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Global Efforts in Education and Knowledge Transfer in the Field of Biotechnology

Globalni napori v izobraževanju in prenosu znanja na področju biotehnologije

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Summary

Education for biotechnology became a distinctive necessity when this field joined other new technologies with tenders for new products and new markets. Formally qualified manpower as an important guaranty of skill attracted new capital resources into various segments of biotechnology development. The conservatism as inseparable but disturbing trait of public education systems hindered the transformation of vocational profiles, needed by new technologies. Biotechnologies are usually not new industries or productions, but enter different parts of the existing technologies, so their adjustment enables a soft passage also in education and training. Internationally, we can find various educational models, from formally stiff and closed to modular and open ones, from solutions starting already at the undergraduate level to the schemes building on postgraduate curricula.

Povzetek

Izobraževanje za biotehnologijo postane izrazitejša potreba, ko se to področje pridruži drugim novim tehnologijam s ponudbo novih proizvodov in odpiranjem novih trgov. Formalna usposobljenost kadrov kot pomemben porok delovne uspešnosti podpre stekanje vse večjih kapitalnih virov v različne segmente biotehnologije. Konservativnost kot neločljiva, a žal moteča lastnost javnih izobraževalnih sistemov zavira spreminjanje poklicnih profilov, ki jih nove tehnologije potrebujejo. Biotehnologije najpogosteje niso novi industrijski ali proizvodni sklopi, ampak vstopajo v različnih deležih v obstoječe tehnologije, tako da njihovo prilagajanje omogoča mehak prehod pri izkoriščanju izobraževalnih zmogljivosti v splošnem izobraževanju. V svetu srečujemo najrazličnejše izobraževalne modele od formalno togih in zaprtih do modularnih in odprtih vzorcev, od rešitev, ki začenjajo v dodiplomskem izobraževanju, do dograjevanja vsebin v podiplomskem delu kurikuluma.

Introduction

Education for biotechnology became a distinctive and accentuated topic when this field joined other new technologies like microelectronics, new materials and information science with tenders for new products, services and new markets. Beside the primary goal of securing professionality, formally qualified manpower also serves as an important warranty of skill which is attracting new capital resources into various segments of biotechnology encouraging development. How important highly skilled personal (HSP) is to competent experts is excellently shown in the definition of small sized biotechnological (SMEs) companies: »... any firm requiring *a highly skilled workforce* for the application of scientific and engineering principles to the processing of materials by biological agents for goods and services...«, characterised by BEMET (which stands for Biotechnology in Europe, Manpower, Education and Training – a CEC project) *(1,2)*.

The astonishing achievements of molecular biology in the fifties and the success of genetic engineering in recent couple of decades soon boiled over into application. New biotechnologies were born, based on gene sequencing, recombinant DNA technology, cell culture and fusion, and fermentation technology. Of biotechnology one expects to have a substantial social and economic impact on quality of life *(3)*. For the development of biotechnology some basics should be attained:

- to prepare a climate of public acceptance, best done by adequate education and objective information, sanctioned by an appropriate legislation,

- to establish a productive understanding with the industry, especially in the more conservative sectors,
- to build up promotional assistance from public administration, and
- to secure the intellectual property rights *(4)*.

Biotechnologies, unlike other fields, are usually not new industries or productions, but enter different parts of the existing technologies, with improvements in technical, economical or ecological sense. So new approaches in the food production are linked to transformation of the traditional farming systems into new sustainable agricultural production schemes and to the widening of the array of foods with new, unconventional products. Biotechnology promises to improve the health sector with new, although sometimes questionable intervention into the genetic background of a diseased organism and by introducing new solutions in diagnostics and therapy. Biotechnology is opening new possibilities in energy acquisition of mankind with less offensiveness to the environment. And finally, biotechnology opens new possibilities for the cure of impacts that accompany the presently prevailing technologies in terms of emissions into air, water and soil, under the heading of depollution technologies.

