

# A Comprehensive Revision of the Industrial Biotechnology Program in Response to Establish a Bio-Based Economy

Rosa Buxeda and Lorenzo Saliceti-Piazza  
Industrial Biotechnology Program, University of Puerto Rico, Mayagüez Campus  
rbuxeda@ece.uprm.edu, saliceti@uprm.edu

**Abstract** - A comprehensive revision of the Industrial Biotechnology Program (IBP) was developed as a response to the efforts of the government of Puerto Rico to establish a bio-based economy. Changes in economy towards science and high technology require new profiles of knowledge and skills to be incorporated into academic curricula. Globally, biotechnology represents a major driver for high technology professional careers. The demands from the biotechnology workforce sector for development of knowledge and competencies were a driving force for the revision of the IBP. The revision involved government and industrial partners to address the required professional profile. An industrial advisory board has been a key instrument to identify competencies that were incorporated across the curriculum. A faculty committee was also instrumental in designing a strategic plan, proposed new courses, and implemented the industry recommendations. The revision provides an interdisciplinary curriculum, with courses from the schools of science and engineering. Short courses taught by industry provide students with current industrial issues and practices and have generated an industrial network for students. The profile involves strong research experiences as well as industrial internships. Outreach initiatives have resulted in an increased interest from high school students to pursue a degree in biotechnology. The revision has also introduced new outreach educational programs for high school students and continued education for post-college professionals. Furthermore, state-of-the-art research and training infrastructures are part of the revision in order to bring industry-sponsored research and training capabilities to the university. This paper will address how these comprehensive revisions have been incorporated into the university.

*Index Terms* – Academic program revision, Bio-based economy, Industrial advisory board, Educational pipeline.

## INTRODUCTION

Advances in science and technology have propitiated the globalization phenomenon. The internet and modern communications can now connect individuals as distant through oceans and continents within a few keyboard strokes. Globalization has imposed countries to achieve high levels of economic development in order to gain, or to

maintain, their global competitiveness. On the same token, economic development is strongly attached to knowledge in the leading scientific and technological trends. This is the base of the so called knowledge-based economy.

The island of Puerto Rico has delineated its economic development on a high-technology, knowledge-based strategy. This economic strategy needs the coalition of government, industry, and academia to interact synergistically and to provide the conditions and incentives to achieve a common goal of a highly educated and capacitated workforce. Academia, as one of the key players in this economic strategy, is responsible to provide the education, learning and research programs to strengthen the knowledge. The academia is a critical driver of a knowledge-based economy by being part of the innovation process and providing the workforce needed to sustain the productive efforts. Puerto Rico has designated biotechnology as the spearhead of the areas of knowledge to be addressed and promoted. In this paper, we will summarize how the University of Puerto Rico, Mayagüez Campus, has revised and improved its Industrial Biotechnology Program to address the development of biotechnology as a stronghold of the economic strategy based on knowledge.

## BIOTECHNOLOGY AS A GLOBAL ECONOMIC DRIVER

Recent estimates from McKinsey & Company indicate that the industrial biotechnology market will grow from \$77,000 million in 2006 to \$125,000 million in 2010. Only in the United States, biotechnology manufacturing companies accounted for 1.2 million direct employments and 5.8 million indirect jobs in 2006 [1]. It is clear that biotechnology companies will achieve higher levels of product development and production after the complete sequencing of the human genome, which brings the possibility of hundreds of bio therapeutics products, from parental protein formulation to innovative therapeutic methods based on DNA to be introduced in the near future to the world market.

Puerto Rico has become a global leader in biotechnology manufacturing. In 2006, over \$16,000 million of biologics were produced in Puerto Rico. Over 140 FDA/EMEA & MHLW approved pharmaceutical and medical devices plants are in operation in the country. The top six biologics sold in USA are manufactured in Puerto Rico. In the past six years, over \$4,000 million have been invested by biotechnology multinational companies to expand manufacturing operations in the island. The

establishment of these biotechnology-manufacturing sites requires a highly skilled and educated workforce, with a strong presence of scientists and engineers to support the industry.

