FOCUS

Popular teaching of Biotechnology

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ABSTRACT

Within a short period of time, the teaching and popularization of Biotechnology has become a need not only for the academic world, but for society as well. The advances in this field have repercussions within the scientific community, as well as politicians, businessmen, manufacturers, lawyers, journalists and the general population alike. At the same time, Biotechnology as a discipline is not stagnant, but evolves with the findings of related disciplines such as Biology, Biochemistry, Genetics, Microbiology, process-related engineering specialties (chemical, biochemical or industrial) and other sciences such as Physics, Mathematics and Information Technology. Given its importance for society and its multidisciplinary nature, designing a method for the popularized teaching of Biotechnology that gives a general approach to this field and not resulting overly complex is a considerable challenge. Such a design, therefore, must take into account the methodological complexity, resulting in courses with very specific objectives and targeted to a certain audience, or conceived with a general structure offering an overall knowledge of this discipline in varying degrees, depending on the cultural and educational level of the learner. The present paper shows our experience in the design of a Biotechnology course, following a methodological conception for the adaptation of the contents to the specific goals of the course for the targeted audience while following a train of thought and a relationship with the facts of everyday life.

Key words: Teaching Biotechnology, fermentation, recombinant DNA, proteomics, genomics

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RESUMEN

Enseñanza popular de la Biotecnología: La enseñanza de la Biotecnología se ha convertido en pocos años en una necesidad, no solo del mundo académico, sino también de la sociedad en su conjunto. Los científicos y también los políticos, los comerciales, los productores, los abogados, los periodistas, los economistas y la población en general están relacionados de una forma u otra con los avances en esta rama, y a la vez la Biotecnología continúa en desarrollo con los avances de otras ciencias como la Biología, la Bioquímica, la Genética, la Microbiología, las ingenierías vinculadas a procesos (química, bioquímica o industrial), y con otras ciencias como la Física, las Matemáticas y las Ciencias de la Computación. La Biotecnología requiere de todas estas ciencias y tecnologías particulares, pero el problema fundamental consiste en diseñar un método para su estudio que posibilite su enfoque de manera integral de manera que no resulte tan compleja. El diseño de un programa de estudio sobre Biotecnología debe entonces tener en cuenta esta complejidad metodológica y su concepción. El curso debe de estar dirigido a objetivos específicos, sectores determinados, o concebido de forma general para que posibilite apropiarse del conocimiento global en diferentes grados en dependencia del nivel educacional y cultural del receptor. En el presente artículos se muestra la experiencia de diseño de un programa sobre Biotecnología, siguiendo una concepción metodológica que permite adaptar los contenidos y los objetivos específicos que se persiguen según el público al que va dirigido, manteniendo siempre un hilo conductor y una relación con la vida cotidiana.

Palabras claves: Enseñanza de la Biotecnología, tecnología de fermentación, ADN recombinante, proteómica, genómica

*I*ntroduction

Since Biotechnology is a multidisciplinary field influenced by sciences such as Biology, Biochemistry, Genetics, Microbiology, Physics, Mathematics, Information Technology and process-related engineering specialties, an understanding of this discipline requires the knowledge of the scope of each one of these sciences and their conceptual elements, as well as an integrating approach to biotechnology. Therefore, teaching

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Biotechnology to the general population becomes a complex educational process, also requiring the development of the proper methodology.

The design of a program for studying Biotechnology that facilitates its teaching from such a complex perspective, is therefore a challenge. The program or study framework must take into account the specific objectives proposed, the target audience, and the multiple disciplines that form part of biotechnology.

This paper presents a program for the popular teaching of Biotechnology, following a methodological conception based on offering biotechnological elements that are close to the everyday life of the learner. This Program follows a conducting thread and is targeted to a heterogeneous audience in terms of interests, motivations, and educational levels.

Development

In order to design this Program for the popular teaching of Biotechnology, it was first necessary to define its conceptual basis and its methodological characteristics.

Conceptual basis

• The use, as the starting point, of biotechnological processes which are near and familiar to people and can be easily identified due to their close ties to everyday life.

