AC 2007-2957: BRIDGES TO THE FUTURE – INFUSING CUTTING-EDGE RESEARCH INTO UNDERGRADUATE BIOTECHNOLOGY CURRICULUM

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Abstract

The last several decades in biology have seen tremendous research in recombinant DNA technology and its applications in medicine, agriculture and the environment. The next century will see the evolution of new technologies needed for bioprocessing therapeutic drugs, proteins and enzymes generated through recombinant DNA technology. These new technologies have profoundly transformed the way scientists design, perform and analyze experiments. As biological concepts and models become more quantitative, biological research is increasingly dependent on concepts and methods drawn from other scientific disciplines. Thus as biology becomes more quantitative and systematic, it will become a foundational science for engineering similar to physics, chemistry and mathematics.

The long term goal of this project is to design and disseminate interdisciplinary teaching material that will bridge different disciplines and provide an increasing understanding of the relevance of concepts of chemistry, engineering, and computing in biology. The objectives are to: (1) Develop an interdisciplinary biotechnology curriculum for Bachelor’s in biotechnology (2) Design and disseminate project-based modules that will guide students through the process of scientific discovery to commercial production to enhance investigative and collaborative learning and implement the parallel process of assessment for this approach to verify student learning.

Due to modular nature of our project, the model can be easily adapted by other institutions nationally and therefore has excellent potential to reach a large number of students.

1. Introduction

The field of Biotechnology has become more quantitative and interdisciplinary as research in biotechnology continues to grow at a tremendous rate with broader and complex applications in medicine, agriculture, the environment and nanobiotechnology. The challenge in biotechnology education therefore lies in designing new curricula that will provide students with a breath of knowledge and skills across a variety of scientific and technological disciplines to better prepare them for employment in this rapidly changing field.

2. Rationale

In spite of efforts by academic institutions to change curricular materials to include concepts from physics, chemistry, engineering and math, undergraduate biology education has not kept up with the rapid changes in life science research in the past two decades and our undergraduate students are at a distinct disadvantage since they lack interdisciplinary skills to face the rapidly changing practices in life science research (as pointed out in the BIO 2010 report from the National Research Council). Therefore, in order to prepare our undergraduate life science students to be future research biologists, we need to transform undergraduate education (as recommended by the same report). This will require life science majors to develop and
reinforce connections between biology and other scientific disciplines so that interdisciplinary thinking and work becomes second nature. With the integration of new technologies in biological research, biology will continue to become more interdisciplinary and will present a challenge to higher institutions that are training future biologists. The challenge therefore in developing a new curriculum will be to provide students with knowledge and skills that span across basic sciences, engineering mathematics and technology. Addressing this challenge is the top priority for this institution, which is surrounded by a medical center that has the highest density of universities, clinical facilities, biomedical research facilities and health care institutions in the world. With its 42 member institutions, this medical center is a hub for world class biomedical cutting edge research. Amongst these institutions is a top ranked cancer hospital conducting research that has significant commercial and technological value and a University Health Science Center, which is nationally recognized as a leader in BioSecurity and public health preparedness. Also located in the city is a university that is considered to be one of the leaders in nanotechnology research.

To address these needs, this institution is developing an interdisciplinary undergraduate biotechnology program. The new curriculum will provide students with a breadth of knowledge and skills across a variety of scientific and technological disciplines. The program requires students to enroll in classes that will provide them with a strong foundation in biology, chemistry, and information technology and computer science. The program also offers a bioprocessing and bioinformatics track. These two tracks, in addition to enhancing employment opportunities in the biotechnology industry, will also expose life science majors to principles and concepts in mathematics, engineering and the use of computers in the acquisition and processing of data. The PI is developing this multidisciplinary undergraduate curriculum in collaboration with the College of Technology and The College of Natural Sciences that will assist students in making these interdisciplinary connections. In addition, she will closely collaborate with Dr. Melinda Wales of Texas A & M University to infuse her research to develop a project based undergraduate curricula. The field of biotechnology that had focused on production and characterization of biomolecules has now evolved to the bioprocessing of recombinant DNA products. Understanding of the principles and applications of these new technologies will require mastering new concepts and skills for the biology major. This project based curricula will go beyond the basic techniques of molecular biology to integrate bioprocessing, bioinformatics and nanobiotechnology into biology. The topic of environmental biotechnology and bioprocessing is also timely, considering the energy crisis and threats of bioterrorism in the recent years. In understanding the principles of environmental biotechnology and bioprocessing, students will also gain knowledge on how living systems manage their chemistry and how society can benefit by mimicking such processes. This project based curriculum will take the students through the guided process of scientific discovery and investigation to follow its applications in the real world. With a combination of field experience, wet and in silico labs, the students will gain a unique perspective on modern day science. In addition, the modular nature of this curriculum makes it very flexible to integrate it into microbiology, environmental biology, biotechnology, and chemistry.