In 1992, the University of Puerto Rico at Mayagüez (UPRM) established an undergraduate B.S. degree in Industrial Biotechnology. A revision of this program that was started in 2000, addressed current biotechnology trends and workforce profiles and involves a close collaboration between the UPRM and its industrial and government partners.

#### **DRIVERS OF INDUSTRIAL BIOTECHNOLOGY PROGRAM REVISION**

The Industrial Biotechnology Program (IBP) identified the stakeholders that would drive the program revision. These stakeholders represented academia, industry, and government.

- Academia – biotechnology as an interdisciplinary field required academic representation from the faculties of engineering, science, and agriculture. UPRM faculty members from the departments of Biology, Chemistry, Horticulture, General Engineering, and Chemical Engineering were appointed for this committee. The Faculty Committee determined the required knowledge and skills, essential for the determination of fundamental concepts, laboratory experiences, and aptitudes needed in the academic profile of a biotechnologist.
- Industry and government – an Industrial Advisory Board was established to assess knowledge and skills that were considered crucial for a workforce profile and became sponsoring partners of industrial experiences for both faculty and students. The Industrial Advisory Board, with members from both government and industry, has been instrumental in addressing and assessing the strategic plan of the Industrial Biotechnology Program on a year to year basis.

The two stakeholders of the program helped to develop a strategic plan for the IBP that identified goals, program objectives and actions for each of the objectives. The strategic plan consists of five main strategies: curriculum, research, strategic alliances, outreach, and evaluation.

#### **REVISION OF THE INDUSTRIAL BIOTECHNOLOGY PROGRAM**

The revision of the IBP has been performed in close collaboration with the academic, industrial, and government partners in alignment with the establishment strategic plan. It involves six main areas of scope in order to cover the whole range of the educational pipeline of a skilled workforce in biotechnology. These six areas are: (i) pre-college education, (ii) college education, (iii) post-college continued education, (iv) graduate and post-graduate education and research, (v) outreach, and (vi) educational and research infrastructure. Figure 1 shows a schematic representation of the UPRM-IBP educational pipeline, with the final goal to achieve a

knowledge-based economy with biotechnology as its front end.

#### **PRE-COLLEGE EDUCATION**

The Pre-College educational component introduced by the IBP at UPRM established two initiatives at high school level that represent the early stages of the educational pipeline.

##### *I. Biotechnology Summer Camp*

The first initiative is the Biotechnology Summer Camp for High School Students. The goal is “to motivate high school students in the importance and applications of biotechnology and its role in driving a knowledge-based economy.” Qualified high school students are selected to participate in the Biotechnology Summer Camp in workshops, activities, and field trips that address the following topics:

- Molecular biology
- Careers in biotechnology
- Environmental biotechnology
- Marine biotechnology
- Microbiology
- Electron microscopy
- Bioinformatics
- Bioprocess engineering

At the end of the summer camp students must prepare a scientific poster summarizing their biotechnology summer experiences and prepare a reflexive diary, among other activities [2].

##### *II. High School Biotechnology Certifications*

The second initiative in pre-college education involves the collaboration of the IBP with the Department of Education, in which IBP faculty and industrial partners addressed the need of highly qualified personnel for clean room maintenance tasks. With this need in mind, the IBP and industrial partners designed and delivered a one-week training to high school teachers who were instructed on all the theory and hands-on experience in clean room technology. With this experience, the teachers would be able to design a two-year vocational high school certification that will capacitate their earners to work in a clean room not only in biotechnology manufacturing facilities, but also in medical device, pharmaceutical, and hospitals.

#### **COLLEGE EDUCATION**

This is the component in which a significant amount of initiatives and innovations have been incorporated into the program.

##### *I. Industrial Internships*

First, the IBP industrial partners provided the means for industrial experiences with the novelty that not only students, but faculty as well, have performed internships. The scheme

of the internships was adjusted to each of the specific intern needs and interests.

Faculty internships were designed to deliver applied knowledge and experiences in biomanufacturing. The faculty industrial internships were programmed for a short two-week stay in a biotechnology company site. Experiences included job shadowing with a subject matter expert from the company, and lectures from key personnel of the company in the processes and the overall aspects of the product being manufactured at that specific site. A total of ten UPRM faculty members from the faculties of science and engineering have already participated in these industrial internships. After their internships, these faculty members have been involved in providing customized curricula in trainings offered by UPRM to biotechnology company employees and also, their experiences have been incorporated into their courses taught at UPRM. At the same time, faculty interns have become resources in training and continuous education offerings, to be detailed further below (Industrial Biotechnology Learning Center).

