A Biotechnology Summer Camp for High School Students to Advance the Paradigm in the Establishment of a Knowledge-Based Economy

ROSA BUXEDA & LORENZO SALICETI-PIAZZA
Industrial Biotechnology Program
University of Puerto Rico, Mayagüez Campus
PO Box 9010, Mayagüez, Puerto Rico, 00681-9010
PUERTO RICO
http://www.uprm.edu/biotech/

Abstract: - The island of Puerto Rico is in a transition of its economic development towards a knowledge-based economy, using biotechnology as one of its main drivers. During the past seven years, investments to establish state-of-the-art biotechnology manufacturing plants have exceeded 4.000 million US dollars. This has driven a redirection of the approaches on the science, technology, and engineering educational pipeline to nurture the workforce needed by the growing biotechnology sector. The Industrial Biotechnology Program at the University of Puerto Rico-Mayagüez Campus (UPRM), in close collaboration with the industrial sector, has worked a key initiative to address a nationwide pioneering program for high school students, the Biotechnology Summer Camp. This initiative seeks to motivate high school students and make them aware of biotechnology as a professional career goal and an economic driver to a knowledge-based economy. This paper will fully address how this initiative was conceptualized, successfully implemented, and assessed by the UPRM. The Biotechnology Summer Camp fills a gap in the early stages of our educational pipeline to promote biotechnology as a higher learning objective to our future professional science and engineering generations.

Key-Words: - Knowledge-based economy, government-industry-academia collaboration, biotechnology education, workforce development.

1 Introduction

In order to achieve sustainability, limited-resource countries must be capable of evolving and adapting their economic development programs to the trends and transitions imposed by an ever-increasing globalized system. To attain a high level of sustainability and global market competitiveness, one of the XXI century economic development paradigms relies on how to implement and achieve high-technology economies, also known as knowledge-based economies. The human resources of a country, if well educated, represent the most important asset in a knowledge-based economy, even if limited natural resources might represent constraints. To achieve a knowledge-based economy, education in science, mathematics, engineering, and technology must have to be well established all over the educational pipeline: from elementary schools to higher education. Furthermore, synergy among the government, industrial, and academic sectors must exist to promote the economic growth and for each of the constituents to achieve a successful and beneficial interaction.

Land and natural resources are limited in the case of the Commonwealth of Puerto Rico. This island with a land area of 9.100 square kilometers is geographically located in the Caribbean Sea and is densely populated with 4,3 million inhabitants. In this paper, we will describe how the Industrial Biotechnology Program of the University of Puerto Rico (UPR) developed and implemented a Biotechnology Summer Camp for High School Students that complements other higher education and workforce development initiatives in biotechnology. The Biotechnology Summer Camp introduces talented high school students into the high-tech learning curve early in their educational path. This initiative contributes in converting Puerto Rico's economy to a knowledge-based economy, using biotechnology as one of the key areas of high-tech development.

2 Knowledge-Based Economic Development

Puerto Rico's economic development has evolved from agricultural (sugar cane, XVI-XX centuries), light industry (textiles, 1950-1960's), industrial manufacturing (oil refining and petrochemicals, 1960-1970's), pharmaceutical manufacturing (1970-

present) to biotechnology and medical devices (1990-present). The forty-plus years of pharmaceutical manufacturing experience have provided Puerto Rico with a strong regulatory industrial environment and a highly skilled workforce. Puerto Rico has become one of the largest pharmaceutical manufacturing sites in the world, with nearly 25% of globally important pharmaceutical products being produced there. The biopharma manufacturing activity amounts to about 30% of the gross domestic product and constitutes a cornerstone of well-paid direct and indirect jobs. On the other hand, the pharmaceutical sector is in decline due to the expiration of several drug patents, which brings serious concerns on the sustainability and competitiveness of the present economic development of Puerto Rico based on this industrial sector. The strong presence of pharmaceutical manufacturing sites has generated a workforce with strong knowledge and capabilities in the FDA and EU regulated pharma manufacturing environments, which are similarly pertinent to biotechnology manufacturing.

