Interdisciplinary "Creative Destruction": A Pedagogical Approach

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Fourteen Departments in four different colleges of California State University, Fresno cooperated to create a comprehensive, interdisciplinary Professional Science Master's (PSM) in Biotechnology degree, which creates graduates who are educated in scientific and technical skills with special emphasis in agricultural biotechnology, prominent in the region, as well as innovation management. This degree not only allows students to explore specific areas of biotechnology interest and expertise, but also provides a curriculum that is industry-responsive by including formal coursework in entrepreneurial skills with an additional industrial internship. The ultimate outcome is an enhanced level of interdisciplinary innovation and pedagogical sophistication.

INTRODUCTION

There is an increasing awareness that a region's economic well-being is directly related to the innovation and growth associated with its distinctive strengths and heritage (Center for the Study of Rural America, 2004). Regions must nourish a sense of "place" and find a niche in a globalizing economy by playing to their distinct strengths. One method of achieving this outcome is growing a "grass roots" regional constituency of a new generation of entrepreneurs. Successful regional economic development should be dependent upon the educational and training programs that serve each region's unique strengths and goals (Drabestoot, et al., 2004).

Colleges and universities are responding to that need by developing and offering more educational opportunities in innovation and entrepreneurship (Zacharakis, et al., 2002). Assessments of these programs in terms of entrepreneurship-team (e-team) satisfaction by many universities have demonstrated that students generally find them to be satisfying and beneficial (Mason, 2002; Bracken, 2002; Rzasa, 2004). Students usually enjoy the "real world" experience of product development, and student outcomes often go beyond what accrediting agencies and institutions require (Mason, 2002). It is clear that interdisciplinary programs have value, are challenging and informative, and offer a holistic view of the innovation process (Vozikis & Cornell, 2006). Experiential and interdisciplinary learning, especially integrating scientific and engineering innovation with entrepreneurship, provides students with an asset that is highly valued in today's job market and that will strongly differentiate these students from other college graduates.

In academia, the rate of success of bringing professionally engineered products to market has been hindered by the lack of business expertise on the projects. Okudan and Zappe (2006) observed that recent

college graduates are rarely prepared to effectively perform in such environments because of a lack of experience with multidisciplinary teams. In response to this concern, diverse multidisciplinary approaches in the educational setting have emerged to introduce engineering students to the basic business fundamentals and, in turn, confer non-engineering and non-technical students with a working knowledge of the design process (Crismond, 2001; Okudan and Zappe, 2006). These recent trends have contributed to the establishment of multidisciplinary instruction among marketing, finance, and legal topics with various technical, scientific, and engineering stages in the prototype development process. The multidisciplinary approaches also have contributed to building critical skills which can benefit technical and nontechnical entrepreneurial inventors, educators, consultants, and small business owner/managers, as well as those who are interested in applied research.

Interdisciplinary collaboration between academic programs and a focus on opportunity creation are the two key drivers of innovation and problem solving. Interdisciplinary teams bring together business students who can develop distinctive "what if" scenarios and logistical concerns to prod technology students to consider issues they might otherwise delay or perceive as being minor. Likewise, technology students bring their problem solving skills, knowledge of materials and tools, and the "scientific method" to develop and test effective innovations. Interdisciplinary teams can combine the different experiences of their members through exposure to each other's reading materials, conceptualizations, points of view, and life expectations, so that each member begins to appreciate a broader range of concerns. For example, in an interview with students after a project presentation, not one engineering student was subscribing to the free email newsletters from *INC Magazine* nor had ever heard of *entreworld.org*. Similarly, business students were unfamiliar with high-impact technology publications, and usually assumed that issues related to production costs "would somehow work out" or be lower than the technical proposal indicated. Neither group seemed to understand pricing and distribution costs or their impact on the potential venture's success (Ballon, 1998).

Entrepreneurship is widely regarded as instrumental in economic growth. Community institutions, colleges, and universities have an incentive to partner in outreach activities that promote economic development. Technology transfer activities serve as one important mechanism to achieve such engagement. Ideally, colleges and universities can foster new product and process technologies that might be converted into business startups with a business generating (BG) education and technology model (Laukkanen, 2000). According to Ronstadt's (1988) terminology, a BG educational model should open a subjective entrepreneurial corridor, i.e., produce innovations as viable business concepts or at least as business launches within the university. Consequently, a second academic revolution is under way as universities combine teaching and research with technology transfer that seeks to transform academic science to entrepreneurial science (Etzkowitz, 2001). One of the most significant arenas for this type of technology transfer is in the molecular life sciences, or biotechnology, where job opportunities for students blending science and business expertise continue to grow (Sheft, 2008).

