

**2006-898: IMPACT OF CONVERGING DISCIPLINES IN CURRICULUM DESIGN
FOR BIOTECHNOLOGY MINOR IN INDUSTRIAL TECHNOLOGY**

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Impact of Converging Disciplines in Curriculum Design for Biotechnology Minor in Industrial Technology

Tremendous advances are being made in pharmaceutical and biotechnology discoveries and their applications (including manufacturing), as well as in health care services. As a result, there is an increasing sophistication of the products and services available and being developed, with an ever-widening scale of applications and marketing. The growth of biotechnology results in ever-expanding needs for college graduates who have knowledge of life-science based products and processes. There have been numerous reports of current and projected shortages of human resources possessing the required knowledge in the growing industry. In order to address the gap between education and the workforce, the Department of Industrial Technology has developed an academic minor in biotechnology being implemented in fall 2004.

This interdisciplinary biotechnology initiative is the result of a partnership among the Department of Industrial Technology, the Department of Biology, and the Department of Pharmacy. The program is administered within the Department of Industrial Technology. The minor is taken while the student continues his/her academic field of study and is made up of the following courses: Fundamentals of Biology, Molecular Biology and Genetics, Cell Biology, Biotechnology Laboratory courses, Regulatory Compliance, Process Quality Control, and Bioinformatics. The minor is available to any Purdue University student majoring in any four-year degree baccalaureate degree program, i.e., science, technology, engineering, agriculture, pharmacy. The purpose of the minor is to offer the graduates of these four-year programs the basic knowledge and understanding of life-science based products, processes, and product quality to seek employment opportunities in the area of biotechnology and biotech-manufacturing.

The objectives of this paper are to describe the design and implementation of the new curriculum.

- Three courses within the biotechnology minor have been designed by faculty within the Department of Industrial Technology: Biotechnology Laboratory I, Biotechnology Laboratory II, and Bioinformatics.
- The paper describes selection criteria for course content and topics as it pertains to biotechnology manufacturing.

The courses within the biotechnology minor prepare students from multiple degree programs for careers within life science-based industries.

Introduction

Biotechnology refers to harnessing the properties of a living organism to develop and manufacture products that benefit human life. Although the biotechnology field has existed for nearly a century, scientific advances have caused exponential growth over the past decade. This growth has resulted in an industry with a shortage of employees familiar with and skilled in the biotechnology field and therefore, a dramatic increase in

biotechnology programs across the country. Many of the biotechnology programs granting degrees are based within life sciences departments. However, the biotechnology program we have developed is unique because it integrates life sciences with technology by encouraging collaborative partnerships across the campus with both faculty and students from diverse disciplines. Currently, the program is offered as a minor: an interdisciplinary partnership between the Colleges of Agriculture, Pharmacy, Science and Technology. The program is administered within the Department of Industrial Technology. In addition, a partnership with the Bindley Bioscience Center at Discovery Park enables students enrolled in the program to participate in authentic research projects that merge the life sciences with technology in an inquiry-based learning environment. The curriculum provides future graduates with the opportunity to enter the growing field of biotechnology and biotech-manufacturing with greater familiarity and a better skill set.

The minor is available to any Purdue University student majoring in any four-year degree baccalaureate degree program, i.e., science, technology, agriculture, and pharmacy. Through this partnership, laboratory activities were implemented fall 2004 to educate and train the students currently enrolled within this program. A Small Group Instructional Diagnosis (SGID) was conducted by the Center for Instructional Excellence at Purdue University after the Spring 2005 semester to determine what components of the curriculum were effective and what components of the curriculum were ineffective. The results of the SGID are indicated below:

Table 1

Small Group Instructional Diagnosis	
I. What do you like about this course?	
<i>Course Content</i>	Liked the content and material; real-life application of material very applicable
<i>Teaching Techniques</i>	Ratio of students to professor has been very helpful, full of appropriate coursework, students were able to influence the teaching style
<i>Instructor Characteristics</i>	Instructor was well-prepared, very flexible, very approachable
II. What specific suggestions do you have for changing this course?	
<i>Course Organization and Structure</i>	More online resources would be helpful
<i>Course Content</i>	Provide a larger knowledge or teaching of some of the more basic concepts so that it is easier to grasp the overall idea; would like to do a greater variety of experiments

