AC 2007-2155: DEVELOPMENT OF A BIOTECHNOLOGY OPTION AREA FOR AN ENTREPRENEURIAL CERTIFICATE PROGRAM

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Development of a Biotechnology Option Area for an Entrepreneurial Certificate Program

Abstract

An undergraduate certificate program in entrepreneurship and innovation has been developed at --- University in collaboration with the --- Center for Entrepreneurship. Option areas are offered to students enrolled in the certificate program in order to explore specific discipline areas or markets. The objective of this paper is to discuss the development of a course within an interdisciplinary undergraduate biotechnology program as an option for students pursuing the entrepreneurship certificate. The course included the incorporation of guest speakers from biotechnology industries and academia that shared their experiences with the students. In addition, students learned interpersonal skills by working on interdisciplinary teams in order to complete their practical laboratory activities. The biotechnology option course has provided experiences that enabled 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.

Introduction

Science and technology impact the economy. In order for science and technology to continue to drive the economy, students need to learn innovation, which has become even more important now with a global economy. In a recent report from the National Academy of Engineering, creativity was cited as one of the key attributes for the engineer 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.*[1, 2]"

Skills identified by the National Academies are in agreement with desirable skills identified by recent workforce reports. In the meeting summary for the Pan-Organizational Summit on the U.S. Science and Engineering Workforce, technical skills combined with a strong math and science background and integrated with problem-solving, critical-thinking, and teamwork skills are sorely needed by modern manufacturing as well as by other sectors.[3] This is also true as science and technology are integrated within the industry of biotechnology.

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. 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. This 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.[4]

A need exists to prepare students for a global working environment and characteristics such as creativity, the ability to work on an interdisciplinary team and transfer new knowledge in innovative ways are necessary. But how do you teach students creativity and innovation? How do you teach students to work effectively and collaborate in diverse groups to solve interdisciplinary problems that tend to be ill-defined? In order to begin addressing some of these questions, an existing, introductory biotechnology course was adapted as an entrepreneurial option for a new entrepreneurial certificate program.

Certificate in Entrepreneurship and Innovation Program

The Certificate in Entrepreneurship and Innovation Program was designed to build on the strengths of ----- University's interdisciplinary initiatives and entrepreneurial leadership by making entrepreneurship education and experiential learning opportunities accessible to undergraduate students in all academic disciplines. Key objectives for the program include fostering passion for entrepreneurship and empowering students to pursue and succeed in entrepreneurial endeavors through course curriculum and experiential learning opportunities. General learning objectives include:

- Develop in the students the skills necessary to be successful entrepreneurs, be it in start-up ventures, small companies, or large organizations.
- Create an appreciation of the role of entrepreneurship in the U.S. and world economies.
- Give students a sense of their own aptitude for entrepreneurship.

To achieve this, the program consists of a sequence of 5 courses (15 credits), including:

- *2 Core Courses* (6 credits): Two required courses introduce students to the theory and practical aspects of entrepreneurship: *ENTR 200: Introduction to Entrepreneurship and Innovation* and *ENTR 201: Entrepreneurship and Innovation II*.
- *2 Option Courses* (6 credits): Students select from specialized option area courses that address entrepreneurship within either discipline specific or market/industry-specific courses.
- *1 Capstone Course* (3 credits): Students work in multidisciplinary groups on real world projects that apply the principles learned in core and option courses. Students

may be involved with a start-up or early stage company, work on launching a venture of their own, or participate in an entrepreneurship- or innovation-related internship or experiential program.

Functional objectives include: (1) ensuring that the program is easily accessible by students pursuing their own majors; (2) creating strong awareness of the program; (3) developing its practical value to undergraduate students; and (4) generating a high degree of satisfaction with the program among those who pursue the certificate.

Enrollment and Participation in the Entrepreneurial Certificate Program

The demand for the entrepreneurial program courses has grown significantly since the first year. As shown in Table 1, since the launch of the program in Fall 2005, over 420 students have enrolled in the first introductory course required for the certificate, Introduction to Entrepreneurship and Innovation (ENTR 200).

