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Need for New Trends in Biotechnology Education and Training

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Abstract: The paper examines recent developments in tertiary education in relation to biotechnology. It discusses new trends in tertiary education that are gaining in importance which include the following: open distance learning, internet, virtual universities, corporate universities, franchise universities, academic brokering, collaborations of universities, consortiums and clusters and university outreach programmes. The potential and advantages of the open distance learning concept is well recognized and demonstrated, but not many developing countries are able to tap its potential for education in biotechnology. This may partly be attributed to the myths about the open distance learning system. Similarly, software, views in relevant areas, articles, discussions, courses, practical protocols – are all available to the biotechnology educator on the internet. But the use of these resources in developing countries is yet to pick up. There are examples of virtual universities globally. Corporate universities are another form of education important to biotechnology education and training as they focus on the skill needs of corporate organizations. The collaborations of universities and the consortia concept are prepared for a variety of reasons and offer advantages to each partner. Clusters are yet another concept which may prove highly beneficial for a multidisciplinary and highly industrialized field such as biotechnology. In developing countries such as India this concept is in its nascent stage and needs to be taken up seriously particularly for fields like biotechnology.

Keywords: Biotechnology, education, training, tertiary education, open learning, outreach programmes, virtual universities, corporate universities, developing countries, consortia, clusters, distance learning.

Introduction

Biotechnology is a multidisciplinary and industrialized field that faces many challenges. One of the main hurdles in biotechnology development and application lies in its workforce or human resource development as there is a need not only for the relevant knowledge education at various levels and for various target groups[1] but also for the capacity building in bio-safety measures.[2] The biotechnology industry is an industry that needs

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little by way of physical infrastructure as did the heavy industries of the past, but it is anchored firmly in the abilities of scientifically trained people at all levels, from the laboratory bench to the capital providers, who understand both science and business. Sagasti (1990)[3] states that in present day society the role that knowledge plays in all human activities is so critical that the concepts of development and progress need to be redefined in terms of the capacity to generate, acquire, disseminate and utilize knowledge; and the presence or absence of this capacity constitutes a crucial divide between rich and poor nations and societies. According to Drucker (1994),[4] the emergence of "information capitalism" has already caused profound social transformations in the industrialized world. The coming "information society" will be qualitatively different from all that came before. This is more evident in the case of fields like biotechnology.[5] For developing countries like India especially biotechnology education and training assumes prime importance. Different challenges faced by biotechnology were discussed at the national level arguing the need for reshaping and reorienting biotechnology education.[6] The importance of biotechnology education is also emphasized by Gundersen (2003)[7] by quoting the movie "The Graduate".

'Certainly most of you remember the 1967 movie "The Graduate". One of the memorable quotes from that movie occurs when Mr. McGuire (played by Walter Brooke) takes Benjamin Braddock (played by Dustin Hoffman) aside at the graduation party to give him some unsolicited advice. The exchange went like this:

Mr. McGuire: "I just wanna say one word to you. Just one word."
Ben Braddock: "Yes, Sir."
Mr. McGuire: "Are you listening?"
Ben Braddock: "Yes, I am."
Mr. McGuire: "Plastics."

If that film were to be remade or updated today, the "one word" would not be "plastics," it would most likely be "biotechnology!" While just changing that one word in this memorable but minor conversation would not materially change the superb story of this movie, the change from plastics to biotechnology has made a very significant change in the future for your chemistry, biochemistry, and molecular biology graduates. And it follows that this change should prompt you, as an educator, to update the preparation of your product, the graduate.'

Industries employing graduates in applied sciences are looking for

individuals with a range of skills. Traditional university science courses are based around a lecture course with accompanying practical classes. They are often assessed primarily by written examinations at the end of the course. Lectures are not an effective way of stimulating students to think or to develop the various skills required[8] while the examination often concentrates on a recall of content. In response, students often focus on developing short-term and limited understanding skills to pass examinations.[9] This traditional education system has several limitations for reorienting biotechnology education and we need novel regional and country-specific biotechnology education and training programmes.[10]

Doelle and DaSilva (2008)[11] explained how the biorefinery concept can be made more society based. We need to assess how our strategies in biotechnology education and training can be made more relevant in the case of such models. There are many educational practices such as flexible learning, problem-based learning, project mode, experiential learning, etc. which also focus on education and are mostly used within the traditional system. The present paper, however, restricts its discussion to certain new trends in educational systems which are gaining importance and offer various options to address the issues in disseminating knowledge of biotechnology.[12]

Open Distance Learning

Open and distance learning programmes have gained importance all over the world as they have been seen as an viable alternative to overcome problems like skill shortage and the need to retrain and upgrade the existing workforce. We can observe a lot of interest among industries in using open learning.[13] Open learning has moved from its original and marginal role in continuing and second chance education into the new field of industrial training. A number of changes in work practices and increase in sophisticated developments demanding flexible training made this path of delivery not just desirable but often essential. The rapid developments in the bio-molecular sciences and technologies especially favour the open distance mode of educational provision and several projects have been undertaken to produce the appropriate learning resources.[14] Some of the advantages of using open learning for food science, also applicable to biotechnology are given in Table 1.[15]

One of the best examples of use of the open learning concept for the benefit of industry is offered by the UK Open University in the late 1980s. They had prepared a biotechnology course which was largely organized

from an industrial perspective. The course uses a powerful combination of learning techniques to make the learner self reliant in the learning process. The learning pack consists of a combination of comprehensive texts (2 volumes of core study pack), 4 case studies, 3 back-up material (source book) and 6 video films.[16] Another best example of biotechnology through open learning is the BIOTOL (Biotechnology by Open Learning) project of the 1990s. Under this the Open University of the Netherlands and the University of Greenwich developed a student-centred learning resource which helps the student to develop biotech industry relevant skills. They cover many areas like bioreactors, bioprocess engineering, tissue culture, food processing, engineering genes, immunotherapies, regulatory affairs, safety aspects, etc.[17] Another development in facilitating open learning is the offering of free course ware on the net. The best example is the free course ware made available by the Massachusettes Institute of Technology (MIT) (www.massbio.org). Recently, the Indira Gandhi National Open University, India made the most of its course