In response to the distinctive regional economic development needs of the San Joaquin Valley, the PSM in Biotechnology degree at California State University, Fresno (or Fresno State, as is commonly known in the region), was established in fall 2005. This multidisciplinary endeavor requires fluency and competency in both science and business to allow development of new technologies and products based on applications of the cellular and molecular life sciences, with special emphasis placed on agricultural biotechnology to align with the predominant commercial and governmental enterprises in the region. The PSM in Biotechnology degree offers students who are educated in various scientific disciplines, the opportunity to acquire the knowledge and skills necessary to comprehend and commercialize these emerging technologies and/or their products. Consequently, it is not a research-focused degree but rather a degree conceived through the Alfred P. Sloan Foundation to develop the competitiveness of science students for direct entry into corporate/public sector jobs and prepare them for entry into mid-level, industrial/agency careers (National Research Council, 2008). The PSM in Biotechnology degree program provides a blend of components from science and business that truly distinguishes it both from a traditional Master of Science in Natural Science and from a Master of Business Administration.

The PSM in Biotechnology degree program provides top-performing business and biotechnology graduate students the opportunity to interact with others having similar interests in innovation, invention, and entrepreneurship. The interdisciplinary curriculum and its faculty guide students through both high-level scientific thoughts and processes and the entrepreneurial evaluation, selection, development, management, funding, and, most importantly, the nurturing of promising technological developments that are critical for California's San Joaquin Valley. Within the program are crucial entrepreneurship core courses designed to:

1. Involve interdisciplinary teams in the principles necessary for development of patentable product innovations from the tools and processes of biotechnology that could lead to commercialization, and;
2. "Sensitize" students from different colleges and disciplines to innovation tools from the legal, business, scientific, and liberal arts perspectives.

For example, in the "New Ventures Creation" course, e-teams, with the help of internal and external mentors, brainstorm and collectively select their entrepreneurial ideas; apply innovative solutions to the technical and scientific feasibility; and apply in-depth market and entrepreneurial research in determining the target market feasibility. Next they defend the scientific rationale and its innovativeness at a presentation of their business plans to a panel of venture capitalists and entrepreneurs, who will be given the first opportunity for investing in any of the projects viewed as commercially viable and worthy. The program's assessment process uses a qualitative methodology to obtain useful feedback for program improvement (Rzasa, et al., 2004).

Our goal is to train students for the demanding interdisciplinary field of biotechnology and to prepare a workforce the developing biotechnology industry in central California. To accomplish this we developed a unique interdisciplinary degree concept designed for students interested in entering the workforce, to promote the development and production of new products and processes from a practical understanding of the molecular and cellular life sciences. The degree program is designed to provide students with an appreciation of the breadth of biotechnology's commercial potential and with a familiarity and working knowledge of all components of a business enterprise. This will, in turn, prepare graduates for leadership roles in the biotechnology industry. Communication and critical thinking skills are emphasized throughout the program providing students a greater applications-based experience than is traditional for a disciplinary Master of Science degree.

The PSM in Biotechnology degree is administered through the College of Science and Mathematics. It is a two-year program allowing students to explore, in the context of entrepreneurship and commercialization, the molecular and cellular life processes that promote, for example, pharmaceuticals development, crop and livestock improvements, industrial processing, diagnostic and therapeutic medicine, forensic identification, genomics and bioinformatics. The PSM in Biotechnology degree is considered a terminal graduate degree and is not recommended for students interested in continuing their graduate education with research doctoral programs.

The PSM in Biotechnology degree at California State University, Fresno encompasses two key drivers: innovation and problem solving. The interdisciplinary nature of the program, as framed by the College of Science and Mathematics, the Jordan College of Agricultural Sciences and Technology and the Craig School of Business, constitutes a marriage between theory and practice, with a focus on the opportunities emerging from positive outcomes of interdisciplinary teams, and by taking into consideration the existing academic political realities, resources, and curricula, as well as real-world industry needs and practical necessities.

DEMAND FOR A MASTER OF SCIENCE DEGREE IN BIOTECHNOLOGY

The 2008 report from the Biotechnology Industry Organization clearly details California's preeminence in this industry as well as predicting that the convergence of genomics, information technology, and nanotechnologies will radically alter every aspect of the health care system. Additionally,

the report confirmed that the demand for bioethanol, biodiesel, and other alternative energy sources is driving technological innovation in biotechnology and that biotech crop acreage grew 12 percent, and 12 million farmers around the world are benefiting, especially in China and India (Burrill, 2008). The Ernst & Young Accounting report "Beyond Borders: Global Biotechnology Report 2008" presents the geographic distribution of the 386 public biotech companies in the United States distributed in 16 regions, three of which are metropolitan areas within California. California's most notable cluster and the nation's No. 1 biotechnology region in the country is the San Francisco Bay Area. In 2007, this region had 77 public companies, a 5% gain over 2006. San Diego is the nation's No. 3 region with 42 companies, also a 5% increase over 2006. Los Angeles/Orange County is the nation's No. 10 region with 21 companies, a 24% increase over 2006. That means that as of 2007, 140 (36.3%) of the nation's 386 public biotechnology companies are located in California, representing some of the largest and most successful in the nation. This is indicated by their market capitalization on December 31, 2007 ($230.6 billion), which represented 62.2% of the total national biotechnology industry market capitalization ($370.7 billion). In addition, there are other industrial entities, not solely identified as biotechnology companies, which operate biotechnology research and development activities within the state. This indicates that California has a large, and growing, interest and commitment to biotechnology.