• To place an emphasis on the history of each product, highlighting its relationship to the scientific and technological developments made by mankind in specific historical settings.

• To identify the fields of influence of Biotechnology and link them to mankind and their needs.

This conceptual basis aims at introducing Biotechnology to the student from the perspective of a well known element for an easier understanding of the contents presented, regardless their complexities.

Methodological characteristics of the design

A mnemotechnical device was used to define Biotechnology that facilitates the identification of the main elements of the concept: biological agents, material or substrate, and product (Figure 1).

The elements of the definition are conceptualized on the basis of the particular description for each one of them and their visual identification in the diagram of the biotechnological process.

Different definitions for Biotechnology were analyzed, taking as a reference their common elements in order to structure a mnemotechnical outline in which they can be replaced by examples from everyday life.

The analysis was based on the following definitions:

• Biotechnology is the integrated use of Biochemistry, Microbiology, Genetics and Chemical Engineering that takes advantage, from a technological point of view, of the properties and possibilities of microorganisms and cell cultures [1].

• Biotechnology is the application of scientific and engineering principles to processes where biological agents transform a material into a useful product [2].

• Biotechnology is the set of technologies developed by man which directly or indirectly use living organisms to obtain a product with the maximum posible efficiency, economy and safety [3].

• Biotechnology is the use of living organisms or substances obtained from living organisms for manufacturing products useful to man [4].

• Biotechnology is the application of scientific and engineering principles to the treatment of materials by biological agents or to the direct treatment of biological materials to manufacture goods and services [5].

The common elements identified in these definitions are:

• The presence of a living organism (biological agent).

• The transformation of a material or substrate into a product.

• A link between biological sciences and engineering disciplines.

• The products and services obtained have a value for man.

• The processes to obtain them are economically feasible.

Each element of the outline is then replaced by images taken from real life, with the aim of placing the concept of a biotechnological process into a context which is more familiar to the student (Figures 2 and 3).

The graphic correlation between the historical development of biotechnological products and the progression of scientific and technological development, represented as the Evolution of Biotechnology, is

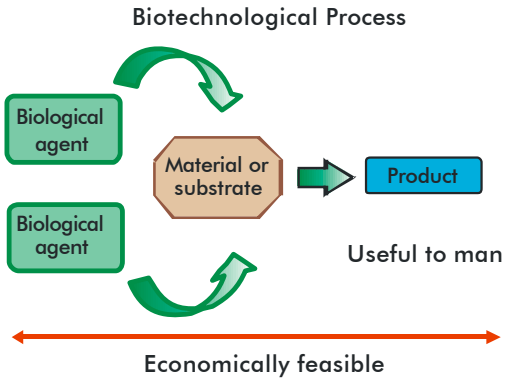

Figure 1. Diagram of a biotechnological process.

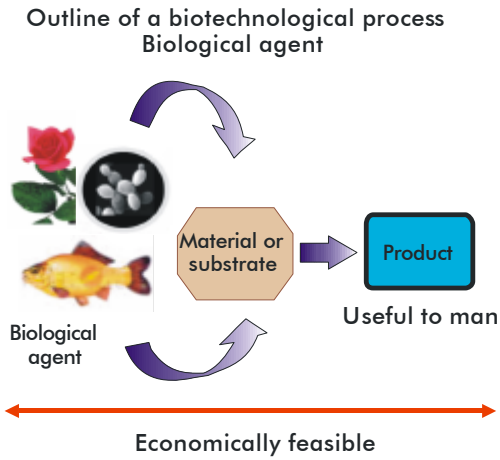

Figure 2. Diagram of a biotechnological process. (Replaced element: biological agent).

1. European Federation of Biotechnology 1978. www.efb-central.org.

2. Bull AT. Compressive Biotechnology: The principles of Biotechnology: Scientific Fundamentals. Publisher, Elsevier Science 1982.

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4. Marx JL. A Revolution in Biotechnology. Cambridge University Press; 1989.

5. Second Organization for Economic Co-operation and Development Ad Hoc Meeting on Biotechnology Statistics, OECD, May 2001.