Table 1: Advantages of Open Learning to Food Science Education[18]

Food Science	Open Learning	Advantages
Multidisciplinary nature	Systems approach	Training packages for local, specific needs Adapt to changing needs Target specific courses programmes
Large Numbers to be trained	Industrial form of education	More defined work procedures and methodologies Mass scale production of learning materials
Wide range of target groups	Learner centred approach	Tailor-made packages Producing learning rather than providing instruction
Threshold numbers	Open access to equipment learning materials & tutors	Reach trainees spread over a wide area Meets the demands of even small groups of learners
Flexibility	Multimedia approach learning styles	Study at home or at workplace Accommodating various
Cost effectiveness	Distance Education	No need of separate infrastructure No travelling costs Training at work place
University – Research institutions – Industry nexus	System approach, adaptability, learner-centred approach, distance education	Treating university research institutes & industry as a single entity

material available through e-Gyankosh (ignou.ac.in). However, the concept of open learning and open distance education provides some thing more than just learning resources which are learner centred.

The European Association of Distance Learning Universities (EADTU) through a project entitled DUNE (Distance Educational Network of Europe) utilizes experiences gained through existing and novel programmes to enhance the development of distance education in an international context. They have developed a course in genetic engineering which is more than simply the delivery of education and training in genetic engineering using pre-prepared learning materials. The materials can be re-packaged to respond to local needs and in identifying good practices.[19] The European Initiative for Biotechnology Education (EIBE) has produced a substantial amount of resource material in support of biotechnology education. A major part of the EIBE's activities is the generation of units of material based on particular themes, aimed at 16-19 year old students. Each unit is a collection of activities designed to engage the learner, e.g. practical laboratory based exercises, role-play, discussion, decision making. Another example is the Open University community education programme in Wales. They established 1800 successful learning groups within 12 months.[20] The Hong Kong polytechnic university started an innovative food science and technology degree course for in-service personnel mostly technicians in the food industry. The students receive training relevant to their daily work, and obtain the qualification required for food professionals, allowing opportunities for progression in their career.[21]

There are various advantages to the open learning concept. The decreased importance of physical distance means that the best universities in any country can decide to open a branch anywhere in the world or to reach out across borders using the internet or satellite communication links, effectively competing with any national university on its own territory. The lack of physical proximity makes it a more flexible and learner friendly system. Teacher inputs through various means make the system suitable even where the threshold numbers of learners are not available. The use of modern communication technologies including educational satellite (EDUSAT) make it possible to build virtual classrooms and virtual laboratories.

Though in developing countries like India also there are biotechnology courses offered through open distance learning, when we closely analyze these courses they are mostly poor repetitions of what is offered in the regular university system. The potential of open learning is

not fully utilized for the issues faced by biotechnology. This may be partly attributed to misconceptions about the open distance learning system. Some of the general myths prevalent are as follows: equating it to conventional correspondence courses which may create doubts in the minds of people about the validity of offering practical and application oriented courses; presuming that open learning occurs in isolation which prevents use of the open learning techniques in other situations like traditional training and on the job training; treating open learning as knowledge dissemination in a more elaborative and exhaustive (information overload) way which makes it difficult to think of simple solutions available for the practical problems; seeing open learning as complex and not using it in a simple and relevant way which makes the system irrelevant in some cases; equating open learning with the application of ICT and other modern communication technologies which may lead people to focus more on technologies rather than using the concept for focusing on solutions to the problems of education and training; presuming that open learning should be always successful, often forgetting the fact that it is only a concept and its success depends on how best we can conceive and implement.

Internet for Biotechnology Education

Articles, software, views, discussions, courses, practical protocols – all and more are available to the biotechnology educator on the internet. Enormous advances in the level of understanding the basic life processes that occur in microorganisms, plants, and animals have occurred in recent years, and this knowledge is being utilized for numerous and diverse purposes as for example: the use of DNA fingerprinting in criminal trials has become routine; higher animals (e.g. sheep) have been cloned; mutant forms of human genes that cause diseases have been identified, isolated, and sequenced; hardy vine-ripened tomatoes have been produced by genetic engineering; sequencing of the genomes of man and rice is progressing rapidly; and the possible misuse of medical information about individual patients is a subject of legitimate concern. These topics and other aspects of biotechnology, such as the patenting of DNA sequences and of biological processes, are of interest not only to scientists but also to the public in general. The World Wide Web contains a great deal of information about them[22] (Tables 2 & 3). The European Initiative for Biotechnology Education (EIBE) has an attractive site covering various topics as for instance Microbes and Molecules (independent practical activities), DNA profiling (information and discussion questions), Biscuits

and Biotechnology (Production of biscuits), Issues in Human Genetics, Fermentation, Human Genetics: Debate of Personal Dilemma (debate game), A model European Council: Pre-implementation Genetic Diagnosis (simulation), Transgenic Animals, Novel Food, Biotechnology in the Third World, Environmental Biotechnology, Biotechnology: Past, Present and Future, etc.[23] There are some sites which offer a collection of biotechnology education resources for particular application fields. For example, the internet site of the biotechnology information centre at the US National Agricultural library (http://www.nal.usda.gov/bic/) provides access to a variety of information services and publications covering many aspects of agricultural and environmental biotechnology. Some of the biotechnology journals give web resources as a regular feature. The National Human Genome Research Institute (NHGRI) site has online lectures and dictionaries that talk apart from a catalogue of resources list on genomic and genetic resources, World Wide Web, sequence and gene databases, genome centres, chromosome maps of model organisms, medical genetics and genetics education.[24] Similarly, the web site on Cell and Molecular Biology online (CMBO)[25] contains links which has readership ranging from high school students, graduate students, post-docs, professors and industry researchers. There are a number of sites and as Pamela Gannon puts it, "More and more biology information is coming online, so I think that it is important for people to have somewhere to go where they are not overwhelmed".[26] We need to train our students in this.