For more than 20 years, California has established a number of initiatives among its state-supported institutions of higher education to promote science and innovation for this important economic sector. Examples of these initiatives include:

1) California State University Program for Education and Research in Biotechnology (CSUPERB), established in 1987 as a system wide program for the 23 campuses of the California State University (CSU);
2) Biotechnology Education Consortium, established in 1995, led by the Community College system (110 campuses) in partnership with the CSU and the University of California (UC) programs (10 campuses); and
3) UC Centers for Excellence. One example is the Institute for Bioengineering, Biotechnology and Quantitative Biomedical Research, which formed in 2001 as a consortium between UC Berkeley, UC Santa Cruz and UC San Francisco.

The Community College programs offer certificates or associate in arts degrees that are largely oriented toward students entering the biotechnology industry as production technicians, particularly for the biopharmaceutical companies in the Bay Area and Southern California. Many of these students are re-entry professionals displaced from other careers. Within the UC, biotechnology pervades the curriculum; but formal degrees are scarce. At UC Irvine, the Master of Science in Biotechnology combines coursework with a research master's degree through the Biology Department, and UC Davis offers an "emphasis" in biotechnology, i.e., a small number of formal biotechnology courses that accompany doctoral degrees in a variety of disciplines.

BIOTECHNOLOGY AS AN ACADEMIC DISCIPLINE AT CSU, FRESNO

In 1988, Fresno State began offering a formal graduate program in biotechnology. The Certificate of Advanced Studies in Biotechnology (biotechnology certificate program) is a laboratory-intensive program and the fourth CSU biotechnology certificate program. Further, this biotechnology certificate program is the first to be interdisciplinary between multiple colleges of Fresno State, which include the College of Science and Mathematics (Biology and Chemistry departments), and the College of Agricultural Sciences and Technology (Plant Science Department). Students with undergraduate degrees in Biology, Chemistry, Plant Science and Animal Science have all completed the Fresno State biotechnology certificate program.

As of May 2008, the Fresno State biotechnology certificate program has graduated 64 students, 50% of which have entered private industrial or government agency careers. The other half have entered professional training for health care (38.5%, medicine, pharmacy, dentistry) or education (34.5%,

teaching at the community college or high-school level), while six (9.5%) went on to doctorate programs (three have entered the biotechnology industry rather than academia). Three certificate graduates entered Master of Business Administration programs (11.5%), while four entered law programs/careers (15.5%). Half of the certificate graduates also have completed a disciplinary master's degree (91% through the Biology Department), especially those graduates who have entered the research side of the biotechnology industry. However, graduates of the certificate program/master's program also have pursued industrial careers, as well, in development (e.g., Berlex Biosciences, Richmond, Calif.) and production (e.g., IDEC Pharmaceuticals [now Genentech], San Diego, Calif.).

While several other CSU campuses have since instituted biotechnology certificate programs, mainly at the graduate level, the California State Polytechnic University, Pomona, became the first to offer an undergraduate degree through the Biological Sciences Department, which includes options in four sub disciplines—biology or biochemistry, agriculture, and business. A few CSU campuses offer undergraduate minors in biotechnology. In 1998, San Diego State University began offering a Master of Science in Regulatory Affairs, primarily directed at biotechnology industry professionals. San Jose State University became the first CSU campus to establish in 2003 a recognized PSM in Biotechnology degree with business college-affiliated components and funding by the Alfred P. Sloan Foundation.