In order to address the concerns of the students noted above in the results from the SGID, the course was modified for Fall 2005. One of the significant changes was a partnership with an interdisciplinary bioengineering research facility on campus, Bindley Bioscience Center within Discovery Park at Purdue University. This partnership provided the

students with hands-on experience on bioengineering research instrumentation and exposed them to a research environment as opposed to a traditional teaching lab. In addition, the partnership increased the impact of the research by engaging undergraduate students. A grant obtained from Purdue University and Li-Cor Biosciences from the Genomics Education Matching Fund program, provided a DNA sequencing instrument to integrate into the biotechnology curriculum also. In addition, a one-hour lecture was added to facilitate teaching more background and theory prior to conducting the experiment. Finally, in order to assess the students' learning an electronic portfolio was completed that contained writing activities and projects. The electronic portfolio assignments were piloted to assess the students' understanding of the impact of the technology on the field of biotechnology, encourage the students to develop critical and creative thinking skills by integrating and applying knowledge from the lecture and laboratory activities. In summary, the goal of the activities developed for the portfolio was to provide the experiences that would enable the students to

- understand the current trends and emerging technology within the biotechnology industry
- identify where gaps exist between current technology needs and existing solutions
- recognize existing gaps between biotechnology needs and current solutions as opportunities
- explore potential solutions for new technology development to address identified needs within the biotechnology industry.

The curriculum developed for the electronic portfolio also addressed the development of key attributes noted in a recent study by the National Academies. As stated in the recent report from the National Academy of Engineering, entitled *The Engineer of 2020*, creativity and communication were cited as key attributes for engineers of 2020.

- “Creativity (invention, innovation, thinking outside the box, art) is an indispensable quality for engineering, and given the growing scope of the challenges ahead and the complexity and diversity of the technologies of the 21st century, creativity will grow in importance.”
- “... good engineering will require good communication...we envision a world where communication is enabled by an ability to listen effectively as well as to communicate through oral, visual, and written mechanisms.” Modern advances in technology will necessitate the effective use of virtual communication tools. The increasing imperative for accountability will necessitate an ability to communicate convincingly and to shape the opinions and attitudes of other engineers and the public.¹”

All college graduates need to be life-long learners, possess good communication skills, and function well on a team in order to be successful in today's global market. The curriculum designed for the first class in the minor, Biotechnology Lab I, addressed these skills. The educational objective of the biotechnology program is to create an interactive classroom learning environment and immerse undergraduate students within action-based research. Students pose authentic research questions and actively participate in the inquiry and discovery process while working together on multidisciplinary teams. The students are directly involved in the experimental design, data analysis and dissemination

of the results. Higher order learning with action-based research and curriculum will increase analytical skills and better prepare students for real world jobs by enabling them to transfer curriculum-based research experiences into the biotechnology industry.

Impact of New Course (Biotechnology Lab I)

The biotechnology program was implemented in fall 2004 and is made up of the following courses: Fundamentals of Biology, Molecular Biology and Genetics, Cell Biology, Biotechnology Laboratory courses, Compliance, Process Quality Control, and Introduction to Bioinformatics (Table 2). The first course that has been developed and offered solely for the biotechnology program is Biotechnology Lab I (Table 3).

The biotechnology labs emphasize experimental design with the use of appropriate instrumentation and cover several techniques employed in biotechnological research. Biotechnology Lab I is a 2 credit hour course intended for undergraduate students and serves as a prerequisite for Biotechnology Lab II and Introduction to Bioinformatics, courses that compose the core curriculum in biotechnology. Biotechnology Lab I has no prerequisites and thus serves as one of the primary entry points into the biotechnology program.

The biotechnology program, administered by the Department of Industrial Technology, continues to draw students from many different departments throughout campus including those within the College of Agriculture, Science, Pharmacy and Technology. In addition, the biotechnology program is growing rapidly from 4 students enrolled in the first semester (Fall 2004) to a current enrollment of 25 students (Spring 2006) and serving the needs of students in many different disciplines by providing hands-on experience with cutting-edge technology within a small classroom environment.

Table 2: Biotechnology Core Curriculum

Semester	First Year of College	Second Year of College	Third Year of College	Fourth Year of College
Fall	Fundamentals of Biology I (BIOL 110)	The Biology of the Living Cell (BIOL 295E)	Introduction to Bioinformatics (CPT 227)	Food and Drug Law, Drug Discovery and Development, and Good Regulatory Practices (IPPH 522)
		Biotechnology Lab I (IT 226)		
Spring	Fundamentals of Biology II (BIOL 111)	Biology IV: Genetics and Molecular Biology (BIOL 241)		
		Biotechnology Lab II (IT 227)		

The Biotechnology Lab I course was composed of the following objectives and activities.