Table 2: Internet Resources – Major Guides and Education Sites

Website Name	Address
Infomine	http://lib-www.ucr.edu/searchucr_balsearch.html
The Biotechnology Information Centre	http://www.nal.usda.gov/bic/
InfoBiotech Canada	http://www.ibc.nrc.ca/ibc/
The World Wide Web Virtual Library: Biotechnology	http://www.cato.com/biotech/
Access Excellence	http://www.gene.com/ae
BiotechBiosources Database: Indiana University	http://biotech.chem.indiana.edu/
1997-98 BIO's Citizens' Guide to Biotechnology	http://www.bio.org/whatis/citizen1.dgw/
Primer on Molecular Genetics	http://www.bis.med.jhml.edu/Dan/DOE/intro.html
BIO Online: Research and Education: Education Resources	http://bio.com/resedu/educate.html

Source: Hart and Hart (1997).

Table 3: Some Examples of Multimedia based Internet Delivery

Source	URL	Focus
Univ.Pennsylvania	http://goldwein.xrt.upenn.edu/tour1_44 ran	Cancer information
Univ. of British, Columbia	www.science.ubc.ca/~chem/tutorials	Acid & base point tutorials
Univ. of Leeds	http://metallo.scripps.edu/PROMISE/main.html	Prosthetic groups &metal ions in protein active sites database
Univ.Liecester, UK	http://www.micro.msb.le.ac.uk/Tutorials/tutorials.html	Microbiology tutorials, practicals and video
Expasy (Expert protein analysis system) proteomics server	http://www.expasy.ch/	Databases, tools & software packages, Education & services, Documentation
The Burnham Inst.	http://franklin.burnhamnst.org	Bio-informatics training
Univ.of California, Berkeley	http://www.cmil.unex.berkely.edu/oline/tot2/html/octop.html	Online classroom (bioscience)
Univ. of Tokyo	http://www.a.utokyo.ac.jp/hennocyte/data/data-e/intro.htm	Agricultural & life Sciences
Lawrence Berkeley National Laboratory	http://www.itg.ibl.gov/ITG.hm.pg.docs/dissect/dissect.html	Virtual frog dissection kit
The Burnham Institute	http://www.rcsb.org	Protein data bank (basic teaching)
Birkbeck University of London	http://www.cryst.bbk.ac.uk/	Biomolecular science course online

Source: Compiled by the Author.

Virtual University

UNU (United Nations University) in 1996 took the initiative to launch UNU Virtual University/On-line Education by providing new means to support and enhance education, research, and dissemination with Internet technologies. The UNU recognized from an early stage that on-line education is a powerful networking and dissemination tool for existing knowledge and that it could be used to support capacity-development activities across the globe with more benefit to developing countries. The UNU has already made considerable investments in this area through the establishment of the Virtual University Media and Technology Laboratory (http://vulab.ias.unu.edu). In addition to developing a range of online learning tools, the laboratory offers a range of fourth generation Virtual University services including web development, web hosting, web streaming of conferences and the development of multimedia education materials (such as the UNEP Global Environmental Outlook, 2000). With

support from numerous collaborative partners in Japan (including the University of Tokyo) and overseas, the UNU Virtual University/On-line Education project has developed several innovative software prototypes (including a customizable whiteboard platform, coordinated chat system, Web co-navigation framework, and an Internet studio for synchronizing audio/video with presentation slides). Through a global partnership approach, the UNU is now focusing its efforts on the development of fourth generation Virtual University technologies as well as the implementation of online courseware and ensuring their extensive evaluation from both didactical and pedagogical perspectives. The UNU in collaboration with UNEP, Agder University College (AUC) and UNEP/GRID-Arendal in Norway, has embarked on a joint initiative to develop a Global Virtual University (GVU) as an on-line e-learning programme with an international outreach. The relationship between environment and development form the core of the programme.

Countries across the world have announced virtual university initiatives of various kinds. The Mexican Virtual University of Monterrey offers 15 master's programmes using teleconferencing and the Internet that reach 50,000 students in 1,450 learning centres throughout Mexico and 116 spread all over Latin America. Thirty-three states in the US have a statewide virtual university. The University of Saskatchewan in 2000 established a Virtual College of Biotechnology. This Virtual College has seen breakthroughs in the biotechnology field in conjunction with the several adjunct research facilities. And further, virtually every area of the University of Saskatchewan has direct involvement with the new field of biotechnology. For example, the college of law explored legal aspects while the philosophy department is involved in studies on the impact of biotechnology science on society's ethics, epistemological systems and metaphysics. (University of Saskatchewan, College of Biotechnology Introduction).[27] Some other countries which have established virtual universities are Pakistan, Greece, Sweden, the UK and Finland, India, Argentina, Kenya and Australia.

In the year 2004, the President of India Dr. Abdul Kalam suggested that the country should consider the possibility of creating a virtual university in providing quality education to all. The virtual university should be created through networking of all the universities and other educational institutions, he said. It would act as a central hub of all universities which are networked, and coordinate, organize, schedule and broadcast the lecture of specialists at a mutually convenient time to all

participants, digitize all the university libraries and make it available for seamless access by all the universities.[28]

The Department of Agriculture, Government of Maharashtra, India in a practical application of such an initiative decided to establish MAHA-AGRINET *for Maharashtra's Agrarian Prosperity*. MAHA-AGRINET is a fairly new concept of forming a coalition of all the interested partner institutions to pool their best expertise, resources and facilities for developing agrarian prosperity in Maharashtra. The objective is to help farmers and villagers through farm-specific, need-based, demand-driven and just-in-time advice and knowledge; mobilize the farmer groups to use it in a self-directed and self-sustainable way and follow a path towards their continuous agrarian development and progress.