Trends

It is difficult to correctly judge the exact number of biotechnological companies in the world today, as they are emerging and disappearing daily, but they certainly exceed one thousand *(5)*. They are a possible basis for the forecasts in employment, that should dramatically rise in future years. In the USA in 1992, the industry based on modern biotechnology had a turnover of over 8 billion (B) US$ with a growth rate of 28 % and employment growing by 13 %. Using the estimates out of present trends, the US biotechnology's revenues should grow by 42 % and reach 52 B US$ by the year 2000. In Japan, the current biotechnology industry size is 3.8 B US$ and should reach, under the estimate of MITI, 52 B US$ by the year 2000. Similar predictions are present for the European community, so we can count on a world market exceeding 100 B US$ by the end of the century *(1)*.

How fast the labour force market can expand, again the data from USA show: the published number of employees in new biotechnology firms has grown from about 20 000 in 1982 to around 200 000 in 1988; for Europe this data are still much lower (nearly 3 times) (IRDAC opinion, 1991). By questioning biotechnology companies in Germany and UK, Hayward et al. revealed, that respondents expect even 100 % increase in human resources in the field, but that the majority of the companies already face recruiting problems for skilled immunologists, molecular geneticists and pharmaceutical scientists and a minority also in animal sciences and engineering disciplines *(6)*. The same authors from The Nottingham Trent University also stated, that it is more difficult to recruit skilled labour in the North than in the South and they explained their finding as an indication of an advanced state of the biotechnology industry based in northern Europe that requests more specialised skills *(6)*.

Serious concern must also be drawn from the evidence of the Nottingham Trent group, that according to the respondents the university courses did not meet the requirements of the industry *(2)*. Unfortunately the conservatism as inseparable but interfering trait of the public education systems is seriously hindering the transformation of those vocational profiles needed by new technologies. The public opinion conflicts, challenged by the breakthroughs in biotechnology, are to a great extent the consequence of inconsistency between the actual accumulation of new knowledge and its assimilation in the public, as Rogers has stated *(7)*.

Foreign experiences

In the beginning, biotechnology relied on classical professional profiles, with their adjustment. But the specificity of the field more and more crystallised the need for specific training, more so as the linkage with the science base was tighter *(5)*, and the market expectations greater.

The standardisation of working skills in the frame of a technology defines the professional profile. If in the R&D arena it is sensible to combine the knowledge of various professionals, for the mastering of the biotechnologies one will usually need a defined vocational profile, combining in the technology manager the skills of several classical profiles. It is simpler in cases where biotechnological solutions are incorporated as smaller innovative parts into existent conventional technologies; in these cases the goal can be achieved with retraining. We can not escape the tendency of future professional profiles being much more flexible, as the general knowledge frame is expanding steadily and rapidly, requesting fast changes (readjustment) in skills. So a continuos refresher training will be compulsory for future job candidates. Additionally one must discriminate the needs of a big company from those faced by small biotechnology firms, that will also in future need a more »broadly trained specialist«. On the other side, when we take the example of larger firms, here again all those specialists must be laterally trained for better communication with colleagues of dissimilar professional background and all of them must get a basic ethical orientation in biology and in ecology.

And then there is even a third separate curricular niche, the one of the educators and trainers, who besides having innovative capacities must also have special knack for teaching and motivating students. They are the ones with the greatest responsibility for building up a better public acceptance of biotechnology, so we must give them a good chance for that *(8)*.

The goals for the training of the technical staff will be different. Although the statement holds, that the qualification and skill level in biotechnology as in all new technology is higher than average, technicians are still needed. From the already quoted IRDAC paper I again cite: »....when the knowledge base has grown, there will be a growing need for generalists and technicians who can spread the technology and apply it. Shortage of technicians is now already being felt, with inadequate education structures available to them« *(9)*. In addition a special, social phenomenon of staff inconsistency is present here. In this group of people not so rarely persons will be found, who are hardly climbing the hierarchical ladder and will sooner or later quit this area or we find