Origins of Fresno State's PSM in Biotechnology Degree

In 1997, the Alfred P. Sloan Foundation (Sloan), a charitable foundation with interests in science education, developed a special initiative (Sloan Initiative) to encourage the development of a relatively new degree concept—the Professional Science Master's (PSM) degree. The PSM degree is expected to prepare students who have been educated in the sciences to enter industry careers directly rather than continuing their graduate education into more research-focused doctorate programs. The Sloan Initiative concept expects a strong industry-centered approach in the curriculum, including familiarity with business practices and culture. Most of the Sloan Initiative awards had been granted to Research 1 Universities. But in spring 2002, Sloan partnered with the Council of Graduate Schools (CGS) to explore establishing PSM degree programs at institutions that traditionally grant master's degrees, such as Fresno State. Almost simultaneously, the CSUPERB organization offered special workforce initiative grants to develop curricula that more appropriately prepared CSU graduates for entry into the biotechnology workforce. The Biotechnology Program at Fresno State applied for and received funding from both CGS/Sloan Initiative and CSUPERB to conduct a feasibility study in spring/summer 2002 on the establishment of a Professional Science Master's in Biotechnology degree (PSM in Biotechnology degree). The initial degree program developed was the product of those grants and is particularly distinctive by its inclusion of Master of Business Administration (MBA) curricula (taken with MBA students), as well as graduate level science (taken with the Master of Science students). By virtue of the award for the feasibility study, Fresno State was eligible to submit a proposal for an implementation award to CGS/Sloan Initiative in November 2002. Fresno State's proposed PSM degree programs, including a forensic science degree as part of the package, were selected for an implementation award (one of only eight universities in the nation from 70 applicants). The funds from this implementation award, plus some matching funding from the institution, supported development of a campus "presence" for these professional degrees and have sustained recruiting and development efforts directly connecting the science and technology components of the university with community business/service projects. The implementation funding was for two distinct PSM degrees in biotechnology and in forensic science that were separated because of the need for disparate non-science, courses—biotechnology required the business perspective, forensic science needed the legal perspective. The biotechnology degree was approved in 2005 and began accepting students in the fall 2005 semester. The forensic science degree did not have the benefit of a pre-existing certificate but was approved in 2006 and began accepting students the fall semester.

Professional master's degrees have been a component of academic curricula for some time, particularly in the health care, business, and special education disciplines. Frequently, these degrees require a larger number of course units than can be accommodated in a traditional 30-unit master's program. These programs often function, however, under the auspices of national accreditation

requirements, which can make these programs attractive to student clientele. The interdisciplinary nature of biotechnology does not have such an accreditation process. Therefore, the benefits of this new degree can seem more illusory to students while the feasibility of engaging sufficient students to support such a graduate program may often be less assured. The dilemma is finding a cadre of students adequately prepared, in what have traditionally been fairly divergent disciplines, to pursue a biotechnology program that is formatted within a master's degree program model. The approach used in the Fresno State PSM in Biotechnology degree was to meet the spirit and skills requirements of a professional master's degree within the parameters of a traditional 30-unit master's degree. Also, to revisit the possibility of a more expanded degree, but only as the biotechnology discipline and industry developed and as our own program's success became more defined.

The dilemma, and also the caveat, of any biotechnology degree is its interdisciplinary nature (even without a business perspective). Students need opportunities to become familiar with the many facets of biotechnology; but they also need a chance to develop some specialization (as with the options of the undergraduate degree at California State Polytechnic University, Pomona), so flexibility within the curriculum is desirable. However, there are few graduate educational programs that are either funded or functionally assimilated outside the traditional disciplinary realm of the university, which can complicate both the degree's sustenance and its approval process. In addition, to begin graduate level work with both the advanced science and business students, there is an expectation that student academic backgrounds should have provided appropriate foundations and breadth of experience for these advanced classes.

The Fresno State program was developed to address these issues with an array of science prerequisites, provide the consistent foundation among the cohorts and, by utilizing existing university courses across the disciplines, draw on existing expertise in a breadth of biotechnology applications, and provide opportunities for some unique educational specializations. The PSM in Biotechnology degree program requires core courses for a cohesive structure, including formal courses in molecular biology, biotechnology and entrepreneurship. In addition, individual interests and expertise can be discovered and developed through both an industrial/agency internship and an applied project or thesis, plus elective courses selected from not only the traditional natural science disciplines, e.g., biology or biochemistry, but also from those associated with the university's science and technology professional schools and colleges, e.g., plant sciences, food sciences, health sciences, computer sciences, and engineering. The Fresno State program engages students with this diverse faculty and helps to build the sensitivity for the capabilities and contributions of distinct disciplines to specific problems among both the students and the faculty members. In comparison to the Fresno State biotechnology certificate program, the new PSM in Biotechnology degree: 1) provides familiarity with business culture; 2) strengthens team-building skills; 3) provides more direct application experiences; 4) includes an opportunity for a biotechnology specialty; 5) invigorates the program with elements most responsive to industry concerns; and 6) does more to enhance the student's communication and critical thinking skills.

THE PSM IN BIOTECHNOLOGY PROGRAM

The primary departments participating in the PSM in Biotechnology program are: Biology, Chemistry, Computer Science, Plant Science, Food Science and Nutrition, Viticulture and Enology, Philosophy, and Management. The College of Science and Mathematics has the primary responsibility for this interdisciplinary degree, while the Biology Department is its formal home. The PSM in Biotechnology degree program has an interdisciplinary curriculum contained in the following academic units: College of Science and Mathematics (CSM), College of Agricultural Sciences and Technology (CAST), College of Arts and Humanities (CAH), and the Craig School of Business (CSB). A program committee consisting of representatives from all participating departments makes recommendations about the program and selects the Program Director/Graduate Coordinator for the PSM in Biotechnology degree. An Advisory Board, consisting of university administrative representatives and, more importantly, regional industry and agency leaders from institutions incorporating biotechnology tools and processes in their operations, advises the Program Director. These Advisory Board's industry/agency

leaders provide crucial insights to keep the program current from the employer's perspective and promote university-industry connections for developing student internships and applied projects.