A full one-semester industrial internship is an important graduation requirement of the IBP BS degree. With the support of our industrial partners, we have been able to expose students to regulatory environments and industrial practices. Our close interaction with industrial partners has allowed the IBP to establish a list of companies with a fixed number of intern positions. We motivate students to keep updated resumes and each semester provide a resume book of internship candidates to industries. We link our candidates with the Human Resources for interview and selection for internships. Following this strategy has resulted in the placement of 30 of students in internships during the past two years.

Once students are placed, assessment by their industrial mentors involves:

- Questionnaire to industrial mentors on student performance.
- Questionnaire to students on their industrial experiences.
- Mid- and final semester report.

## *II. New Courses and Curriculum*

New courses and a new curriculum has been the product of counseling from the Faculty Committee and the Industrial Advisory Board. The new curriculum was designed to satisfy the needs of a professional profile that would fit into the workforce needed to excel in biotechnology industry and/or to prepare well students for continuing graduate school. The new curriculum incorporates new courses like:

- Introduction to Biotechnology provides students with an entry-level understanding of biotechnology and an overview of the field and its applications. A module on knowledge-based economy is a component of the course in which entrepreneurship will be addressed.
- Capstone Course in Biomanufacturing provides students with an overview of industrial upstream and downstream manufacturing bioprocesses, in which a recombinant proteic molecule is produced using microbial and/or mammalian cell culture technologies. All important aspects in producing a biotechnology product will be

covered theoretically and with a hands-on laboratory experience. The regulatory aspects (cGMP, validation, FDA) of the industrial processes will also be emphasized.

- A physical chemistry course for biotechnologists was developed with the educational objective of providing students with the principles and applications of physical chemistry on living systems and biomolecules.
- A seminar in biotechnology will develop oral skills in the students and will expand their knowledge in biotechnology by examining current trends in the field.
- A one-year biochemistry laboratory became required in order to strengthen student knowledge and laboratory skills in biomolecule production and purification.

## *III. Research*

Undergraduate research is another curriculum requirement for IBP students. A profile of UPRM faculty with undergraduate research projects in biotechnology-related areas was developed by the IBP. Students are interviewed by the researcher. After an agreement is reached, and student starts working under the researcher's mentorship, assessment is performed along the semester. A questionnaire is filled out by the researcher on the student's performance by mid- and end of the semester. Students also fill out a questionnaire on their research experience. Students have the opportunity to perform their research experience either in-campus or in other US mainland campuses. Many US universities provide for summer session undergraduate research internships, which can be validated as their undergraduate research required course. In the past two years, some of our students have also held international research experiences with placements in Spain and France. Industrial sponsorship for travel and housing was crucial to support these international undergraduate research activities.

## *IV. Undergraduate Research through Global Clinic*

The Global Clinic in Biotechnology was established through collaboration among two academic partners, Harvey Mudd College (HMC) and the UPRM; and an industrial sponsor, Amgen Manufacturing, Limited. Student teams from the universities, of diverse cultural backgrounds and different disciplines of study, were assigned an industrial problem to be solved as a team. The summer session was used to allow students to visit each other's campuses and teambuilding. A significant part of the summer also immersed students in a two-week internship at the company to become aware of the assigned industrial project scope. By the end of the summer, the students would have to write and present a proposal to the industrial sponsors for approval. Each university branch was assigned faculty and industrial mentors. Faculty mentors provided counseling on the project's theoretical concepts at their campuses. Industrial mentors provided expertise on the project's goals and applied experimental setup. The industrial mentors facilitated the experience of networking students from different cultural and disciplinary backgrounds. A more detailed description of this initiative

has been submitted to this conference and should be available as reference in the proceedings [3].