Table 1. Forecasted demand by biotechnology SMSs for HSP in 5–10 years *(6)*
Tabela 1. Predvidene potrebe malih biotehnoloških podjetij po visoko kvalificiranem kadru v naslednjih 5–10 letih *(6)*

	Companies based in North Europe Podjetja v severni Evropi			Companies based in South Europe Podjetja v južni Evropi		
	Percentage change Sprememba v procentih					
Disciplines Disciplina	Decrease Zmanjšanje	Increase Povečanje	Static Nespremenjeno	Decrease Zmanjšanje	Increase Povečanje	Static Nespremenjeno
Animal science Živalska proizvodnja	6	57	37	–	63	37
Biochemistry Biokemija	5	43	52	–	60	33
Information technology Informacijska tehnologija	–	46	54	–	67	33
Engineering Tehnika	6	55	39	–	43	57
Fermentation Fermentacija	10	46	44	–	62	38
Immunology Imunologija	3	64	33	–	75	25
Microbiology Mikrobiologija	5	50	45	–	60	40
Molecular genetics Molekularna genetika	4	69	27	8	65	27
Pharmaceutical sciences Farmacija	7	64	29	–	86	14
Plant sciences Rastlinska proizvodnja	–	48	52	12	65	23

here profiles being overrun by the progress but not wanting to go into an effective (re)training. These are often very valuable people with great dedication to the work and the crew but without formal qualifications.

The IRDAC study states: »....there is a need for a better insight into the current R&D and training efforts, so that they can be integrated into a more coherent European framework. At the time that the number of postgraduates is decreasing and that many lesser developed regions lack sufficient facilities, there appears to be a need for concerted action and increased supply of postgraduate specialists (engineers and scientists at pre-doctoral and post-doctoral level) in a number of specific areas. If no action is taken, it seems unlikely that biotechnology will develop significantly in Europe« *(9)*. Similar observations are in the CBI (Confederation of British Industry) report, stating an overall decline in qualified manpower for the nineties, especially in candidates for postgraduate training *(10)*.

An overwiew of possible trends in HSP (highly skilled personnel) in Europe for the next 5 to 10 years is given in Table 1.

The importance of these question in the developed societies can be seen in various initiatives that are emerging to address these problems in Europe. In UK there is NCSB – National Center for School Biotechnology organised with the goal of building and co-ordinating education for biotechnology. Within the European Federation of Biotechnology (EFB) there is a special working group Education in biotechnology. They initiated, under COMETT II, a project with the following tasks:

- estimation of professional and educational capacities in European biotechnology,
- inventory of educational capacities in biotechnology,
- fostering the development and offering educational programmes for biotechnology,
- preparation of training and didactic materials for educational needs,
- co-ordination of mutual recognition of qualifications to enlarge the mobility of students and teachers,
- organisation of international exchange of staff in industry and schools,
- preparation of a network for exchange of educational material, and
- improvement of the public acceptance of biotechnology and its usage.

And where are we? The position is much less organised, even more serious. Especially as we face a double challenge, one of a new technology and the other of the restructuring of the national economy in transition to an effective market type, hopefully with social admixture. Careful observation of the world biotechnology market reveals a regrouping, especially of the small companies. They are growing bigger or merging with huge international corporations. Probably repeating these processes, we will most likely to a certain extent firstly face the initial phase of small companies' appearance, especially should we rely solely on scarce locally available capital. Furthermore, we should not underestimate the fact that in biotechnology the brain drain is still quite considerable, especially of biochemists and molecular biologists, as they are in short supply in the G-7 countries as well.

We can find in Europe as well as in the world some transnational »experiments« that bid training possibilities. A good example, although of a more regional character was the EC network organisation initiative, the so called European Laboratories Without Walls (ELWWs). As a multidisciplinary collaborative association, that was open to researchers from either commerce or academia, it offered excellent training opportunities for those involved. There are also several organisations offering training for the needs of the developing countries. The International Centre for Genetic Engineering and Biotechnology (ICGEB) in Trieste is well known. Similar services are offered by the European Molecular Biology Organisation (EMBO) in Germany and The Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia *(11)*.