The program originally arose from a strong cross-disciplinary effort among campus faculty and the results of a biotechnology industry survey regarding the need for this degree in the region. In 2002, faculty collaborators from the departments of Management, Biology, Food Science and Nutrition, and Chemistry formed biotechnology working groups (e.g., Current Biotechnology, Business, Bioinformatics, Bioprocessing, Agriculture, and Forensics) to collect ideas about the skills and curricula that were available and desirable to prepare students for a professionally focused master's degree in biotechnology. The extensive online survey of 250 statewide and regional biotechnology industry and agency units was conducted in summer 2002 to ascertain the appropriate required skills and knowledge for a professional biotechnology master's degree education. The results were used for the formulation of the initial degree proposal. Despite an exhaustive attempt to secure survey results, only 32 companies completed the entire survey, but the group responding represented a good diversity of business and specialization emphases. Among the nearly 30 categories, the survey highlighted six types of skills and knowledge that were identified by nearly all responding companies or agencies as being either priority No.1 ("essential") or priority No.2 ("highly desirable"). In late August 2002, the online survey was supplemented with a face-to-face workshop/discussion between industry/agency representatives from the San Joaquin Valley region and the Fresno State faculty closely affiliated with biotechnology education. In this workshop, the six critical skills and knowledge sets identified in the survey were confirmed for their importance, with immunological skills (next highest category) also cited; flexibility in electives also was mentioned as key in preparing students for employment among the broad diversity of biotechnology businesses. These guidelines significantly shaped the curricular components and prerequisites for the overall program, ensuring these cited, employment-relevant requirements would be included and reinforced throughout the program.

Program Mission, Goals, and Objectives

The mission of the PSM in Biotechnology degree at Fresno State was stated as one that *"offers students who are educated in various scientific disciplines the opportunities to acquire the knowledge and skills required to comprehend and commercialize emerging technologies and/or the products related to their field,"* and was considered a priori a multidisciplinary endeavor that would produce professionals fluent in science and business, who would engage in the development of new technologies and products based on the unique applications of the cellular and molecular life sciences. The corresponding PSM goals and objectives are as follows:

1. To educate students in the current knowledge and skills of the cellular and molecular life sciences.
    a. Comprehend current scientific literature presenting the concepts and technologies of molecular/cellular life sciences.
    b. Demonstrate knowledge of information resources for biotechnology including scientific journals, databases and biotechnology Internet resources.
    c. Demonstrate hands-on comprehension of scientific methodology and analysis.
2. To develop student familiarity with business practices and culture. Specifically:
    a. Comprehend the broad aspects of business operations and development, from product/process conception to commercialization.
    b. Demonstrate the ability to work collaboratively on projects involving typical business time lines.
    c. Demonstrate ethics, leadership and consensus-building skills relevant to the scientific aspects of a business enterprise.
3. To help students develop effective oral and written communication skills in both scientific and business settings. Specifically:
    a. Effectively disseminate technical information using written progress reports, strategic reports, formal scientific written communications, and operations and procedures manuals.

b. Organize and give both informal summaries and professional written and oral presentations.
c. Organize presentations and demonstrate listening/networking skills for unique professional situations, e.g., posters or equipment demonstrations.

4. To develop student effectiveness as liaison between the research, development, and production staff of a biotechnology enterprise and/or the scientific components and the management and marketing components of a biotechnology enterprise. Specifically:
   a. Demonstrate comprehension of a breadth of biotechnology processes and applications.
   b. Develop expertise in a coherent area of biotechnology enterprise.
5. To develop a master's program that can promote biotechnology industry development within the Fresno State region. Specifically:
   a. Successfully engage regional representatives of the biotechnology industry sector in the ongoing development and evaluation of the program
   b. Develop and sustain project and internship collaborations with regional industries.

Program Coursework

The courses used to launch the PSM in Biotechnology degree were already available within the curriculum, except for the required courses of an Internship (BIOTC 275) and the Interdisciplinary Culminating Experience (BIOTC 298 or BIOTC 299). A concentration or emphasis is developed from the particular array of electives selected; but the volatility of biotechnology as a field of study argued against formal concentrations that may necessarily change in very short time frames. The realms of biotechnology that can be studied under this curriculum are extensive, but its areas of excellence in biotechnology include: Agricultural; Medical and Medical Diagnostics; Environmental and Industrial, including Biofuels; Regulatory, and Quality Control; International Business; and Forensics. The program coursework with the required and approved elective courses are presented in Table 1.