Another virtual university of interest with relation to biotechnology is the virtual university launched by ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) for semiarid tropics. The Consultative Group on International Agricultural Research (CGIAR) institutions including ICRISAT, CIAT (International Centre for Tropical Agriculture), ILRI (International Livestock Research Institute), ISNAR (International Service for National Agricultural Research) and the CGIAR (Central Advisory Service for Intellectual Property) are involved with biotechnology for improving agricultural productivity and reducing poverty. To work more effectively these institutes are building partnerships with the private sector, civil society and farmers. The Virtual University for the Semi-Arid Tropics can be a platform for linking the stakeholders in biotechnology.

Facets of Various University Systems

Corporate universities which are another emergent form of education mainly focus on the skill needs of the corporate organizations. Recent estimates suggest that there are more than 2,000 such initiatives among large companies (such as Ernst and Young or Lufthansa) and large organizations such as the US Army or the UK's National Health Service. Two significant examples of successful corporate universities are those of Motorola and IBM. Recognized as one of the most successful corporate universities in benchmarking exercises, Motorola University, which operates with a yearly budget of 120 million dollars representing almost 4 per cent of its annual payroll, manages 99 learning and training sites in 21 countries.[29] IBM's corporate university, one of the largest in the world, is a virtual institution employing 3,400 professionals in 55 countries and offers more than 10,000 courses through Intranet and satellite links.

Corporate universities have developed rapidly in the USA in the past twenty years.[30] Examples of corporate universities are also evident in Europe and Australia.[31] Corporate university initiatives vary in scale and scope; some involve little more than a reorganization and 'rebranding' of internal training and human resource functions, while others are a more systematic attempt to connect human resource strategies, skills development and continuing education, knowledge management, organizational learning and culture change. Experts are predicting that, by the year 2010, there will be more corporate universities than traditional campus-based universities in the world, and an increasing proportion of these will be serving smaller companies rather than corporate giants. In India, the corporate university concept is to be seen with the establishment of University of Petroleum & Energy studies and Kalinga Institute of Industrial Technology recently. We can predict many biotechnology companies may find the corporate universities concept useful.

Yet another novel form of the education system is that of Franchise universities. In many parts of the world, and predominantly in South and Southeast Asia and the formerly socialist countries of Eastern Europe, there has been a proliferation of overseas "validated courses" offered by franchise institutions operating on behalf of British, U.S., and Australian universities. One-fifth of the 80,000 foreign students enrolled in Australian universities are studying at offshore campuses, mainly in Malaysia and Singapore.[32]

Another unconventional form of educational provision comes from the new "academic brokers", virtual entrepreneurs who specialize in bringing together suppliers and consumers of educational services. To quote a few examples to illustrate this new trend - companies like Connect Education, Inc. and Electronic University Network build, lease and manage campuses, produce multimedia educational software, and provide guidance to serve the training needs of corporate clients world-wide.[33] Similarly, Rennselaer Polytechnic Institute coordinates and delivers degree programmes from Boston University, Carnegie Mellon, Stanford University and Massachusetts Institute of Technology (MIT) for the employees of United HealthCare and United Technologies.[34] Examples of educational brokers include Western Governors' University in the USA or Learn Direct in the UK. Western Governors' brings together a range of partners to deliver new kinds of programmes (based on a competency model) to new groups of students. Courses are developed and delivered by more than thirty participating organizations including universities, colleges and commercial companies such as Apple, KPMG and Microsoft. An Australian team

researching 'borderless education'[35] noted the huge growth in educational brokers of all kinds. They also reported the expansion of educational services, including educational guidance, testing and assessment, learning support and electronic libraries, and accreditation services.

Another important development in higher education is the increasing tendency towards fragmentation of the universities into specialized universities. In India this started with agriculture which happened almost at the beginning and now there are different universities for separate subjects – technical, medical, engineering and law. The Government of India recently started a tribal university. There are also separate universities started for a particular community or section (tribal university, Women University), a particular language (Telugu university, Kannada university, Sanskrit University and the like), a particular field like music. Besides, the strategic sectors of space, defence research and atomic energy have all also turned into educators. This rise of 'directed universities' intended to produce students trained to fulfill a special need is a new phenomenon leaving the original university to function with only the sciences and humanities as areas of study. Ruthnaswamy[36] points that 'A University teaching one special subject is a contradiction in terms. It is opposed to the basic idea of a university which is a corporation of teachers and students engaged in a variety of studies. Corporate social life and a liberal education are its differentia'.

The above discussed concepts may be relevant for education in biotechnology and training taking into consideration the nature of biotechnology and its application to a wide array of industries.

Collaborations of Universities, Consortia and Clusters

Every day there are announcements of new companies being formed to market online and distance-taught courses, or new partnerships among existing institutions to broker courses and programmes both at national and international levels. Just like airline companies, universities around the world are 'partnering up'. There are a variety of reasons for forming partnerships or consortia of universities:

- sharing resources, costs and infrastructure to deliver e-learning;
- competing with international providers;
- reducing duplication among existing universities.

Such partnerships can also act as a means of entry into the global e-learning market for less economically advanced countries. The partner institution from the less economically developed country brings adaptation

to local culture, language benefits, local or national accreditation, sharing of costs and risks, and access to neighbouring markets or markets with similar language and culture. These are all considerable benefits for the partner from the more developed country.[37] However, it is not an easy task to establish collaborations, but without strategic partnerships, universities will find it difficult to compete with the mega-market spaces that are emerging in the higher-education landscape.