After the Human Genome Project disclosure in 2003, human healthcare has entered into the post-genome era. Much public interest has been generated on the direct impact biotechnology will have on our lives. The decodification of the human genome opens a new universe of therapeutical treatments based on genetics, DNA manipulation, and biotechnology applications. Within a span of ten years it is expected that roughly 50% of the advanced therapeutic medicines will be obtained through biotechnology. Biotech manufacturing companies are part of the so-called bioscience industries, which account for 1,2 million direct employments in the USA [1].

During the past seven years, the government of Puerto Rico has been able to promote the establishment of new biotechnology manufacturing sites. Economic incentives, as well as the presence of a skilled workforce knowledgeable in the pharma-regulated manufacturing environment, have attracted global biotechnology companies to build manufacturing plants and bring biotechnology transfer for production of their recombinant proteins to Puerto Rico. The Puerto Rico biotech-manufacturing investment portfolio has surpassed an impressive 4.000 million US dollars mark. These include companies like Amgen (2.200 million USD), Eli-Lilly (1.000 million USD), Abbott (500 million USD), Becton Dickinson (50 million USD), and J&J (its subsidiary Ortho Biologics, 12 million USD). Based on this investment profile, Puerto Rico has adopted biotechnology as its spearhead to transform its economic development into one based on high-tech knowledge.

2.1 Biotechnology Initiatives at University of Puerto Rico, Mayagüez Campus

To sustain and achieve global excellence and competitiveness in biotechnology, a knowledge structure must be built from its roots. Furthermore, the government, industrial, and academic sectors must interact and collaborate towards common goals [2, 3]. The University of Puerto Rico at Mayagüez (UPRM) pursued the challenge to collaborate with government and industry to overcome the paradigm of transforming the economic strategy to a knowledge-based one. As part of academia, the UPRM assumed a leading role in transforming Puerto Rico's economy into a biotech-based economy by developing visionary initiatives to advance the knowledge, practice and research in biotechnology in the island of Puerto Rico [4]:

- A BS degree in Industrial Biotechnology, providing young people the fundamental, scientific, and knowledge tools in biotechnology [5].
- An Industrial Biotechnology Learning Center (IBLC), offering customized training in biotechnology basic knowledge and skills, which allows for an accelerated job transition from pharma to biotech manufacturing of senior professionals with experience in pharmaceutical manufacturing [6, 7].
- A Bioprocess Development and Training Complex (BDTC), a facility under construction that will allow academia and biotechnology industries to interact and generate process development and training in biotechnology products.

In order to expand and broaden the educational pipeline in biotechnology, a fourth initiative was needed to motivate high school students and make them aware of biotechnology as a professional career path. This initiative, referred to as the Biotechnology Summer Camp (BSC), will be described with regards to its conceptualization, successful implementation, and assessment.

3 Implementation of the Biotechnology Summer Camp

A proposal to obtain funds for the establishment of a three-year Biotechnology Summer Camp was submitted by the UPRM Industrial Biotechnology Program to the Amgen Foundation. A generous grant from the Amgen Foundation was awarded to UPRM to offer the BSC during the summers of 2005, 2006, and 2007.

The main goal of the BSC was "to motivate high school students in the importance and applications of biotechnology, and its role in driving a

knowledge-based economy". The Industrial Biotechnology Learning Center (IBLC) was used as the main laboratory facility, where most of the summer camp experiences took place. The government of Puerto Rico and other biotechnology industries established in the island were instrumental in providing financial and equipment assistance to establish the IBLC. This is another instance on how government, industry, and academia need to interact to establish a knowledge-based economy.

The BSC objectives included:

- To teach the importance and applications of biotechnology,
- to introduce technology and the critical thinking involved in biotechnology,
- to bring awareness of biotechnology career paths,
- to develop interdisciplinary interactions among peers from different parts of the island,
- to develop written and oral presentations, team work and scientific poster skills, and
- to nurture a mentoring relationship from college faculty and upper level biotechnology students to high school participants.

3.1 Participants Selection Criteria

Biotechnology Summer Camp brochures and application forms were posted at the UPRM website, printed forms were also mailed to nearly 500 public and private high schools throughout Puerto Rico. On average, 400 applications per year were received, of which 60 students were finally selected to participate each summer. In the three BSCs, selected students represented 59 municipalities around the island (Fig. 1). Selection criteria were based on outstanding grades, letters of recommendation from their mathematics and science teachers, and student-written assays stating their motivation in applying to the Biotechnology Summer Camp.