Table 1: Entrepreneurial Course Enrollment for Fall 2005

College	Number	Percent	By Semester	Number	Percent
Management	16	39%	Freshman 1st	5	12%
Technology	15	37%	Freshman 2nd	1	2%
Liberal Arts	3	7%	Sophomore 1st	11	27%
Engineering	3	7%	Sophomore 2nd	2	5%
CFS	1	2%	Junior 1st	11	27%
Science	1	2%	Junior 2nd	3	7%
Health Sciences	1	2%	Senior 1st	4	10%
Graduate School	1	2%	Senior 2nd	3	7%
			Graduate Student	1	2%

As shown in Table 2, in Fall 2006, approximately 300 students were enrolled in these courses.

Table 2: Entrepreneurial Course Enrollment for Fall 2006

ENTR 200 & 201 ENROLLMENT	ENTR 200		ENTR 200 ELC*		ENTR 201		TOTAL	
FALL 2006	No.	%	No.	%	No.	%	No.	%
Management	25	17%	40	59%	27	38%	93	32%
Technology	35	23%	3	4%	15	21%	53	18%
Liberal Arts	22	15%	7	10%	6	8%	35	12%
Engineering	18	12%	7	10%	10	14%	35	12%
CFS	18	12%	2	3%	0	0%	20	7%
USP	12	8%	5	7%	1	1%	18	6%
Science	9	6%	1	1%	6	8%	16	6%
Agriculture	7	5%	0	0%	6	8%	13	4%
Other	4	1%	3	0%	1	1%	8	1%
Total	150	100%	68	100%	72	100%	290	100%

* Entrepreneurial Learning Community

Finally, as shown in Table 3, an additional 240 students are enrolled in ENTR 200 for Spring 2007 (Table 3) and a total of approximately 700 students have registered for ENTR 200 since the launch of the program.

Table 3: Entrepreneurial Course Enrollment for Spring 2007

	ENTR 200		**ENTR 201**		**ENTR Finance**		**ENTR Capstone**		**Total**	
	#	%	#	%	#	%	#	%	#	%
Agriculture	18	8%	6	4%	0	0%	10	25%	34	8%
Consumer & Family Sciences	27	11%	11	8%	3	17%	4	10%	45	10%
Education	1	0%	0	0%	0	0%	0	0%	1	0%
Engineering	25	10%	6	4%	1	6%	2	5%	34	8%
Liberal Arts	37	15%	22	16%	2	11%	3	8%	64	15%
Management	37	15%	44	32%	7	39%	12	30%	100	23%
Pharmacy	4	2%	0	0%	1	6%	0	0%	5	1%
Health Sciences	1	0%	1	1%	1	6%	0	0%	3	1%
Science	10	4%	4	3%	0	0%	1	3%	15	3%
Technology	60	25%	29	21%	3	17%	8	20%	100	23%
Undergraduate Studies Program	18	8%	13	10%	0	0%	0	0%	31	7%
Graduate	1	0%	0	0%	0	0%	0	0%	1	0%
Total	239	100%	136	100%	18	100%	40	100%	433	100%

The entrepreneurial program was integrated with the Entrepreneurial Learning Community (ELC), a four-year program that embraces entering freshmen with an interest

in entrepreneurship in addition to their chosen academic degree objective. These students live together in a residence hall located near the ----Center for Entrepreneurship, enjoy extra access to entrepreneurship-related activities and speakers, and share courses within the entrepreneurial program. Initially, there was a high participation of management students within the Entrepreneurial Certificate program, due to the high percentage of management students within ELC. However, the percentage of students from other colleges has continued to steadily increase, as noted in Tables 1-3, highlighting the growing multidisciplinary nature of the student population within the Entrepreneurial Certificate program.

