is an intellectual feat.

13. Molecular Plant Breeding (MPB) provides an integrative overview of issues from basic theories to their applications to crop improvement that include molecular marker technology, gene mapping, genetic transformation, quantitative genetics, and breeding methodology. MPB is projected as a safer and better alternative to GE technology, though transgenic technology also comes under it. Those technologies of MPB that do not involve GE would not attract regulatory oversight.

14. Agroecology is the application of ecological principles in the management of agricultural ecosystems for the production of food, fuel, fiber, and pharmaceuticals. The term encompasses a broad range of approaches, and there is no unanimity in principles and practices even among its advocates. Agroecology, like organic farming, is the current favorite choice of the opponents over GE technology. Both agroecology and organic farming are packages of agricultural practices and not technologies *per se*, promoted more from an emotional platform rather than on a solid science base.

15. Integrated Pest Management (IPM) is a package of diverse practices, both conventional and modern, to control the large number of pests and diseases of crops. IPM does not exclude crop GE or the judicious use of chemical inputs. It includes the use of biopesticides and cultivation practices that discourage pests and diseases. While transgenic technology focuses on one or two

most important of pests or diseases of each crop, IPM simultaneously addresses several of them.

16. Biofuels are derived from biomass (whole or parts of plant or animal bodies). Mined coal, natural gas and petroleum fuels are also biological in origin; they are 'fossil fuels' formed hundreds of millions of years ago and are not renewable. Wood, coal made by burning wood, dung cakes, crop waste, etc., in use as fuel for ages, are biological too. Consequently, the definition of the term biofules is not precise.

Bioethanol is ethyl alcohol produced by fermenting the sugars in biomass from cereal crops such as corn, sugarcane, sugar beet, agricultural residues, etc. Bioethanol is used in automobiles either in pure form or more often as a gasoline additive (10 to 20 per cent) in the US and South America.

Biodiesel is made by processing oil seeds, vegetable oils and other fats. Biodiesel also is used either in pure form or as an additive to petroleum-based diesel fuel. Specifically designed processing plants are needed to produce both bioethanol and biodiesel.

Biogas is a mixture of methane and carbon dioxide produced by the anaerobic decomposition of organic matter such as sewage and municipal wastes by bacteria. Biogas has been in use as domestic fuel and in the generation of hot water and electricity for several decades.

The 'first generation' biofuels are derived from raw materials that may be used as food and so exert some pressure on arable land and food production. The 'second generation' biofuels also use plants or animals, but their production is more complex as it involves the use cultured organisms such as the algae (a group of mostly aquatic green plants, which are small and do not have stems, roots and leaves as the flowering plants) and extensive fermentation and extraction processes.

The main benefits of biofuels are that they are renewable, save on the use of the fossil fuels and produce significantly lower quantities of environmental pollutants.

17. Bioenergy is the energy derived from biological sources, as detailed at No. 16 above. Barring energy produced through solar, wind, water and nuclear facilities, all energy is bioenergy. Unfortunately, the term bioenergy is also used in other contexts, as for example in the complementary and alternative systems of medicine to describe the process of healing through channeling human body's internal energy. In consequence, there is no precise definition for the term bioenergy.

APPENDIX: INDUSTRY'S NEEDS OF MANPOWER IN MODERN BIOTECHNOLOGY

Questionnaire (data to be gathered separately for each stream of MBT)

1. What are the typical roles for which you hire fresh Masters level Bioscience graduates?
   a. Quality Control Executive (Example)
   b. ________________________________
   c. ________________________________
   d. ________________________________
2. For each role mentioned above could you fill Table 1 to detail the required knowledge, skills and behaviours (Competencies) that determine success in the role.

3. What is your current selection methodology for fresh graduates? How do you screen and shortlist a resume?

   ____

   ____

   ____

   ____

   ____
4. What improvements/modifications do you recommend to the curriculum, to improve the employment readiness of a fresh graduate?

   ____

   ____

   ____

   ____

   ____
5. Do you have a new joinee training program? If so, could you highlight the key elements of the training provided for a new joinee?

   ____

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Table 1. Compentencies

Sl No	Role	Desired Minimum Knowledge	Fundamental concepts required	Desired Skills	Desired Behaviours	Typical Gaps observed
1	Quality Control Executive	1. 2. 3. 4. 5.	1. 2. 3. 4. 5.	1. 2. 3. 4. 5.	1. 2. 3. 4. 5.	1. 2. 3. 4. 5.
2	R&D Executive (E.g.)					
3	Regulatory Affairs Executive (E.g.)					
4	Production Executive (E.g.)					