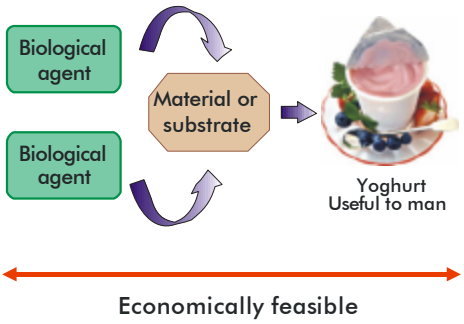

Figure 3. Diagram of a biotechnological process. (Replaced element: product).

designed as another mnemotechnical device for a deeper insight into their history and the development of science and technology, thus becoming a motivation that expands the cultural knowledge on this topic (Figure 4).

The diagram of the evolution of Biotechnology, based on the development of science and technology and on the biotechnological products developed in each historical stage, facilitates the explanation and understanding of each technological breakthrough and places the biotechnologies in a historical context. Furthermore, as an additional motivational element, the most important scientific personalities and the biotechnological products characteristic of each stage are highlighted.

After defining the conceptual bases and establishing the methodological design, these elements were used to structure the contents of the framework of a Program for an Introductory Biotechnology Course addressed to the general population.

The biotechnological products selected for this course were bread, beer, natural vaccines, antibiotics, recombinant vaccines, interferons, enzymes, genetically improved plants and animals, monoclonal antibodies, transgenic plants and animals, tailored medicine and gene therapy.

In order to explain what characterizes each of these products as an element of scientific and technological development, each one of them were linked to the historical developments of mankind. This not only expands the specific knowledge of the learner on Biotechnology, but their general culture as well (Figure 5).

There is a difference between a biological product, obtained from the transformation of a substrate or material by a living organism, and a biotechnological product, defined as a biological product obtained from the transformation of a substrate or material by a living organism, but with the addition of the necessary assays that turn it into a finished product and therefore make it commercially feasible.

Yoghurt is a well-known example of this concept. This biological product can be prepared using a certain amount of fresh milk (the substrate) to which a small volume of yoghurt containing the lactobacilli (biological agent) is added that will transform this milk again into yoghurt (biological product). However, when mentioning yoghurt as a biotechnological product,