Curricular schemes

Internationally, we can find various educational models, from formally stiff and closed to modular and open ones, from solutions starting already at the undergraduate level to the schemes building on postgraduate curricula. Here we need besides the power of vision also rationality, besides the openness also the restraint that not all can be solved by copying foreign paragons. Yet the environment of the developed world is a valuable source of information, especially when it successfully warns us of their mistakes that we should not repeat.

In Europe, one can observe a definite entrance of biotechnology into the high school programmes, on the more general explanatory, but also on the practical skill level. The primary goal that has to be supported is an improvement in the general knowledge concerning biotechnology that should defeat the public resistance against new technology through understanding. But it has to be admitted that it is difficult to be persuasive in fighting the prejudices in cases where these technologies are endorsed by unscrupulous capital interests.

General information on biotechnology should be incorporated in all curricula facing encounter with it, such as agriculture, food science, pharmacy, medicine, environmental sciences, etc. Basic facts on the topic could be included, within a general frame, together with information on other new technologies, also into humanities curricula. We can find this type of programmes in different countries in different forms and they are part of college and university type schemes. There are forms where it is organised as a complete undergraduate programme or in the form of postgraduate training, alone or as a joint programme with biochemistry, microbiology or molecular biology. It is difficult to judge the quality of these programmes, as the background for particular solutions can vary. It is important that in either form, the students get the information and that they acquire knowledge on all the basic items comprising contemporary biotechnology: MABS, animal biotechnology, plant biotechnology, pharmaceuticals, chemicals, biosensors and human (and animal) genom project(s) *(5)*, that are enabled through new powerful techniques like genetic engineering, fermentation technology, protein engineering, transgenesis and immunotechnology.

In composing a curriculum we have to follow elementary strategies, where we prepare a basic subjects framework, and then add specialist and applied contents to cover the vocational needs. Expectations of the students in terms of comparable educational standards, presented by a degree and a type of diploma have to be kept in mind. Basic topics are biochemistry, cell physiology, microbiology, immunology, gene technology, enzyme engineering in biochemical processing. There is a compulsory part in applied mathematics, data evaluation, analytical chemistry to include. The curricular volume finishes with basics in economy, social sciences, economics, patent and safety legislative.

Dill and Dunham reported in a survey about undergraduate biotechnological education in the United States, that they found 30 institutions offering a programme in biotechnology and that in 1991/1992 there were 718 students enrolled. The first programme initiated in 1980, peaking with 6 new programmes in the years 1986 and 1987. It is interesting that 34 % of the graduates chose to further their education in graduate programmes and 42 % of them entered a job in the industry *(12)*.

As already mentioned, a special concern at the tertiary level must be given to the education of the educators. This has to be based on an actualisation and restructuring of the present curricula in biological sciences, but also on a compulsory in-service training of science teachers *(3)*.

Even graduates from a programme with strong applied emphasis need an adaptation period after entering a job, that must be carefully planned. Another postulate in any quality programme are refresher courses, and it is sound if they are already planned in the frame of the original study programme. In this case the knowledge transfer will be most effectively achieved. Here a great chance exists particularly for the distance learning practices (open university). The retraining requirements are especially useful for the marginal knowledge, where there is a greater chance for losing the contact, as a permanent interest coverage is not present. People with biological or processing background ought to get some background in commercial and marketing knowledge. On the other hand people from the management should be permanently kept in touch with the progress in biological sciences but especially with bioethical and biosecurity concerns raised by it. Highly important prerequisites for a successful educational and training undertaking especially in new technologies is an effective electronic data processing and communication support as well as relevant demonstration and training resources for practical work.

In lieu of conclusion here is a statement from the IRDAC Opinion Paper *(9)*:

»... IRDAC above all is convinced that education and training issues related to industrial competence and competitiveness have an overriding importance in relation to the future well-being of Europe and its citizens and merit a trust and a degree of coordination at least equal to that given to the Framework Programme for Research and Development...«

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