3.2 Design of Biotechnology Summer Camp

The BSC experiences were designed to combine the scientific learning through hands-on experiences with the development of interpersonal skills and team work through social activities and plant trips. UPRM faculty, staff, and mentor students were selected and involved in designing the summer camp workshops and activities in order to be relevant learning experiences as well as fun and interactive.

3.2.1 Biotech summer camp facilitators

The BSC facilitator team was composed by an interdisciplinary group of faculty representing the areas of sciences, agriculture, and engineering. The team was responsible of preparing the lecture and laboratory experiences. A group of graduate students and upper level undergraduate students was chosen and trained to serve as mentors for the participating high school students. The selection of mentors was of utmost importance, since the participants would work in teams under their supervision. The mentors would have to assume a role model for the summer campers. Mentor's profiles included coop experiences in industry, research, oral and written scientific presentations, and leadership skills.

3.2.2 Biotech summer camp workshops and activities

Each Biotech Summer Camp session (two weeks of length) included workshops in fundamentals and applications of biotechnology, as well as plant trips and social activities. Teamwork was emphasized in every activity since a group of six campers were assigned to a mentor. The Summer Camp workshops and outcomes are listed in Table 1.

Fig. 1. Municipalities with participation in the BSC.

Table 1. Workshops of BSC and outcomes.

WORKSHOP	LEARNING OUTCOMES
Teamwork	Interactions between mentors-campers and among campers were established.
Poster Presentation	Students familiarized with software to prepare scientific poster and developed the templates to be completed throughout the summer camp for their team poster.
Careers in Biotech	Learnt about the roles of a biotechnologist in industrial and research environments.
Molecular Biology	Performed DNA extraction, bacterial transformation, gel electrophoresis, and forensic applications.
Microbiology	Experienced microscopic examination, aseptic techniques, culture of microorganisms, environmental monitoring, and gowning.
Environmental Biotechnology	Were shown the role of biotechnology in bioremediation.
Marine Biotechnology	Learnt about the potential of marine ecosystems to obtain new products.
Bioprocess Engineering	Cultured a recombinant bacterial strain in bioreactors, monitored physical and chemical parameters, constructed a growth curve and purified the recombinant protein.
Protein Modeling	Manipulated software for protein visualization and conformational changes.

Table 2 shows a significant increase in the knowledge of participating students, who were exposed in the several BSC workshops to careers in biotechnology, academic programs to pursue a biotech-related career path, preparation of a scientific poster, and experiments in biotechnology.

Table 2. Comparison of knowledge and skills improvement as a result of the BSC experiences.

CRITERIA	% STUDENTS	
STUDENT'S KNOWLEDGE AND SKILLS IN:	BEFORE	AFTER
Careers in biotechnology	13	93
Academic programs in biotechnology	16	90
Preparation of a scientific poster	30	99
Experiments in biotechnology (DNA extraction, fermentation, microbiology, etc.)	11	99

In order to promote teamwork, the following recreational activities and tours were provided to complement the scientific experiences:

- Tour of a tropical forest and its biodiversity.
- Tour of a coral reef and a mangrove, their ecological importance.
- Tour of a biotechnology manufacturing plant.
- Paper recycling.
- Pool party.
- Movie night.
- Volleyball competition.
- Bowling competition.
- Talent show.

3.2.3 Biotech summer camp assignments

Each team of campers was assigned the following tasks:

- To write a reflexive diary.
- To organize and perform a talent show.
- To prepare and present a scientific poster.

The reflexive dairy allowed the students on a daily basis to address what they learnt and how relevant it was to them as a student and as a person. In the talent show, the students had to team-perform a show in which they used their talents to address an issue in biotechnology. Finally, at the end of the BSC, each team would have to present to the community a scientific poster in which they documented the impact that the BSC exerted on their learning and perception of biotechnology; while at the same time, to discuss the topics covered during their experience.