Biotechnology Option Course within the Entrepreneurial Certificate Program

Many new "option" courses have been approved Entrepreneurial Certificate Program courses since the program began. These consist of newly developed, tweaked, or existing courses across ------'s various colleges. Option courses provide discipline- or industry-related depth in areas relevant to entrepreneurship or innovation. One of the entrepreneurial program objectives includes continuing to develop and refine curriculum for "option" and "capstone" courses in cooperation with colleges across campus.

The Biotechnology Laboratory I (IT226) course within the Biotechnology program was offered as an option course for the Entrepreneurial program for the first time in fall 2006. Biotechnology Lab for Entrepreneurs (IT226E) provided hands-on experience with the latest biotechnology equipment at ---- Bioscience Center. The course also incorporated guest speakers from biotechnology industries and academia that shared their experience with the students. For students interested in entrepreneurship, the biotechnology course provided the experiences that enabled 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 learning objectives stated above were assessed by student completion of an electronic portfolio that included writing activities and projects. In addition, students learned interpersonal skills by working on interdisciplinary teams in order to complete their practical laboratory activities. One of the units within the electronic portfolio is described in detail below.

Teaching Creativity through Engineering Design

Graduates that can frame problems and use a design-oriented approach with inquiry-based learning are needed in order to adapt to a rapidly changing society. Workforce demands that students are able to diagnose and identify problems and design working solutions for ill-defined problems. The demand is magnified as disciplines merge and

problems become interdisciplinary, such as within the field of biotechnology, thus creating a need for more inquiry-based learning at the undergraduate level. In order to prepare graduates for the global workforce, it is critical to develop a method to teach students creativity and potentially provide a model for innovation and creativity in other Science, Technology, Engineering and Mathematics (STEM) disciplines. Current research supports the connection between scientific inquiry and technological design and its effectiveness when integrated in curriculum design.[5, 6] In addition, other researchers have shown that scientific inquiry and technological design can be successfully integrated within the classroom. [7,8,9,10]

The objective of the biotechnology program is to engage undergraduate students from multiple disciplines in authentic research and create a learning environment that encourages creativity and design by integrating knowledge from biology and technology and applying it to develop new experimental analyses.
Specific objectives include:

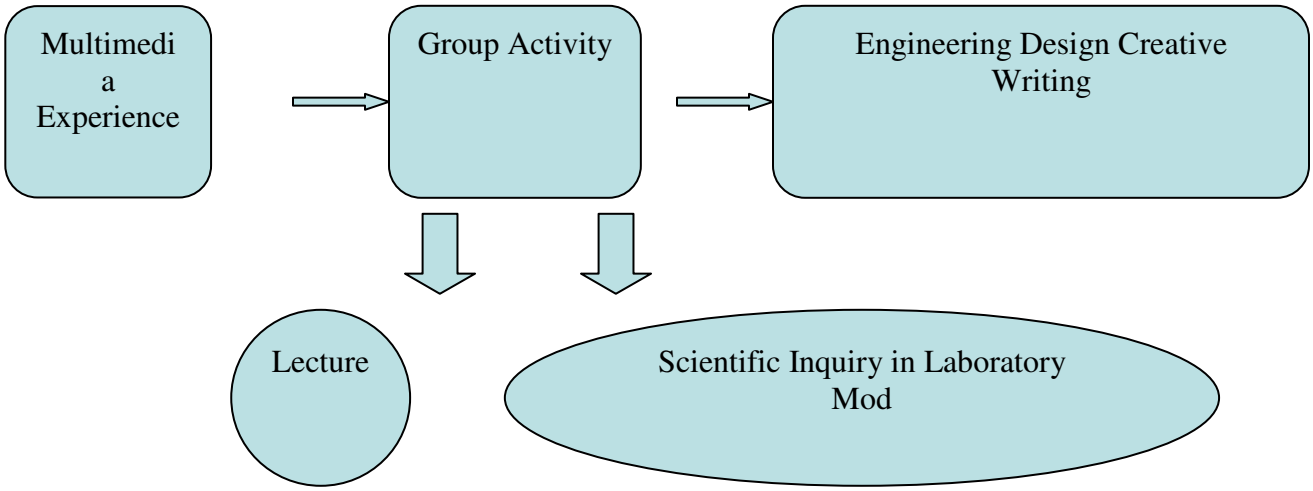
- learn basic terms for biotechnology
- understand basic concepts for biotechnology
- acquire basic research skills