#### *V. Short Courses by Industry*

Industrial partners have also collaborated with the IBP in offering short courses by subject matter experts from the companies that have been appointed as joint faculty. These short courses introduced in the curriculum as elective courses provide students with the current trends in industrial biotechnology practices and applications. During the past years, short courses on cGMP, validation, process control, and computer-assisted documentation are a few examples of the courses been taught.

#### *VI. Industrial Plant Tours*

Several plant tours to biotechnology manufacturing facilities have allowed our students to become aware of industrial-scale unit operations and bioprocessing in biomanufacturing. These visits enable students to extrapolate the theoretical and bench-scale knowledge acquired in university with the real-world commercial biotechnology processes.

### **POST-COLLEGE CONTINUED EDUCATION**

Starting on 2003, the IBP established a novel biotechnology manufacturing continuous education program called the Industrial Biotechnology Learning Center (IBLC). The IBLC's main goal is to train and educate the workforce needed to support the biotechnology manufacture environment. This goal has been accomplished by offering customized curricula to biotechnology companies in order to educate and train their employees in several aspects of biotechnology. The customized curricula includes critical areas of knowledge in biotechnology, that span environmental monitoring, documentation, validation, cGMP, fermentation technology, cell culture harvesting, and recombinant protein recovery and purification. The design of the IBLC curriculum involves the strategic partnership between industry and academia to ensure a training that can facilitate the knowledge transfer within the context of current industrial practices under a high-tech environment. This partnership involved selection of the major thrust areas of training, faculty internships in the industry, design of teaching modules (cooperative learning) and hands-on experiences, and feedback from industry subject matter experts with regards to module applications in biomanufacturing processes [4]. The IBLC has impacted over 500 employees from the main biotechnology companies and supply chain distributors.

### **GRADUATE AND POST-GRADUATE EDUCATION AND RESEARCH**

Strong research programs are needed to sustain a knowledge-based economy. In the area of biotechnology, the IBP has been a leader in proposing and making all the efforts for the implementation of the Bioprocess Research and Training Complex (BRTC). This complex will be the host to research

laboratory facilities that will perform industry-sponsored research, in which faculty, graduate students, and post-doctoral interns will work in collaboration with industrial partners in bioprocess development projects. The BRTC will also provide for special training facilities, with microbial and mammalian cell culture technologies, as well as recombinant protein recovery and purification suites. The BRTC will operate under the administration of a board of trustees with members from the government, industry, and academia. An Executive Director is in charge of the operational and research project contracts. The vision of the BRTC is "to contribute to Puerto Rico's knowledge-based economy by providing workforce development services and fostering corporate sponsored research in biotechnology."

In a separate initiative, the Dean of the College of Science at the UPRM is developing a PhD program in biotechnology. An interdisciplinary faculty committee has already designed the curriculum and the graduate courses. The proposed PhD program is expected to be presented to the university officials and faculty within the present year for approval and submission to the UPR President's Office for final implementation.

### **OUTREACH**

#### *I. UPRM Biotechnology Week*

This outreach initiative involves visits of K-12 students in- and out campus. Every year, during the UPRM Biotechnology Week, an Open House activity is organized for high school students, where they are oriented on the different career paths in biotechnology or related areas. This open house includes visits to laboratories in the science and engineering faculties. The Biotechnology Week at UPRM is also used to disseminate biotechnology to the rest of our academic community.

An "Executive Talk Show" with panelists from the biotechnology industry and the economic development government sector was devised to promote consciousness among our students on biotechnology as a business, and of its importance in global economy. Our "Executive Talk Show" has had over 40 participants during the past two years.

Student teams from the major universities throughout the island compete in our Biotechnology Competitions: "BiOlympics" in trivia questions on biotechnology topics during the Biotechnology Week.

#### *II. Latin America and Caribbean Biotechnology Congress*

Every other year, the IBP organizes a Latin America and Caribbean Biotechnology Congress, in which industry and academia present on the current status on biotechnology from the standpoint of both academic research and manufacturing company perspectives. The attendance of our last congress went over 500 participants with sessions spanning from plenaries, science, education, industrial applications, Latin American, technology transfer, roundtables, patient testimonies, and student posters.