Written and oral communication skills are emphasized throughout the program; assessments of these skills also serve as formative evaluation tools for the program's components. Team-building components are a recurring theme within the program, as are completion of tasks meeting business-related time lines and performance standards. The unique properties of this professional degree include both the interdisciplinary nature of study and the strong applications approach expected in the thesis or project serving as the culminating experience. Current science disciplinary master's programs at Fresno State, which can involve biotechnology skills, typically require a research thesis designed to prepare the student for further graduate study to pursue a doctorate program rather than for entry into the business world. The PSM in Biotechnology degree offers students the option to acquire advanced skills, but within the context of a program designed for direct career entry.

TABLE 1
PROGRAM COURSEWORK

		Units	Required
I.	**Core Curriculum**		
A.	Molecular Biology Lecture (BIOL/CHEM 241A-B)	3-3	**6**
B.	Biotechnology Seminar (BIOL/CHEM 248)	1	**2**
C.	Seminar in New Ventures (MBA 270)	3	**3**
D.	Seminar in New Venture Management (MBA 272)	3	**3**
	Or New Venture Creation (MBA 273)		
E.	Industrial Experience (BIOTC 275)	3	**3**
F.	Culminating Experience with an Oral Defense Required	4	**4**
	1. *Thesis (*BIOTC 299) An Interdisciplinary Research Project		
	OR		
	2. *Project* (BIOTC 298) Written Report as a Science Leader for a Team-Based Project		
II.	**Approved Additional Courses (Electives):**		**9**
	(Elective courses could include a maximum of one undergraduate course)		
A.	Protein Purification Techniques (BIOL/CHEM 242)	3	
B.	Nucleic Acid Techniques (BIOL/CHEM 243)	3	
C.	Cell Culture Techniques (BIOL/CHEM 244)	3	
D.	Industrial Biotechnology (BIOL/CHEM 245)	3	
E.	Biometric Statistics (AGRI 200 or BIOL 274)	3	
F.	Bioethics (PHIL 123)	3	
G.	Plant Micropropagation (PLANT 108)	3	
H.	Computational Foundations Bioinformatics (CSCI 101)	3	
I.	Analytical Instrumentation (CHEM 106)	4	
J.	Quality Assurance in the Food Industry (FSC 120)	2	
K.	Food Laws, Regs, Inspection & Grading (FSC 178)	3	
L.	New Venture Management (MBA 272),	3	
	And/or New Venture Creation (MBA 273), And/or Seminar in Business Ventures (MBA 270)	3	
M.	Relevant Topics Courses, e.g. Computational	3	
	Biophysical Chemistry (CHEM 2XX) or Unit Operations in Food/Bio Processing (FSC 2XX)		
		Total Program	**30**

Course Prerequisites and Admission Standards

1. Completion of specific coursework requirements of equivalent courses at Fresno State (see listing below; courses are in parentheses). It should be noted that the industrial survey from regional biotech firms and the industry-faculty workshop revealed a strong interest in specific prospective employee qualifications: communication skills; application of the scientific method; laboratory/field instrumentation; laboratory/field management; business management; and molecular biology knowledge. The core courses met many of these goals but seemed lacking in laboratory instrumentation skills largely associated with analytical chemistry activities and statistical tools for interpretation of scientific data and experimental design. Thus, the new prerequisites were added to the list required for the Fresno State biotechnology certificate program to ensure all our graduates meet basic qualifications in these areas. Because the students entering the program come largely from classical disciplinary undergraduate degrees, admission to the program requires a minimum of three categories of prerequisites and requires that all six categories of courses be completed for a degree award:
   a. General Genetics (BIOL 102)
   b. Microbiology including a laboratory (BIOL 120)
   c. Biochemistry (CHEM 150 or 155) with a laboratory (CHEM 156)
   d. Immunology with a laboratory (BIOL 157 and 157L)
   e. Analytical Chemistry (CHEM 105 or CHEM 102)
   f. Statistics (MATH 101)
2. Appropriate undergraduate science degree with a minimum 3.0 grade point average in science and math coursework.
3. Graduate Division admission requirements, including satisfactory general exam of the Graduate Record Exam (GRE) and, when appropriate, the Test for English as a Foreign Language (TOEFL) exam scores.

Suggested Program of Study

The two-year program of study presented below represents a suggested pattern, including some opportunities for prerequisites. No specific program prerequisites were deemed necessary in business, but the rigor of graduate level business courses has prompted the suggested program of study to provide adequate time to assimilate business concepts. However, for entry into this curriculum model, students will need to have completed both the genetics and biochemistry prerequisites.

Limiting the course load for the first year provides additional time to study research concepts and practices of biotechnology and business, as well as additional opportunities to fulfill any program prerequisites. In addition, by having all the students engage in the core courses in unison, a cohort of students is established to strengthen peer group networking. Such networking is expected both to reinforce the team approach to problem solving that dominates business organizational cultures and to provide the positive peer pressure that often helps students through the more rigorous elements of a program. Another advantage of the first-year program is that nearly all courses are offered in the evening to accommodate students with daytime employment or student assistantships, until the certainty of a specific career direction is established.