3.3 Summer Camp Assessment

The effectiveness of the BSC in compliance with the program goal to "make high school students aware of the emerging field of biotech" was determined using the following instruments:

- Pre-test.
- Post-test.
- Overall assessment forms.
- Workshops assessment.
- Mentor performance and assessment.

3.3.1 Pre-test

The pre-test was administered the first day of the Biotech Summer Camp to learn about student's previous knowledge and experiences in biotechnology. Eighty one percent of the participants had never been exposed to biotech throughout their high school courses or activities.

On student study preferences, data suggested preferences toward classical careers, such as engineering, biology and chemistry. Approximately, 77% of the population indicated having no knowledge about the role of a biotechnologist in the workplace. Forty-two percent of the participants considered biotechnology as a major driver of Puerto Rico's economy.

On the profile of the participants' previous experiences in activities addressing biotechnology as a career path, data indicated that less than 45% and only 26% of the students had the opportunity to visit universities and industries, respectively. In addition,

only 16% had knowledge of academic programs in biotechnology. Thirty percent had been exposed to the preparation of a scientific poster. Surprisingly, 71% correctly defined DNA, while only 11% had practical experiences extracting DNA.

3.3.2 Post-test

After completing the two-week BSC experience, a post-test was administered to all participants. Collected data indicated a shift in student preferences toward academic programs when compared to their preferences prior to the Summer Camp. A three-fold increase in preference to the biotechnology field was expressed by the students. In addition, 93% of the participants indicated that the BSC exposed them to the role of biotechnologists in the workforce. This represents a four-fold increase when compared to the pre-test. Eighty three percent of the students demonstrated understanding the importance of biotechnology in Puerto Rico's economy, representing a two-fold increase when compared to pre-test data.

The post-test data suggests that after completion of the BSC students successfully became exposed to:

- using a computer to design a scientific poster,
- learning about biotechnology academic programs, visiting the university and the biotech industry, and
- working hands-on with laboratory experiences in biotechnology.

The post-test data also indicated that while 79% of the students knew about DNA after completing Summer Camp, 87% of the participants were able to properly define DNA and its applications. This represents a 1.2-fold increase over their previous knowledge. Practical experiences with DNA increased by a nine-fold.

3.3.3 Overall and workshops assessments

After completing the BSC, students filled out an evaluation form to assess their overall learning experience.

Using a scale from 1 to 5 (1–poor, 5–excellent), the criteria involved assessment of all workshops as well as format and impact of the experiences. Criteria are listed on Table 3 along with the resulting student assessment. The data showed values higher than 4 for all criteria, with an overall assessment of 4.8. A hundred percent of the students would recommend the BSC to a friend and 93% would consider biotechnology as a career path in the future.

Individual workshops were also assessed by the students using the same scale. Values over 4 were obtained in all criteria, as shown in Table 4.

3.3.4 Assessment of mentors

Participants assessed mentor performance in criteria such as leadership, role as a facilitator, accessibility and contribution to make the Summer Camp a successful experience. Mentor assessment results indicated values above 96% for the following criteria: accessibility, contribution to a positive environment, leadership, expertise, facilitation in the work and group interaction.

Table 3 Overall assessment using a scale of 1 to 5 (1–poor; 5–excellent) in a population of 120 students.

CRITERIA	AVERAGE
The workshops were provoking, stimulating and exciting.	4.6
The summer camp provided familiarization with biotech applications.	5.0
Information was presented in an organized fashion.	4.7
I learned about career paths in biotechnology.	4.7
The information presented was relevant to the field.	4.8
The objectives were clearly stated and accomplished.	4.7
The overall summer camp atmosphere was friendly.	4.8
Preparing a poster was a valuable professional experience.	4.7
There was an invaluable interaction with the upper level undergraduate and graduate students.	4.8
Workshops were interactive.	4.6
Mentoring was a positive experience.	4.9
I learned about the importance of biotech for Puerto Rico's economy.	4.7
The summer camp stimulated a teamwork environment.	4.9
Development of interpersonal skills was part of summer camp.	4.8
Being in a university environment was an invaluable experience.	4.9
The summer camp has created consciousness in sharing my experiences with the community.	4.8

Table 4. Assessment of workshops offered in the BSC, using a scale of 1 to 5 (1–poor; 5–excellent) in a population of 120 students.