## EDUCATIONAL AND RESEARCH INFRASTRUCTURE

## CONCLUSION

The IBLC initiative is supported by a 2,000 square feet facility that houses microbiology and bioprocessing equipment such as bioreactors, tangential flow filtration units, liquid chromatographs, gas supply system, and benches. The equipment was essentially acquired through cash donations. Construction funds were acquired from industry and government.

The BRTC building is under construction through a combined grant from the Puerto Rico government and the US Economic Development Administration (EDA) that totals \$12.5 million. An additional government grant of \$3.5 million was appropriated for the acquisition of laboratory equipment and operational expenses. After its completion, this complex will provide support to the graduate biotechnology programs and will generate industry-sponsored research projects in bioprocessing improvement.

Biotechnology has become a major driver of Puerto Rico's knowledge-based economy. The UPRM has been a strategic partner in supporting biotechnology manufacturing through its Industrial Biotechnology Program. Figure 1 summarizes the holistic approach that the IBP has followed to contribute to the development of a knowledge-based economy, with biotechnology as a main target area of development. Our program has been able to develop and implement several initiatives that cover the spectrum of educational levels, from high school to post-graduate and graduate school. This would not have been possible if the relevant stakeholders of our system: industry, government, and academia, would not have collaborated synergistically to develop and implement a strategic plan.

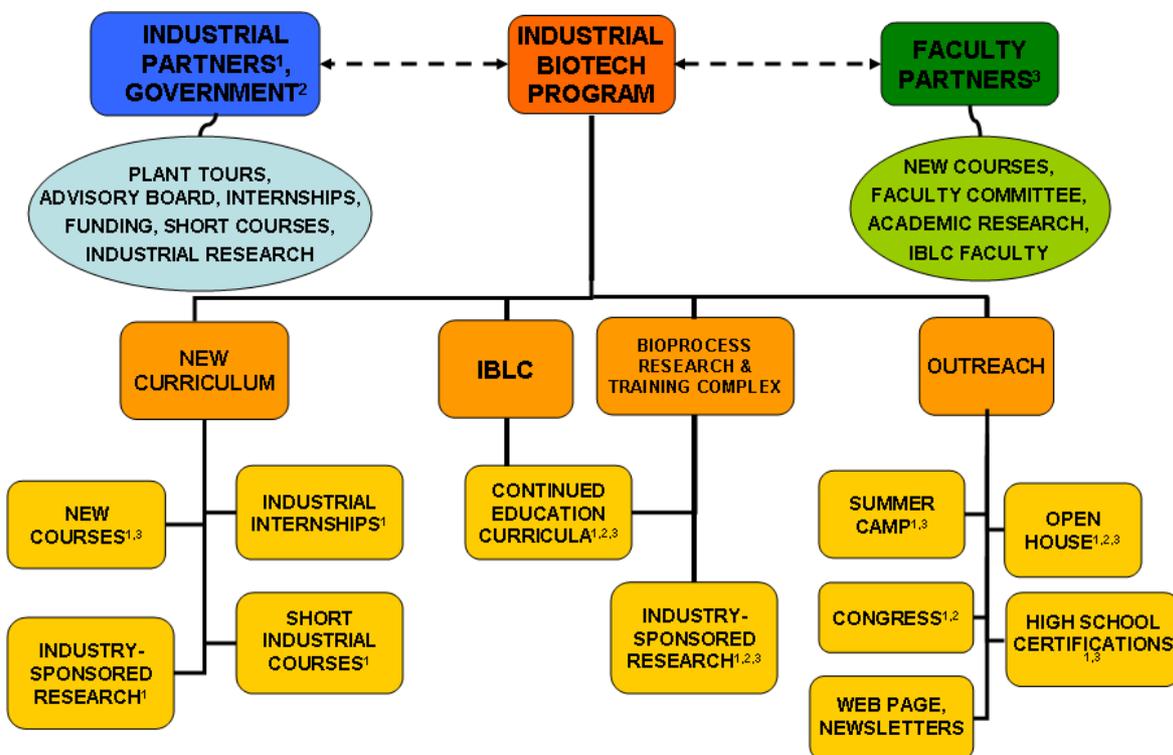


FIGURE 1  
A HOLISTIC APPROACH TO AN INDUSTRIAL BIOTECHNOLOGY THRUST AREA.

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