The complete sequence of the two year program leading to this interdisciplinary Professional Science Master's (PSM) in biotechnology/ business degree is presented in Table 2.

A recent change in the suggested program's sequencing has been a delay in the onset of the core MBA course sequence. This semester delay allows the students some time to identify scientific examples which might be ripe for commercialization. To heighten this awareness, the first installment of Biotechnology Seminar (BIOL/CHEM 248) now centers on presentations of individual biotechnology company "case studies" associated with a specific product and focusing on the positive and negative aspects, both scientific and commercial. This framework should improve the student's understanding of what is required for an effective business plan, a main focus of Seminar in New Ventures (MBA 270).

TABLE 2
PROGRAM OF STUDY

Fall Semester of First Year	**Spring Semester of First Year**
Molecular Biology I (BIOL/CHEM 241A)	Molecular Biology II (BIOL/CHEM 241B)
Biotech Seminar (BIOL/CHEM 248)	Biotech Seminar (BIOL/CHEM 248)
Prerequisite or Approved Elective	Seminar in New Ventures (MBA 270)
Identify Graduate Thesis/Project Advisor	Prerequisite or Approved Elective
	Skills training for Thesis/Project
First Summer	
Thesis/Project Investigations and Activities; Complete Graduate Writing Requirement	
Fall Semester of Second Year	**Spring Semester of Second Year**
Seminar in New Venture Management or	Approved Elective (if necessary)
Creation (MBA 272 or 273)	Internship (BIOTC 275)
Approved Elective	Culminating Experience (BIOTC 298 or 299)
Approved Elective	
Advancement to Candidacy	
Second Summer	
Final Completion of Internship/Culminating Experience Written and Oral Reports	

The Industrial Experience (BIOTC 275), the internship segment of the program, was originally conceived for the first summer, when many industrial organizations offer specific internship programs. However, because the length of many industrial internships has grown from a few months to sometimes 6-12 months, and because of a desire to strengthen the student's overall science and business skills before moving into the industrial setting, it is suggested the internship should occur nearer the end of the program of study. Flexibility is imperative, although the internship is listed at the very end of the program to meet opportunity availability and to make good student-industry matches. The enrollment listing in the last formal semester of the program represents the semester in which each student will participate in the "Internship Forum" event, showcasing their experiences through oral presentations before their industry partners, current and prospective biotechnology students, university faculty and administrators, and the interested public.

Changes in fulfilling the Culminating Experience–Biotechnology Project (BIOTC 298) or Biotechnology Thesis (BIOTC 299) are also being considered. The biotechnology faculty now considers a team-based project as more relevant to a professional program, even if a thesis has an applications focus. A five-year program review, which may further resolve this concern, is currently under way.

Status of the Program and the Program Graduates

New student enrollments in the program have continued to climb from seven students in the inaugural 2005-2006 academic year to 19 students entering with the 2010-2011 academic year. The desired program size is 20 new students entering the program each year. There has been a strong interest in the program among international students (more than 100 applicants per year), and consequently, the program has been composed of roughly one-third domestic students and two-thirds international students. Biotechnology program students have won entrepreneurship competitions through Fresno State's Craig School of Business with teams of scientists and MBA students. Internship partnerships continue to grow, primarily with agricultural and health care organizations in the Central Valley or with biopharmaceutical companies across California and the nation.

Industry satisfaction in the program's students is demonstrable from the strong evaluations received by those completing their internship. In addition, the post-graduate employment of five of the 10 program graduates, either directly with the company/agency where the student served as an intern, or with a similar company or agency in a position secured through the direct recommendation of the supervisor of the internship, reveals the positive impact of our students on their industry supervisors. The industry/agency Advisory Board meets annually to receive updates and provide insights for program improvement. The biotechnology program faculty (from all eight campus departments) also meets annually to discuss logistical issues and implementation of industry-relevant components into the curriculum. In addition, numerous formal program assessment activities have been conducted, including the aforementioned evaluation of each student intern by the industry. Much of the assessment effort centers on evaluating communication skills, written and oral, as the most critical area identified prior to formation of the degree and continuing in citations from the industry evaluations. These assessment activities have identified areas for improvement to enhance student success, e.g., by requesting inclusion of organizational charts and background information for the oral internship presentations and by incorporating stronger mentoring activities prior to the internship forum to improve comfort, enthusiasm and content scores. In addition, scrutiny of a wide variety of variables, e.g. GRE or GMAT scores, numbers and types of prerequisites completed, biotechnology faculty input on productivity, and the varied curricular elective pathways taken by the matriculated students, have identified some elements that seems to determine who will be successful or not in completing the program. This analysis has led to revisions in admission decisions, e.g. requiring stronger writing scores for the standardized entrance exams for consideration, as well as prompting earlier connections between incoming students and prospective mentoring faculty for the Project or Thesis component of the program. Additionally, comments from the students in Exit Interviews prompted the need for additional networking opportunities with regional industries, in order to improve appropriate social and communication skills and to also expand the breadth of internship placements. Our efforts to press the students to complete the Graduate Writing Requirement early, has significantly decreased the time to degree completion from the onset of the program. Students are now regularly finishing within the expected two-year time frame. In the rapidly changing world of biotechnology, continuous assessment and updating of our program are indeed critical.