WORKSHOP	AVERAGE
Teambuilding skills	4.8
Career paths in biotechnology	4.6
Molecular Biology	4.9
Microbiology	4.7
Bioprocessing	4.6
Marine Biotechnology	4.7
Environmental Biotechnology	4.5
Protein Modeling	4.1

3.3.5 Scientific posters

Throughout the BSC session, student teams had to design a scientific poster in which they would

summarize in their own words and creativity, their learning experiences. Parents and community would attend the poster session meeting to learn from the students about biotechnology and the BSC. This was one of the most relevant and rewarding activities of the program, to stimulate participants in the dissemination on the relevance of biotechnology in providing the humankind with useful discoveries and products.

4 Conclusion

As has been discussed, the economic development of a country based on knowledge involves a complex paradigm in order to attain success under a global context. Puerto Rico has decided to base its economic development on biotechnology as one of its key areas. In order to be successful, the learning of biotechnology subjects has to be incorporated early during the educational and learning curve of future generations. The academia, in collaboration with industry, established an implemented a Biotechnology Summer Camp to introduce biotechnology topics and its importance to high school students. The assessment of the BSC pointed out that this initiative was successful in teaching pre-college students the basic fundamentals and applications of biotechnology, as well as its importance in the economic development of their country. The main goal of UPRM to broaden and disseminate the Commonwealth of Puerto Rico's biotechnology educational pipeline to achieve a bio-based economy was expanded with the initiative of the Biotechnology Summer Camp.

References:

[1] Batelle Technology Partnership Practice and State Science and Technology Institute, Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006, *Technology Partnership Practice,* April, 2006.

[2] Buxeda, Rosa, Lueny Morell, Jorge I. Vélez-Arocho, Alejandro Ruiz, William Lockwood-Benet, and Manuel Hormaza, Multi-Sector Alliance to Strengthen Biotechnology Programs in Response to Economic Development Based on High Tech, *Proceedings of the International Conference of Engineering Education and Research (iCEER)*, Ankara, Turkey, 2002.

[3] Saliceti-Piazza, Lorenzo, Rosa Buxeda, Emilio Rivera, Manuel Hormaza, and Lueny Morell, University-Industry Partnership: An Important Cornerstone for Puerto Rico's Biotechnology Cluster Development, *Industry & Higher Education*, Vol. 17, 2003, pp. 435-439.

[4] Rosa Buxeda, Lorenzo Saliceti-Piazza, Emilio Rivera, and Enrique Mirandes, Support of a Bio-Based Economy in Puerto Rico through Academia-Industry-Government Collaboration: Implementing a Biotechnology Educational Pipeline, *Proceedings of the 2007 International Technology, Education and Development Conference,* Valencia, Spain, 2007.

[5] Rosa Buxeda, Lorenzo Saliceti-Piazza, Rodolfo Romañach, Carlos Ríos-Velázquez, John Gill, Jorge I. Vélez-Arocho, Doris Ramírez, and Alejandro Ruiz, Industrial Biotechnology - the Incorporation of Biotechnology into the Higher Education System to Contribute to a Knowledge-Based Economy, *Proceedings of the 6th International Consortium on Agricultural Biotechnology Research (ICABR)*, Ravello, Italy, 2002.

[6] Lorenzo Saliceti-Piazza, Rosa Buxeda, and Rodolfo Romañach, Industrial Biotechnology Learning Center: an Industry-Academia Training Model in Response to Strategic High-Tech Economic Development, *Proceedings of the 7th Baltic Region Seminar on Engineering Education*, St. Petersburg, Russia, 2003.

[7] Lorenzo Saliceti-Piazza and Rosa Buxeda, The Industrial Biotechnology Learning Center: a Key Strategy for Economic Development Through Workforce Training in Biotechnology Manufacturing, P*roceedings of the 10th International Consortium on Agricultural Biotechnology Research (ICABR)*, Ravello, Italy, 2003.

Acknowledgements:

The authors wish to acknowledge the Amgen Foundation for their generous financial support to the Biotechnology Summer Camp initiative.