There are many consortia which deal with biotechnology. The alliances may cover industrial activities, research studies, education and training, sharing of resources, etc. We present some examples of these. In India a public limited company Biotech Consortium India Limited (BCIL) was established in 1990 with the support of Department of Biotechnology, Government of India and All India financial institutions to accelerate commercialization of biotechnology. BCIL networking covers universities, central & state governments, research institutions, international organizations, funding institutions, industry, resource persons and entrepreneurs.[38] The Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB) assists the countries in organizing consortia to tackle more complex or long-term projects. The Scottish Colleges Biotechnology Consortium (SCBC) supports biotechnology activities from the school sector to industry. It has developed excellent and highly relevant course content for biomanufacturing, particularly through their innovative Bioprocess Workforce Development Programme, tailored Higher National Diploma courses such as HND Biotechnology, HND Applied Biological Sciences, and HND Chemical and Process Technology, and their programme for short courses such as Introduction to GLP and An Introduction to Biotechnology Techniques. It also offers a wide range of biotechnology training courses for industry technicians and managers.[39] The Bay Area Biotechnology Education Consortium (BABEC) is a regional network of local science education organizations based in the North California Bay area. To accomplish their mission, BABEC and its partnerships work with teachers, educators, scientists, industry and academia to develop, disseminate, implement, and sustain contemporary laboratory-based biotechnology curricula that increases professional skills of the classroom teacher, capture the interest and challenge the capabilities of students.

In addition to regional and international consortia, a variety of other forms of transnational education has emerged to add to the traditional modes of staff and student exchanges between countries. In the UNESCO/

Council of Europe Code of Good Practice in the Provision of Transnational Education (2001) these are categorized in terms of collaborative and non-collaborative arrangements. The former include franchising, twinning and joint degrees whereby study programmes, parts of a course of study, or other educational services of the awarding institution are provided by a partner in another country. The latter include branch campuses, offshore institutions, corporate and international institutions whereby study programmes, parts of a course of study, or other educational services are provided directly by an awarding institution in one country to another country or countries.

We can define cluster as geographical concentration of companies in similar or related economic activities and their supporting knowledge organizations.[40] Clusters might facilitate interactive learning and the acquisition of competences required for upgrading. The clusters can be categorized – traditional manufacturing, resource-based industries, complex product systems and specialized suppliers. We may take an example of a resource based industries cluster to put the cluster concept in the present context of the paper - The Taiwanese floral cluster. This is dominated by the small and medium scale enterprises (SMEs) with other local players in the cluster being biotech labs, the marketing cooperatives and the government. Most upgrading is generated by suppliers (machinery, seeds, chemicals, etc.) or is the result of cooperation with scientific institutions. In some cases, upgrading is the result of joint technology development and coordinated actions between firms, business associations, universities and other actors. In some others, Trans National Companies (TNCs) provide the technology and knowledge required for the upgrading of the local SMEs.[41] Devaguptapu *et al.* (2008)[42] takes the case study of cytokinetics which is built around its academic expertise in the field and which has collaborations with big pharma companies and venture capitalists. The case of cytokinetics illustrates what San Francisco (and certain other academic-industrial 'clusters' in the US) had, that the Indian entrepreneurial ecosystem does not yet have in adequate abundance. The department of biotechnology (DBT) promoting cluster concept and some of the recent additions are Health Biotech Science cluster, Faridabad, Bangalore Biotech cluster, Bangalore, and Agri-food Biotech Cluster, Mohali (Punjab). The recently approved National Institute of Bio-medical Genomics (NIBMG) at Kalyani (West Bengal) is proposed to be set up within a cluster of hospitals, research institutions, education institutes, biotech service providers and industries for synergy and symbiosis.

University Outreach Programmes

The following excerpt from the speech of Magrath[43] in a seminar on outreach gives a good idea of outreach programmes and their importance to society:

> *"Personally I prefer Engagement, but have little interest in debating labels and terminology. What ultimately counts is the concept of a major state university being in partnership with its community, its state and region, and, yes, the wider world with which we are inextricably involved in this new globalized environment. Ultimately all that counts is what we do in effective working partnerships with businesses, civic organizations, government agencies, and, indeed, other colleges and universities. Everything we do in this future—which is here right now—must involve the fundamental responsibility of educating men and women of all ages and from our diverse populations (we can call this learning); discovering new knowledge and applying it (typically labeled research); and providing service to society."*
>
> *"There is another reason why I am passionate about engagement as being a core mission of universities that involves the total institution and its abilities and resources. It, again, goes back to the original land grant mission, which draws no distinction between pure learning and the liberal arts and the economic purposes of universities. Though undoubtedly some disagree, universities are a part of society, though they need certain independence for their creativity to blossom in order to serve that society effectively. This, to use a familiar phrase, involves learning for its own sake which is of estimable value; but that objective in no way conflicts with the absolute imperative that universities—and most especially land grant and state universities—serve economic development needs. We have always done this, going back to the early years of the land grant movement after the enactment of the 1862 Morrill Act."*

University outreach is considered to be a critical form of scholarship provided by an effective university that cuts across teaching, research and service (Table 4). The community college concept can be also included in this. In the university outreach concept the key phrase is "Knowledge sharing". Those who have useful knowledge should be able to share it with others.