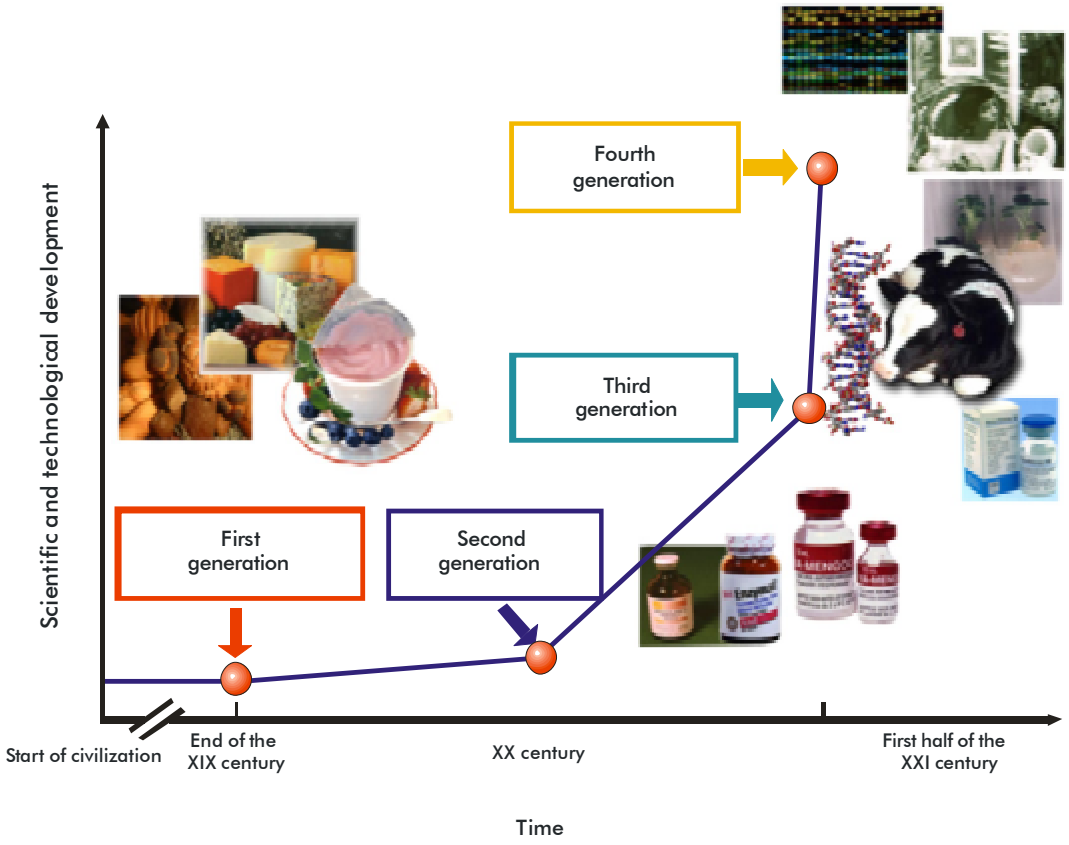

Figure 4. Diagram of the evolution of Biotechnology.

Figure 5. Products of Biotechnology.

reference is being made to a product that undergoes a standardized manufacturing process, to obtain a large volume that meets the demands of the market and that is subjected to assays and tests that guarantee its quality.

This manufacturing process includes not only the biological product, but also bottling, labeling, brand registration, compliance with current regulations, the design of pricing plans and marketing.

The outline of a biotechnological process is then used as the background to illustrate the production of drugs, vaccines and genetically improved animals or plants, which represent biotechnological products (Figures 6 and 7).

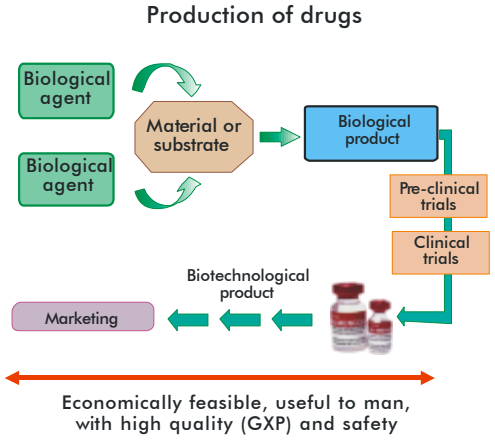

Figure 6. Outline of a biotechnological process. (Obtaining a vaccine). GXP: Good X Practices.

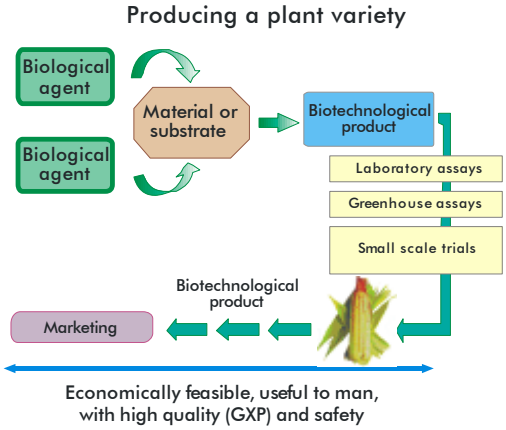

Figure 7. Outline of a biotechnological process. (Producing a transgenic plant). GXP: Good X Practices.

The program of the Introductory Biotechnology Course, based on the mnemotechnical devices mentioned above (Figures 1 and 4) is shown below. This program was structured taking into account that it is targeted to the Cuban population; therefore it also considers its educational and cultural characteristics and its relationship with the public health achievements of our country.

Program for the Introductory Course on Biotechnology (Targeted to the general population)

Role of Science and scientists in the "Battle of Ideas"

Title: Biotechnology for all

The fascinating world of Biotechnology at the reach of the people

Objectives:

•To contribute to the expansion of a general and comprehensive culture of the Cuban population by providing basic knowledge on this discipline in which our country has reached international prominence, facilitating the appropriate interpretation of the biotechnological processes found in our everyday life and environment.