3. Project Plan
Currently the biology department offers only one course, “Principles of Biotechnology” that surveys molecular methods used in modern biotechnology. Guest presentations on legal, ethical, medical and business aspects of biotechnology cover the relevance of biotechnology in this field. However, it does not discuss the elements of bioprocessing and biomanufacturing that follow the cloning of gene and expression of the gene product. Embedded in these processes are concepts of engineering, technology, and computers that the students are required to master in order to understand the principles of bioprocessing. The course also does not go beyond immediate applications to include advances in nanobiotechnology and its applications. The plan is to develop an introductory section, which will be infused in this course that will survey the principles of bioprocessing and it applications. This section will then be a foundation upon which the new courses, “Biotechnology Manufacturing Processes” and “Biotechnology Regulatory Environment” will be developed.

The current laboratory curriculum offered is a group of independent and unrelated laboratory activities that provide information on classical biochemical and molecular techniques. This project will develop lab activities from data collection, molecular techniques of isolation, transformation, gene cloning to bioprocessing of the gene product and applications and is based on research conducted by Dr. James Wild and Dr. Melinda Wales at Texas A & M University. These lab exercises will then be the foundation of two proposed laboratory courses for the undergraduate biotechnology program. The first lab will teach basic molecular techniques and its applications and the second lab will concentrate on bioprocessing of recombinant product including upstream and downstream processing and concepts and principles of nanobiotechnology. The soil bacterium *Pseudomonas diminuta* will be used as a model for this project- based curriculum. A plasmid encoded gene in this bacterium is responsible for degradation of pesticides, namely organophosphorous compounds (OP) and is activated only by the presence of these pesticides in the soil, thus providing a unique method of detection of pesticides. The OP system was chosen for this project because of the ease with which it can be integrated into the undergraduate curriculum. The bacteria are commonly found in soil and are fairly easy to isolate and grow. The OP degrading gene has been identified, cloned and expressed and the upstream and downstream processes of the protein production very well characterized. In addition, the potential application of this research in nanobiotechnology makes it extremely valuable to undergraduate curricula as students can relate the potential values of scientific discoveries in everyday life. We believe that using this approach will provide a cohesive framework of interdisciplinary elements that incorporates 21st century cutting edge research and its applications into undergraduate teaching to prepare our undergraduates for the future challenges in biological research.

4. Goals and Objectives

The long term goal of this project is to design and disseminate interdisciplinary teaching material that will bridge different disciplines and provide an increasing understanding of the relevance of concepts of chemistry, engineering, and computers in biology. Phase I objectives in developing this interdisciplinary curriculum are: (1) **Modifying and Updating Curricula for biology majors course** by introducing concepts, techniques and applications of bioprocessing and nanobiotechnology in the course, “Principles of Biotechnology” to follow the pipeline of the recombinant product from cloning to expression of the product to production and applications in
nanobiotechnology and (2) Designing and disseminating project-based modules which will be integrated into the new biotechnology and bioprocessing laboratories.

4a. Modify and Update Curricula for biology major’s course:

This module will consist of Industrial and Environmental Biotechnology, beginning with discussion of enzyme based biocatalyst and their role in breakdown of chemicals, production of renewable energy, the role of biotechnology in monitoring environmental pollutants and use of biosensors in detecting chemical warfare agents. The biomanufacturing module will discuss the upstream and downstream processes of recombinant product manufacturing that includes design and use of bioreactors in isolation and purification of recombinant protein. This lecture will be followed by a presentation by Dr. Melinda Wales on the role of OP research in nanobiotechnology. During the course of the semester presentations will also be conducted by experts relevant to the topic of discussion. For example, a lecture on patenting biotechnology inventions will be followed by a presentation on patent law. The courses will end with a capstone activity in which students will use the information that they have learned and tie together the central concepts of the course by writing a business proposal for a biotech start up.