There are several universities world wide conducting outreach programmes. The outreach programmes are available in various subjects

and cover various target groups.[44] University outreach as a concept is based on the notion of partnerships. The World Universities Network outreach (WUN outreach) consisting of universities from the UK, US and Norway conduct outreach programmes for various objectives like education, research and outreach in seismology, engaging public with science, reaching out to the public in Bristol area by taking the university off-campus including the free lunchtime lectures, developing a range of resources and events for diverse audiences, skills required by young research scientists to communicate complex scientific ideas to a variety of audiences, etc., Pennsylvania State University has enormous involvements with its state's business and industry. It offers more than 2,000 programmes and services in collaboration with academic colleges. The programmes are delivered in all 67 Pennsylvania counties, 50 states, and 80 countries worldwide. In Washington-Seattle, US, the outreach and continuing

Table 4: Comparison between Traditional Academic Activity and Outreach Activity

Traditional academic activity	Outreach scholarly engagement activity
Teaching University faculty provide instruction to students in campus classroom and laboratories	Engaged **Teaching** occurs when … Learning opportunities are taken off campus, online, and to community-based settings to increase access. Contract courses or programs designed for specific audience; participatory curriculum development, community service learning, conferences, seminars and workshops
Research Faculty members pursue research studies according to their various professions and interests, and publish results in academic books and journals	Engaged **Research** occurs when …. A collaborative partnership conducts an investigation for the direct benefit of external partners; community based research; knowledge transfer and research; demonstration projects; technical assistance; participatory research projects; outcomes of the research lead to improved, evidence-based practice.
Service University faculty and students undertake departmental or college administrative duties and serve on committees	Engaged **Service** occurs when …. A faculty member summarizes current research literature about an issue for working professionals or community organizations; offers research-based policy recommendations to legislators or provides medical or therapeutic service to the public; commercialization of discoveries; knowledge transfer and workshops; expert testimony; education and awareness programmes to general public; consultation services; technical assistance

Source: Bargerstock (2007).

education opportunities abound on campus – in departments, through campus organizations, institutes, libraries, centres, and through public and private sector partnerships. The University of Edinburgh, School of Informatics offer outreach programmes promoting exploitation, public understanding, and informed debate – through projects and initiatives that support engagement with industry and society. The University of California at San Diego, a leading engineering and biological sciences university, works in partnership with business and IT companies. Oklahoma State University started a tiny project with a few faculty members and students from its School of Electrical and Computer Engineering supported by a modest grant from a company called Flight Safety International that trains pilots. Portland State University, not a research intensive university but a significant urban one, has an extensive community-based teaching and learning programme in which it has community-based learning courses exceeding 150 and in approximately 23 departments. These courses started out as traditional disciplinary courses, but had been transformed by the integration of community work with a direct relation to the academic content. Similarly Virginia Tech University also has started many unique outreach engagements in association with many partners.[45] In Nigeria the on-campus, part-time programmes are offered at main campuses; outreach programmes are offered at satellite outreach centres.

Many US universities offer outreach programmes in biotechnology. Iowa state University outreach programmes in biotechnology include programmes for the general public, students, faculty and industries. This centre helps the Iowans understand the science underlying the twenty first century biotechnology developments and the associated economic, ethical, and social issues. In addition to the training and educational experiences that can be provided the centre coordinators facilitate education throughout the state. There are also programmes which help the faculty to build up relationships with the industry and community. For example, the University of Missouri – Columbia faculty members participate in cross-disciplinary outreach programmes of the University Biology department. The Scientific Partnership and Resource Connection (SPARC) is a series of networking events that build relationships between MU scientists and the business community to facilitate technology transfer, entrepreneurship, and career opportunities for students. The largely informal programmes are designed to introduce MU faculty members to the realities of the business world and to let business people know about

potential new technologies developed by MU faculty members. University of Arizona developed the BIOTECH Project to provide technical support for Arizona teachers to conduct experiments in molecular genetics (DNA science) with their students. The BIOTECH project consists of three components: professional development workshops for teachers, classroom visits for modeling hands-on biotechnological activities, and extensive materials support for teachers to carry out biotechnology experiments independently. The Providence Biotechnology Centre is a partnership between URI's College of the Environment and Life Sciences and the College of Continuing Education, along with the Community College of Rhode Island. It has become the base of operations for a number of workforce development programmes for the biotechnology industry in Rhode Island serving future, transitioning and incumbent workers. Through its Biotechnology Training Initiative, it works with local and regional companies to provide workers with short course lectures and hands-on workshops either at URI or on-site at a company facility. Table 5 gives examples of outreach programmes in genetics.

The University Grants Commission of Government of India had recognized the importance of outreach programmes. In its Tenth Plan document it states:

> *'The acceptance of Extension as the Third Dimension equal in importance to teaching and research was in the context of a growing realization that the universities and colleges having institutional resources-knowledge, manpower and physical-have an obligation to develop sensitivities to involve the development of the community with particular reference to the overall and diverse learning needs of all the segments of the people of the community.' (UGC Tenth Plan document, Financial support : 1.5).*

> *'Firstly its objective was to extend knowledge and other institutional resources to the community and vice-versa and secondly its objective was to gain insights from a contact between knowledge resources and socio-cultural realities with a view to reflecting these in the entire curricular system of higher education including teaching and research. It was to be a two-way process between the experts and the people, an intellectual intervention in the community's living problems which need to be overcome through an educational process. It was to be that education which helped students to face life and its challenges and which created an ambience for a learning society.' (UGC Tenth Plan document, Financial Support: 2)*