•To train the present and future generations for a better interpretation of the scientific and social phenomena that will inevitably take place as a result of new revolutions in human knowledge.

Characteristics of the Program:

•Flexibility, since it is conceived for different sectors of the population (learners).

•It serves as a starting point in structuring other popularization cycles for a more in depth treatment of these topics.

•It enables the interaction of different institutions.

•It may serve as a reference in preparing programs and printed materials for different educational levels.

Organization of the course

The course is divided into 30 classes and 6 debates.

The audience is trained at the television studio and it involves the participation of high school and university students as active learners.

The course:

• Identifies products of Biotechnology and delves into the scientific milestones that have made them possible.

• Illustrates the advancement of science and its influence on this field, as well as the evolution of biotechnologies up to now.

• Includes debates on the biotechnologies and their incidence on scientific, social, economic and political plans. It compares the Cuban situation with that of other countries, especially Third World countries.

• Presents the development of science in Cuba, particularly that concerning biotechnologies.

Subject plan

Topic I: Introduction to the fascinating world of biotechnologies.

Motivating activity and the presentation of the course.

Topic 2: What is Biotechnology?

Organisms, processes and products of Biotechnology. Related sciences and basic concepts. Evolution and historical development of biotechnologies. Scientific discoveries, processes and products.

Topic 3: Part 1 First-generation biotechnologies:

Beer, wine, bread, cheese, yoghurt and vinegar.

Spontaneous fermentation.

Topic 3: Part 2 Second generation Biotechnology:

Antibiotics, vaccines, vitamins, enzymes, unicellular proteins, alcohol.

Continuous fermentation, cell immobilization, cell and organism cultures. Microbial transformations.

Topic 4: Third generation Biotechnology:

Human insulin, monoclonal antibodies, interferons, human and veterinary recombinant vaccines, plants or animals with resistance to diseases or with higher reproductive rates.

Genetic engineering and cellular engineering.

Topic 5: Fourth generation Biotechnology:

Tailored drugs and gene therapy.

Genomics, proteomics and bioinformatics.

Topic 6: Fields of influence of the biotechnologies:

Pharmaceutical and biomedical sectors. Products.

Topic 7: Fields of influence of the biotechnologies:

Agricultural sector. Products.

Topic 8: Fields of influence of the biotechnologies:

Chemical, environmental and energy sectors. Products

Topic 9: Biodiversity, biosafety, bioethics and biotechnology

Debate and reflection topics: to be defined according to the interests identified during the course. For example:

Debate 1: Intellectual property and the human genome

Debate 4: Gene therapy

Debate 3: Transgenic organisms as a part of the solution

Debate 2: Laboratory animals and their role in Biotechnology

Debate 2: From the laboratory to clinical trials. What are GXP or BXP?

Debate 6: Diagnostics and Biotechnology

Conclusions

An introductory course on Biotechnology was designed using a framework for the popularization of biotechnology, targeted to the Cuban population and taking into account its knowledge, educational levels, interests and motivations. The population, as a whole, is heterogeneous. The basic concept for the design of this course conceives the whole element representing the general population.

Outlines conceived as mnemotechnical devices were designed, representing concepts and processes of Biotechnology in order to facilitate a straightforward appropriation of the elements of the course by the learners and a teaching methodology leading to simpler and more understandable, but still rigorous, explanations of the fundamental elements of this subject.

Everyday images, extracted from the daily life of the target audience and constituting the expression of the biotechnologies in their environment, were used to substitute abstract elements in the diagrams for the course. These elements were taken as starting points, developing the acquisition of knowledge by stimulating the motivation for a more thorough understanding of Biotechnology, following a critical route from simpler to more complex entities.

The conducting thread was the historical evolution of biotechnologies, their products and the scientific knowledge accumulated in each one of them, as well as the most prominent historical personalities within this body of knowledge.

The course was implemented as a set of telecasted classes on a television-based infrastructure; combining the presence of a teacher and the use of independent didactic materials as well as domestic or foreign recordings.

Furthermore, this course is flexible enough for its adaptation to other pedagogical means targeted at specific learners, where a more thorough study of the subject matter is desired.

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