Table 3: Biotechnology I Course Objectives

General Objectives	Activities	Learner Outcomes and Assessment
The student will gain literacy in the basic methods and applications of bioinformatics	I. Bioinformatics Modules	Bioinformatics Lab Report & Communication Lab Activity
The student will be able to perform techniques currently used in cell, molecular, and microbiology, while understanding the rationale behind the specific approaches	II. BioRad Biotechnology Explorer Modules IV. Electronic Portfolio Activities	Participation in hands-on laboratory activities & Lab Notebook & Communication Lab Activity
The student will be able to explain the experimental basis of techniques used, indicating the significance of the work, presenting, calculating, and discussing the data, and drawing conclusions	II. BioRad Biotechnology Explorer Modules IV. Electronic Portfolio Activities	Lab Report & Communication Lab Activity
Given a specific biological question, the student will be able to determine appropriate applications of specific cell, molecular, and microbiological techniques	II. BioRad Biotechnology Explorer Modules IV. Electronic Portfolio Activities	Lab Report & Communication Lab Activity
The student will gain experience in dissecting and extracting pertinent information from scientific journal articles	III. Class Discussion & Critique of Scientific Journal Article IV. Electronic Portfolio Activities	Research Report on Scientific Journal Article & Communication Lab Activity

The implementation of the curriculum in the first three activities listed, Bioinformatics Modules, BioRad Biotechnology Explorer Modules and the Class Discussion and Critique of a Scientific Journal Article, have been discussed in a previous publication.² The results of this paper will focus on the incorporation of the Electronic Portfolio Activities and the Communication Lab Activities into Biotechnology Lab I in order to meet the needs of the students as recorded in the SGID in Table 1.

Communication Lab Activities

The communication lab activities were developed to pilot a portion of the assessment known as an electronic portfolio and they were composed of writing assignments that integrated with key concepts learned in lecture and laboratory exercises. The writing

assignments were designed to promote creative thinking and develop effective written communication. In addition, as the students learned to search information from databases and draw conclusions from the primary literature, they were developing analytical and critical thinking skills that are important for life-long learning. The communication lab activities were developed to integrate into the existing inquiry-based laboratory modules discussed in the implementation of the biotechnology curriculum.²

I. Portfolio Assignment: Scientific Paper Analysis

Students were instructed to select an article on a current biotechnology topic that interested them from a secondary source (newspaper, popular magazine, website, etc). Then, find the original sources cited in the paper, examine the primary source(s), and compare to the secondary article. In addition, the students were instructed to consider the following questions in their report:

- Why did you select the original article—what piqued your interest?
- What is the relevant background information & the significance of this paper and its impact on the field?
 - What was unknown? What made this article newsworthy?
- In the primary article:
 - What was the hypothesis (if present) or goal?
 - Why did the authors do this work? What question(s) were they trying to answer?
 - What was unknown in the scientific field that needed to be addressed?
 - What approach did the researchers use to address the hypothesis or accomplish the goal?
 - What were the results of the paper?
 - Were appropriate controls used?
 - Was each figure necessary?
 - Is more data needed?
 - Are the conclusions of the primary article accurate (correlate well with the data presented) or are the conclusions over-stated?
 - Did the work address the hypothesis? Support or refute it?
 - What does the work contribute to the field?
 - What is at least one future direction and the method/s to use to address it?
- Based on your extensive analysis of the primary paper (the original source) do you think that the authors of the secondary article provided an accurate interpretation of the scientific work? Why or why not?

This communication activity helped students develop skills that would allow them to critically analyze information that they read from newspapers, popular magazines and the internet.

II. Portfolio Assignment: Protein Engineering

Students were instructed to design an industrial application for fluorescent proteins by applying knowledge from laboratory activities in genetic engineering and lectures on recombinant DNA technology. In addition, students were given the following guidelines for the design of their proposed engineering:

- must improve the human condition
- and meet legal concerns of federal regulatory agencies.

Students were also exposed to recent examples that used the green fluorescent protein. For example, in class we discussed the use of GFP for art by Eduardo Kac as documented at www.ekac.org and also as an attempt to combat malaria at www.guardian.co.uk/uk_news/story/0,,1588449,00.html in which scientists create GM mosquitoes to fight malaria and save thousands of lives. Students provided a written proposal for their industrial application including design sketches, details necessary for industrial production and considerations for application to appropriate regulatory agencies.