The activities that address the above learning objectives include hands-on, inquiry-based laboratory experiments, bioinformatics modules and creative writing assignments that have been described previously.[11, 12] This paper will focus on the module developed for the entrepreneurial option course.

Within the introductory biotechnology course, students learn basic biotechnology concepts such as the role and function of proteins in living systems, and investigate the processes of living systems through hands-on experience. The Green-Fluorescent Protein (GFP) has been chosen as a vehicle to teach these basic concepts due to its engaging biological properties. GFP was discovered in bioluminescent jellyfish and sea pansies in the 1960s, characterized in the 1970s and has recently become one of the most exciting and useful molecules in the field of biotechnology. When expressed in either eukaryotic or prokaryotic cells and illuminated by blue or UV light, GFP yields a bright green fluorescence. In current laboratory activities, biotechnology students explore the concepts behind gene transfer, expression and regulation, and the relationship between protein structure and function. During these investigations the students obtain experience in the basic techniques involved in biotechnology including: DNA and RNA isolation, transformation of cells with foreign DNA, protein and nucleic acid electrophoresis, polymerase chain reaction (PCR), protein detection using antibodies, protein purification and UV/visible and fluorescence spectroscopy.

The biotechnology option course for entrepreneurial students extended the GFP laboratory modules with creative writing activities as outlined by the proposed curriculum model below in Figure 1.

Figure 1: Proposed Curriculum Model to Integrate Scientific Inquiry with Engineering Design in Biotechnology Entrepreneurial Option Course



Multimedia experiences included online animations, interactive tutorials and videos. The group activities consisted of both lecture and laboratory interactions to provide the foundational knowledge, in combination with the multimedia experiences, for the creative writing activities.

I. Group Activity: Introduction to Engineering Design with Green Fluorescent Protein

Students were provided with a design project to introduce them to the principles of engineering design. The first step in the project was the definition of the problem or need and idea generation. Based upon the unique properties of the green fluorescent protein, student groups were instructed to brainstorm and list 20 problems or needs that exist within society that a product using the green fluorescent protein could potentially solve. Students were advised to clearly state what the need or problem is that exists and what product utilizing GFP will meet that need and how. The following table represents the guide that the students received in class and sample results from the students have been provided.

Table 1: Student Results from Engineering Design with the Green Fluorescent Protein

Existing Need or Problem	**Potential Solution using GFP: What is the product? How will it meet the need or solve the current problem?**
If harmful liquid spills such as oil it can be hard to track	Place a bonding agent into a medium that would bond with the harmful liquid which would help workers clean it up
Instrument gauges in the dark are hard to read	Color code instrument gauges so they can be seen in any lighting environment

Underwater tagging, because of low light conditions at significant depths	Divers could see gear better with proper illumination through tagging
Companies use fluorescent ink to stamp hands at event but it can easily be copied	Use proteins to make different ink that would allow large companies who utilize stamping technology to create tamper proof ink, stamps on hands
No glow in the dark paint for cars	Proteins would be created to interact with the environment and contrast to the colors surrounded by it, so in the dark it would glow and in the day it would look like a normal paint job
Hard to identify where bacteria is in kitchen and food production areas	Spray counter tops, or kitchens to determine location of bacteria
When hiking/camping hard to see maps in low light conditions and it can be hard to hold a flashlight and try to look at a map	Maps that can function in very low light conditions, giving off glow to help identify different parts
People exercising at night have a higher risk of injury	Create vests and other equipment that would make runners and bikers more visible to traffic using different colored glowing proteins
Paintball players wiping off exploded paintballs to stay in the game	Include in the mixture inside the paintball proteins which would not easily be washed away
Cannot figure out which is the right cord behind the television in low light	Color code audio and video cords to allow users to easily plug stuff in during low light conditions

Next, students were instructed to select one of the topics from their group and submit their writing for the portfolio using the following guide.