Table 5: Genetics, Genomics, and Biotechnology Outreach Programmes

Nationwide	Biotechnology Institute
Regional	SEE Biotech: Social, Ethical, and Economic Impacts: Iowa, Minnesota, North Dakota, South Dakota, Wisconsin
Alabama	Center for Community Outreach Development, University of Alabama, Birmingham Science Education Outreach, University of Alabama, Huntsville
Arizona	BIOTECH Project, University of Arizona
	Biology Project, University of Arizona
Arkansas	Partners in Health Sciences, University of Arkansas for Medical Sciences
California	Bay Area Biotechnology Education Consortium
	Science Achievement in Biology, San Diego State University
	Science and Health Education Partnership, University of California, San Francisco
	Biotechnology in the Classroom, Partnership for Plant Genomics Education, University of California, Davis
Colorado	Biological Sciences Initiative, University of Colorado, Boulder
Connecticut	Connecticut's BioBus
Delaware	Molecular Biology Through Inquiry, University of Delaware
Florida	Center for Precollegiate Education and Training, University of Florida
Georgia	K–12 Outreach, Georgia Tech/Emory Center for the Engineering of Living Tissues
Iowa	Office of Biotechnology, Iowa State University
Kentucky	Biotechnology Research and Education Initiative, University of Kentucky
Maryland	Education Programs, MdBIO
	Education and Training Department, The Institute for Genomic Research
Massachusetts	Citylab, Boston University School of Medicine
Minnesota	SEE Biotech, University of Minnesota
Missouri	Science Outreach, Washington University, St. Louis
Nebraska	Ag Biosafety Education Center, University of Nebraska, Lincoln
New York	Dolan DNA Learning Center, Cold Spring Harbor Laboratory
	LIGASE: Long Island Group Advancing Science Education, SUNY Stonybrook
North Carolina	DESTINY Mobile Lab, University of North Carolina, Chapel Hill
	Fungal Genomics Laboratory, North Carolina State University
	The Science House, North Carolina State University
Ohio	Biotechnology Education Initiative, Ohio State University
South Carolina	Division of Genetic Education, Greenwood Genetic Center
Tennessee	*C-fern* Project, University of Tennessee, Knoxville
Texas	BioTech, University of Texas
Utah	Genetic Science Learning Center, University of Utah
Virginia	Fralin Biotechnology Center, Virginia Tech
Washington	Washington State Genetics Outreach Education Programs
	Fred Hutchison Cancer Research Center Educational Opportunities

Table 5 continued

Table 5 continued

Washington, DC	DNA Goes to School/El DNA va a la Escuela
	Discovery Center for Cell and Molecular Biology, Catholic University of America
Wisconsin	BioQUEST

Note: The Table 5 summerises outreach and partnership programmes that specialize in precollege biology, genetics, or biotechnology education. The list is not intended to be comprehensive, but to highlight a number of existing efforts that could serve as resources for interested geneticists. Because such programs often receive state funding, most can provide services only to state residents. URLs can be found at http://www.biotech.vt.edu/outreach/programs.html.

Source: http://www.genetics.org/cgi/content/full/166/4/1601/T1

The outreach programmes were planned by various institutes/universities in India. The Avinashalingam University for women has been networking with government and NGOs and several collaborative outreach programmes are being undertaken. There are few other universities like Calicut University, SNDTs' Women's University, University of Allahabad, Bundelkhand University, Mata Amritanandamayi University, and Indian Institute of Sciences, etc. which have taken outreach activity in some form or other. The renowned Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune has active Public Outreach Programmes whose primary aim is to inculcate scientific interest among school students (especially underprivileged ones), encourage and help talented children to do scientific projects, promote amateur astronomy and inform the general public about the importance and excitement of recent scientific achievements, especially in astrophysics. NALSAR (National Academy of Legal Education and Research) University's outreach programmes are conducted through NALSAR Proximate Education. NALSAR PRO conducts various Post Graduate Diploma Programmes for legal fraternity and other professionals. The Allahabad University strongly emphasizes 'outreach' programmes, recognizing the need to relate the academic activities of the university with social imperatives. The Department of Psychology, Maharaja Sayajirao University of Baroda is associated with number of community outreach programmes. The University of Mysore established Centre for Outreach Programmes in 2006 where collaborations with various organisations were planned. It entered into a Memorandum of Understanding with various institutions/organizations covering business schools, NGOs, finishing schools, education trusts in rural areas, hotel management institutes, IT industries, infrastructure management and software development training institutes, clinical research organizations,

animation industries, etc. During the interaction with the chairpersons of various departments of the university several other unconventional but relevant courses were suggested for outreach concept.[46] However, if we analyze closely the University outreach concept in India is in its nascent form and universities need to take it more seriously.

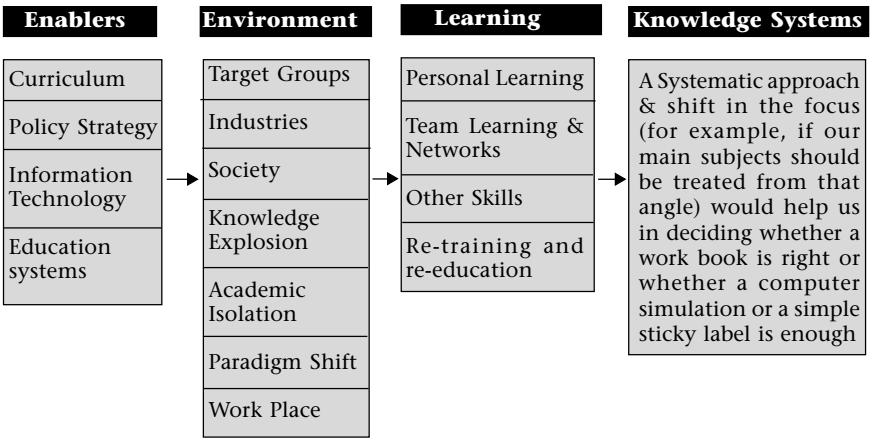
Conclusion

Doelle and DaSilva (2008)[47] stated, 'Rich and rooted in traditional biotechnologies like the age-old dairy and food fermentation, biotechnology can make a significant contribution towards the unveiling of its human dimensions in efforts to curb the onslaught of poverty, improve the welfare of men, women and children – the primary investors and practitioners of rural biotechnology. Further, it can build immunological firewalls against intrusion of inimical entities that erode valuable indigenous and skilled human resources, and that gives the much needed substantive and tangible push to the development of the bioentrepreneurial spirit.'