The program is still new but is beginning to "gel" more extensively with local start-up industries, particularly in biofuel technologies. The nature of life sciences research, which lacks much of the mathematical predictability inherent in the physical sciences and engineering, can frustrate the classic approaches to the entrepreneurial process. But, the potential rewards of unique, and innovative positive outcomes ensure that advances and originality in commercialization processes can be found, and the cooperative interactions between biotechnology and entrepreneurship faculty in a university setting can serve as a platform to negotiate any inhibiting hurdles.

CONCLUDING REMARKS

Entrepreneurship is the way the economy and society take advantage of new wealth-creating opportunities that arise from constant change. However, when change accelerates, as it does during periods of rapid technological change such as during the rise of the industrial revolution or the rise of the

information or knowledge age, entrepreneurship and enterprise development also tend to increase (Stough, 2000). Therefore, technological change creates new, exploitable possibilities and opportunities; and one of the main reasons entrepreneurship and interdisciplinary entrepreneurship education has been increasing is rapid technology change and the associated increasing innovation rates. The Genetics and Biotechnology Revolution is an especially exemplary example such an opportunity, and it is critical for the universities to take steps to improve the chances that such opportunities come to fruition by integrating science and entrepreneurship mindsets. However, conflicts of interest and conflicts of values sometimes stand between university-based research and commercialization of that knowledge, which can often delay or deter the commercial application of research (Bird, Hayward & Allen, 1993). Regardless of this inherent conflict, fostering entrepreneurial attitudes among university scientists creates a dynamic mental landscape within the university walls, in which application possibilities constantly respond to user needs to yield a stream of new product concepts by fostering a "what-could-you-do-with-it?" attitude (Armstrong & Tomes, 2000).

Within the context of the Professional Science Master's Degree in Biotechnology at California State University, Fresno, there have been unique benefits not always enjoyed by other similar programs. The Management Department faculty have invited the biotechnology science graduate students into their regular classrooms, and students who were undergraduate business majors have found access through the program to the graduate science classes. Master's Degree-granting institutions, such as Fresno State, tend to nurture more Teacher/Scholar and Service orientation among the faculty themselves than at traditional Research Universities, so the spirit to link programs was more easily attained even during the first visits between Science and Business faculty interested in considering an interdisciplinary program. The fact that the strong agricultural college and industry in the Fresno region is supportive, and that the industry and discipline routinely integrate both business and science, further nurtures this cooperative aspect of the Fresno State experience.

Entrepreneurship programs across the United States have demonstrated that the appropriate intellectual environment can produce successful start-up companies, combining the best of university-developed technologies and student interests with competent and professional managerial and financial advice. A Technological Entrepreneurship Certificate program at the University of Iowa requires the completion of a minimum of six entrepreneurship courses. Its 1,200 engineering undergraduate students take at least one such course during their engineering program; otherwise, according to its College of Engineering Dean Richard K. Miller, "too many engineers will end up in a white coat in the back room of some organization" (Ballon, 1998). George Mason University also has implemented a new university wide curriculum that fuses entrepreneurship skills into Education, Arts, Engineering, Public Administration, Liberal Arts, and Health/Nursing programs of study that already exist. This establishes synergistic and cooperative networks challenging the resourcefulness of students (Stough, 2000).

A similar successful program offered at Swinburne University of Technology in Melbourne, Australia, tracks the entrepreneurial performance and activities of graduates, over time (McMullan & Gillin, 1998). Even smaller colleges can develop creative entrepreneurial programs. Hope College in Holland, Mich., established a collaborative research, education, and entrepreneurship program in its chemistry curriculum that relies on an interactive, web-based discussion board (Polik, 2000). As some universities have discovered, it takes creativity on the part of administrators to foster innovative thinking in students and to knock down the barriers between disciplines (Rae-Dupree, 2002). Furthermore, it takes more than technology to be successful. A Stanford Technology Ventures Co-Op Program quickly found a "doable" technology is intriguing but also needs to address a customer's problems (Bellinger, 1996).

The developing biotechnology industry needs entrepreneurial leaders. The industry is quickly changing and growing, without continuing entrepreneurial efforts businesses fail. The PSM in Biotechnology Program at Fresno State has been developed to meet this growing demand. Though most of our students have become employed by existing enterprises, their entrepreneurial and business skills are needed by these industries. Our program prepares students to take on the challenges of this demanding and exciting industry.

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