4b. Designing and disseminating project-based laboratory

Three sets of activity modules will cover topics from microbiology techniques, molecular techniques and applications to biomanufacturing techniques/technology and introduction to nanotechnology. The common theme that connects these modules will be the soil bacterium *Pseudomonas dimunita*, its OP gene, the gene product and applications in environmental biotechnology.

4b.1. Description of Module 1

The content of the first module is ideal for non-majors and high school students, where students will pose questions and learn science through discovery, a useful skill regardless of the discipline. Students will collect different soil samples to isolate the soil bacterium *Pseudomonas dimunita* and perform basic microbiological techniques. Students will be challenged to pose logical questions and then collect data to support or refute their hypothesis. This module includes a field trip, where students will collect, compare and analyze different soil samples for the presence of the OP enzyme. This pesticide degrading activity is often detected in soils that contain pesticides. A parallel theme of interest, antibiotic resistance, will also be discussed. As students cover introductory concepts central to microbiology, they will be able to identify essential features of their isolates. After identifying isolates they will conduct experiments to investigate the antibiotic resistance of their isolates. Students will be assigned reading from Dr. Wales’ selected publications to study the relevance of the concepts they studied.

4b.3. Description of Module 2

The content of the second module will include activities that integrate analytical and interpretive skills, through asking questions and problem solving and achieving a goal at the end of the experiment. Some of the techniques will be repeated, so that the students can apply techniques
in multiple settings. The activities using wet and in silico labs will assay for the enzyme, study the structure of the gene and protein, cloning transformation and expression of the gene product. The capstone activity for this module will be a paper discussing the potential application of what they have learned in the field of commercial biotechnology.

4b.4: Description of Module 3

This module is comprised of activities that emulate large scale production used in industry. Students will monitor a variety of cells and become familiar with sterilization, aseptic inoculation, operation and monitoring of fermentors and bioreactors. Students will recover and purify the recombinant protein using centrifugation, ultrafiltration and chromatography techniques. The module will also emphasize current good manufacturing practices as they apply to the biotechnology industry. Students will work in groups to develop best strategies to operate the bioreactor for protein purification and production. This module includes activities that will expose the students to the new and emerging area of nanobiotecholgy and its applications. Students will be introduced to biosensors and the use of OP enzyme in detection of chemicals, including those used in chemical warfare. They will visit a local biotech company that runs a biomanufacturing facility to observe products been developed for market under compliance. Capstone activity for this module will be a group presentation of commercial production of a recombinant product; each team member will also discuss the importance of different areas (regulatory affairs, Research and Development, protein production and purification, cell culture) as they relate to commercial production. For this module we will develop an additional assessment tool in collaboration with our advisory members from the biotechnology industry. The performance review tool developed by the biotechnology industry routinely assesses performance of their employees and will be used to assess mastery of laboratory techniques for this module.

5. Assessment and Evaluation:

Both formative and summative evaluation will be conducted for assessment. Since this project includes both learner and instructor centered outcomes, the assessment and evaluation phase of the project will include methods that address both goals. For the instructor-centered outcomes (laboratory manual), we will first review our own work at every step. The experiments will be developed at our institution and the material will be accessible on the web portal for our colleagues to peer review. We will also enlist faculty from other institutions to review the materials. In addition, this material will also be assessed by our industry advisory committee and academic advisory committee.

The learner-centered assessment of this project will consist of two main parts. The first phase will involve testing the effectiveness of the course in terms of knowledge, skills and overall impact. Student success will be measured through pre and post tests, quizzes, exams, presentations and written assignments. In addition, the performance review tool which will be developed in collaboration with our industry representatives will be used to assess student skills in module 3.

6. Conclusion:
With the evolution of new technologies, the field of biotechnology has become more quantitative and interdisciplinary as research in biotechnology continues to grow at a tremendous rate with broader and complex applications in medicine, agriculture, environment and nanobiotechnology. As biological concepts and models become more quantitative, biological research is increasingly dependent on concepts and methods drawn from other scientific disciplines.

In order to prepare our students to face the new challenges of an increasingly interdisciplinary research, this institution is developing an interdisciplinary project based biotechnology program in collaboration with industry and academic partners which will provide a cohesive framework of interdisciplinary elements that incorporates 21st century cutting edge research and its applications into undergraduate teaching. The modular nature of this curriculum makes it very flexible to be adapted by other institution and can serve as a model for interdisciplinary undergraduate biotechnology education.

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