III. Portfolio Assignment: DNA Sequencing

As mentioned previously, an educational grant was obtained to purchase a DNA sequencer. In addition to the hands-on experience the students gained from working with the research instrument in lab, the students were able to consider the impact of technology on progress within the field of biotechnology and the ability to obtain research results. DNA sequencing instrumentation has evolved considerably since it was originally introduced and continues to change with the needs of genomics researchers. Concepts and applications of DNA technology were discussed in class and then students were directed to visit the Annual Reviews home page at www.AnnualReviews.org to find and print the article: New DNA Sequencing Methods, by Andre Marziali and Mark Akeson in Annual Reviews Biomedical Engineering 2001: 3: pp.195-223, and answer the following questions:

- Describe in your own words how DNA sequencing works.
- How has the technology for DNA sequencing changed since it was first discovered?
- How have the changes in DNA sequencing technology impacted genome sequencing?
- Compare and contrast 2 methods that may change DNA sequencing in the future.

IV. Portfolio Assignment: Emerging Technological Disciplines

The final assignment examined the impact of different technologies, not just DNA sequencing, on the field of biotechnology. Students were instructed to complete the following readings:

- Committee on Bioprocess Engineering, National Research Council. Putting Biotechnology to Work: Bioprocess Engineering. pp.1-37 and pp.77-101 access via National Academies Press at <http://books.nap.edu/catalog/2052.html>

- The Engineer of 2020: Visions of Engineering in the New Century. pp.1-25 and pp.47-82 access via National Academies Press at <http://www.nap.edu/books/0309091624/html>
- Educating the Engineer of 2020: Adapting Engineering Education to the New Century (2005) pp.1-16 and pp. 51-58 access via National Academies Press at <http://www.nap.edu/books/0309096499/html>

Then the students were instructed to describe, citing specific examples:

- How well the Committee on Bioprocess Engineering did in predicting the future needs and challenges of the emerging field of biotechnology.
- How emerging technologies are impacting the emerging field of biotechnology

The students seemed to enjoy looking at the field of biotechnology from a different perspective and also learning how to communicate more effectively.

Course Evaluation

Another Small Group Instructional Diagnosis (SGID) was conducted by the Center for Instructional Excellence at Purdue University at the end of the Fall 2005 semester to determine what components of the curriculum changes were effective and what components of the curriculum were ineffective. The results from the SGID are illustrated below.

Small Group Instructional Diagnosis	
III. What do you like about this course?	
<i>Course Content</i>	Liked the lab
<i>Teaching Techniques</i>	Ratio of students to professor has been very helpful, full of appropriate coursework
<i>Instructor Characteristics</i>	Instructor was well-prepared
IV. What specific suggestions do you have for changing this course?	
<i>Course Organization and Structure</i>	More relevant information on the internet than the book; internet websites worked best because it would give a slide show or animation as to how something worked; reading descriptions in the book got very confusing easily
<i>Course Content</i>	Course could be made better by building better connections with topics in Industrial Technology; it seems most of our experiments are very small scale and I do not always see how it is tied into IT except that it was the beginning of how something worked (growing proteins) to grow into something bigger to be produced on a larger scale; I think the class could be better if we did things on a slightly larger scale since IT has a lot to do with production, cost, and manufacturing doing homework and experiments in that area would increase student participation in the IT department and be more relevant to what our major is

Individual comments from class evaluation forms:

- “This class does a great job of tying in biotechnology to the Industrial Technology department. The material is relevant. The biotechnology program should do very well.”
- “I think biotechnology is very important for our world on a scale of 1 to 10, I would make it 11”

The use of online resources received positive feedback from the students. Currently, the instructor is developing additional ways to incorporate the use of more technology into the curriculum in order to rely less on the classical textbook delivery of the material. In addition, the green fluorescent protein module will be expanded in order to provide practical industrial concepts and apply bio-manufacturing specific topics such as scale-up and illustrate that the best method may not always be the most cost-effective or the method approved for production by the regulatory agencies. Finally, the communication activities discussed above will be combined with the existing curriculum to formalize electronic portfolio assignments by adapting Task Stream, the electronic portfolio software system currently used by the College of Education at Purdue University. The portfolio will serve as a documentation of the students’ competency in biotechnology and can be used later by the students for demonstrating their skills in the emerging field of biotechnology.

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