II. Electronic Portfolio Assignment: Designer Genes

From the ideas that your group developed in the class session, select one product and solution to further explore for industrial application. Determine the basic application of the genetic engineering project, select the best approach, and include sketches of the proposed designs. In addition, discuss the appropriate organism, describe the genetic

manipulation and determine the appropriate contacts for the regulatory approval of the your product.

The final activity within the module was not limited to the GFP and encouraged the students to explore their topic of interest within the field of biotechnology, applying the design principles they had learned from the previous two activities.

III. Electronic Portfolio Assignment: Final Independent Study Research Paper

1. Select a topic of biotechnology of interest.
2. Identify a problem that currently exists within your selected area of biotechnology.
3. Identify a solution that would address the current need.
4. Follow the process of engineering design (note handout from class), research your selected area and explain the solution you have designed.
5. Support the identified need and solution with primary references.

Samples of projects from the students included using a viral vector to control disease, design of biotechnology management teams to provide the right environment for scientific innovation and success, genetically engineered rice to combat global health concerns, and the use of growth hormone to address hair loss.

Course Evaluation of the Biotechnology Option for Entrepreneurs and Future Directions

A survey was administered to the students in order to obtain feedback for course improvements.

Table 4: Instructional Diagnosis for Biotechnology Entrepreneurship Option Course

I. What do you like about this course?	
Course Content	Could do basic and important experiments needed in the biotechnology field; understand technical jargon as it pertains to biotechnology; activities were valuable and educational; enjoyed working in a real lab environment; Explanations were thorough
II. What specific suggestions do you have for changing this course?	
Course Organization and Structure	Increase lecture so students can discuss laboratory material in more depth; Assign group members; use lab time to discuss current biotechnology trends and procedures to help students learn more about a real biotechnology environment including proper lab etiquette
Evaluation and Grading	Provide quizzes to enable students to see a representation of the material they are learning and the progress they are making; more business related biotechnology topics

Some students had positive comments specifically regarding the team learning and the final project: "It was good to sit down with students with different disciplines… I had fun and learned a lot through the creation of my independent study paper."

Based upon feedback from the students, the biotechnology option course for the entrepreneurial program will be modified. Students stated that they would have benefited from more direction in potential topics and deadlines throughout the semester to keep them accountable for the different components of the final research design paper and they also expressed a desire to have more direction in selecting an appropriate topic. In response to the students' concerns, dates have been established for the current semester to help the students stay on task and scenarios to stimulate brainstorming potential topics are also being developed.

The students also recommended providing more time in laboratory for interactive group work in order to build better relationships and help them draw connections and comprehend the interdisciplinary subject matter more fully. Additional activities are currently being developed to enhance the group interactions within the laboratory. In addition, the students would like more guest speakers to provide a more well-rounded understanding of the field of biotechnology. Due to the small class size and even smaller number that elected to take the course for entrepreneurial credit, it was difficult to arrange guest speakers. In future semesters, the biotechnology option course will take advantage of complementary programs on campus that invite guest speakers with topics related to entrepreneurship. An example is the biomedship program, a focused educational program at -----University that provides formal training in innovation and entrepreneurship in the context of biomedical technology.

Finally, it is important to note that some of the comments may be a reflection of the diversity of the students and must be interpreted in respect to Tables 1-3. The students that enrolled in fall 2006 represented the first cohort of the entrepreneur program and thus because there were not many option courses available, some students may have taken the class that were not very interested in biotechnology. The first cohort of students also had a significantly higher number of management students as illustrated by the previous figures. This may also explain why some students struggled to select a biotechnology topic of interest for their final project.

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