This is an important observation based in the world wide perception that continued economic growth depends on a new type of 'raw material' that is nothing but individuals who require training and higher education and who are available locally. In developing countries many of the governments support the poor people economically. However, examples from Singapore and Korea show that the poorest part of the population is benefited by high priority given to the creation of wealth rather than to how it is distributed.[48] This wealth creation can be achieved by developing the skills which are required at the local level initially to innovate and produce new products or increase the productivity for the benefit of the local populace. Knowledge generation, creation and utilization will be the key to act locally and think globally. The role of the tertiary education in building up the capacity of developing countries in participating in the global knowledge economy is crucial. Narasimharao (2009)[49] discusses how universities can play a very crucial role in achieving the inclusive growth and in realizing the potential of India to become a global leader in the knowledge economy. In this attempt, one of the foremost fields to be concentrated on more is that of biotechnology.

We have different education systems which have proved useful in one context or the other. We need to see how the developments in the tertiary education discussed above can lead to successful knowledge generation, utilization and integration in developing countries so that

Figure 1: Developing Knowledge Systems – Enablers, Environment and Learning



they are benefited by these developments. Both opportunities and threats arise out of the developments and changes in the tertiary education landscape. Most developing countries continue to wrestle with difficulties produced by inadequate responses to the long standing challenges faced by their tertiary education system. Biotechnology education and training is no exception to this. It may be argued that the universities need to come out of the rigidities and habits of the traditional education system and play a progressive role in tapping the potential of different systems of education which are gaining in importance. For this, it is essential universities develop relevant knowledge systems considering enablers and the environment (Figure 1). For applied and highly industrialized fields like biotechnology there is an urgent need for universities to adopt strategies and programmes for knowledge integration involving the various stake holders of biotechnology. The developments in the tertiary education system discussed in the paper may prove helpful in the field of biotechnology education if these opportunities are properly tapped.

Endnotes

1 Narasimharao (1992).
2 Rao (2005).
3 Sagasti (1990).
4 Drucker (1994).
5 A recent report commissioned by Scottish entreprise assessed the potential skills, knwoledge and labor demands for biomanufacturing in Scotland. In line with previous research studies companies agreed that new graduates were readily available. However, they highlighted a shortage of graduates with practical and technical experience and other expertise including validation engineers, quality assurance, regulatory affairs, and quality control personnel. Again, of these the lack of staff to fill technical level positions such as production operators and process operators was a pressing need (Thomson *et al*., 2003).
6 Narasimharao (in Press).
7 Gundersen (2003).
8 For review see Bligh (2000).
9 Biggs (1999).
10 Dahms (2002).
11 Doelle and DaSilva (2008).
12 Narasimharao (in press).
13 See Temple (1991), Trindadem (1993).
14 Davies & Jennings (1991), Leach *et al*., (1994).
15 Narasimharao (2000).
16 Narasimharao (1992).
17 Jenkins *et al*., (1995). Books in the BIOTOL series includes: *The Molecular Fabric Cells, Infrastructure and Activities of Cells, Techniques used in Bioproduct Analysis, Analysis of Amino Acids, Proteisn and Nucleic Acids, Analysis of Carbohydrates and Lipids, Principles of Cell Energetics, Energy Sources for Cells, Biosysntesis and the Integration of Cell Metabolism, Genome Management in Prokaryotes, Genome Management in Eukaryotes, Crop Physiology, Crop Productivity, Functional Physiology, Cellular Interactions and Immunobiology, Defence Mechanisms, Bioproces Technology : Modelling and Transport Phenomena, Operational Modes Bioreactors, In vitro Cultivation of Micro-organisms, In vitro cultivation of Plant Cells, In vitro Cultivation of Animal Cells, Bioreactor Design and Product Yield, Product Recovery in Bioprocess Technology, Techniques for Engineering Genes, Strategies for Engineering Organisms, Principles of Enzymology for Technological Applications, Technological Applications of Immunochemicals, Biotechnological Innovations -in Health care, -in Crop Improvement, -in Animal Productivity, -in Energy and Environmental Management, -in Chemical Synthesis, -in Food Processing, Biotechnology Source Book: Safety, Good Practice and Regulatory Affairs*.
18 Narasimharao (2000).
19 Leach *et al.*, (1997).

[20] Richards (1989).
[21] Ma *et. al.* (1995).
[22] See Hart and Hart (1997).
[23] http://www.eibe.reading.ac.uk:8001/menu.html
[24] www.nhgri.nih.gov/
[25] www.cellbio.com/index.html
[26] www.cellbio.com
[27] http://biotechnology,usask.ca/Introduction.html
[28] PTI, August 13, 2004.
[29] Densford (1999).
[30] Corporate universities operate under one of any combination of the following three modalities namely: (i) with their own network of physical campuses (e.g., Disney, Toyota and Motorola), (ii) as a virtual university (e.g., IBM and Dow Chemical), or (iii) through an alliance with existing higher education institutions (e.g., Bell Atlantic, United HealthCare and United Technologies).
[31] Taylor and Paton, (2002).
[32] See Salmi (2005).
[33] Abeles (1998).
[34] Motti (1999).
[35] Cunningham *et al*., (2000).
[36] Balram (1995).
[37] Bates (2001).
[38] http://bcil.nic.in
[39] Thomson, *et al*., (2003).
[40] Porter (1998).
[41] Chaminade and Vang (2008).
[42] Devaguptapu *et al*., (2008).
[43] Sagasti (1990).
[44] There are several varieties of courses which are offered under outreach making outreach a portrait of diversity – diversity of ideas in action. Some examples are – third graders learning about ancient Greece and Rome to meet educational requirements of the new standards of learning; food industry professionals learning how to ensure food safety; a corporation redesigning and updating its brand image; rural governmental agencies using research and economic development analyses to enhance economic growth; students assisting small business in developing marketing plans; working professionals earning graduate degrees through extended campus sites; homeowners receiving advice on hazardous waste; using mobile chemistry lab to train public school teachers and students, etc.
[45] Magrath (2006).
[46] Narasimharao (2009).
[47] Doelle and DaSilva (2008).
[48] Thulstrup *et al.*, (2005).
[49] Narasimharao (2009).

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