

From the Classroom

The University of California, Davis, collaborative model for biotechnology education and training

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ABSTRACT

UC Davis and its partners are addressing the need for innovation and entrepreneurship in graduate education and training. This paper will showcase the Designated Emphasis in Biotechnology graduate education program, cross-disciplinary partnerships and technology brokering. These interactions can bring diverse groups of individuals together to translate ideas into real world applications. The creation of intellectual and human capital at universities must be linked to financial capital and social capital. This can be accomplished by creating dense social networks. PhD programs in science and engineering must be transformed in order to stay relevant in the 21st century. UC Davis has been addressing these issues for close to 20 years and is now seeing significant outcomes.

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INTRODUCTION

CALIFORNIA, THE NATION and the world need well trained scientists and engineers, who can move ideas to the real world and drive the new knowledge-based economy. These individuals must have technical skills but more importantly, they must possess: 1) Business skills; 2) Social and emotional intelligence; 3) The ability to work effectively in cross-disciplinary teams; 4) An entrepreneurial spirit and 5) A dense social and investment network to assist in the process.

This paper will showcase how innovative graduate education programs as well as technology brokering can bring diverse groups of individuals together to create dynamic partnerships and lead to the development of technology clusters and employment opportunities for new graduates. As Prof. Andrew Hargadon states in his book, *How Breakthroughs Happen*¹, brokers are need to bridge gaps in existing networks to create intellectual capital, social capital, investment capital and human capital. He explains that “Innovation is really about creatively recombining ideas, people and objects from past technologies in ways that spark new technological revolutions.” He contends that Edison, Ford, Watson and Crick, Steve Jobs and others were no smarter than the rest of us – they were just better at moving through the networks of their time. The creation of intellectual and human capital is just the beginning. The next phase is

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financial capital and social capital. The goal is to create dense social networks that enable a smooth flow of capital: human; intellectual; financial and social.¹

Prof. Hargadon was the founding director of the UC Davis Center for Entrepreneurship (C4E) in 2006 to promote these dense social networks and in November of this year, the C4E received a \$5M commitment from UC alumni, Mike and Renee Child to establish a new interdisciplinary institute devoted to education, research and outreach in innovation and entrepreneurship. The Child Family Institute for Innovation and Entrepreneurship will help to integrate innovative and entrepreneurial thinking and actions across the university, and strengthen UC Davis' role as a vital player in catalyzing economic development in the region, state and beyond. Prof. Hargadon will serve as the faculty director. The institute will be housed in the Graduate School of Management and will serve as a hub for the coordination of entrepreneurship and innovation activities across UC Davis' colleges, schools, centers and organized research units. For example, the institute will help coordinate such current UC Davis initiatives as the Biotechnology Program, the College of Engineering's Engineering Translational Technology Center, the Science and Technology Studies program in the College of Letters and Science, and the Center for Science and Innovation Studies, among others.²

The University of California, Davis (UC Davis) has been involved in building these technology networks for over 20 years. For more than 100 years, UC Davis has engaged in teaching, research and public service that matter to California and transform the world. UC Davis has more than 32,000 students, more than 2,500 faculty and more than 21,000 staff, an annual research budget that exceeds \$678 million, a comprehensive health system and 13 specialized research centers. The university offers interdisciplinary graduate study and more than 100 undergraduate majors in four colleges — Agricultural and Environmental Sciences, Biological Sciences, Engineering, and Letters and Science. It also houses six professional schools — Education, Law, Management, Medicine, Veterinary Medicine and the Betty Irene Moore School of Nursing. Collaboration across colleges and schools is a guiding principle of research and teaching at the university.

The University of California, Davis, produced about 56,000 jobs and \$5.5 billion in economic activity during the 2009-10 fiscal year, generating almost \$10 for every dollar invested by the state, according to a new analysis released by the University of California Office of the President economic impact report was prepared for the UC Office of the President by Economic & Planning Systems, Inc., a consulting firm. "According to this report, UC Davis researchers are at work creating new inventions that can be the catalyst for new companies and jobs.

In 2009-10, the university had a portfolio of 419 patents on inventions, generating licensing income of \$10.4 million from products ranging from optical network switches to strawberry varieties. The preliminary figures from the UC Davis Office of Research, showed that campus scientists and engineers generated 73 patents (29 U.S. and 44 foreign) in fiscal year 2010-11, while 67 licenses were executed on existing patents. Since 2004, 34 startup companies have spun off from UC Davis, seven of them in 2010-11".³

Chancellor Linda P.B. Katehi is committed to expanding these efforts through an "Innovation Hub" that will better connect campus research with entrepreneurs and accelerate the transformation of university inventions into commercial products and services. Following a "request for concepts" in early 2011, campus officials are now developing a strategy to implement the "i-Hub" concept. The new chancellor's vision is to create an "ecosystem" that fosters technology transfer and build long-term relationships among the campus, industry, local governments and communities. In her vision statement, she wants to build on the interdisciplinary strengths of its faculty, by promoting a collaborative environment that spurs innovations in learning and research by discovering ideas that take shape at the frontiers and intersections of academic disciplines. She promotes a range of university incentives and funding mechanisms, training programs, policies, reward structures and recognition opportunities for faculty, staff, students, alumni and external partners that foster innovative collaborations, self-sustaining initiatives, team science, "high-risk/high-impact" discovery, next-generation technologies, entrepreneurial activity and other forms of core, interdisciplinary scholarship.³

The UC Davis School of Medicine (SOM) is an active partner in this vision of translational research education and entrepreneurship. In a recent paper in *Science Translational Medicine*⁴ by SOM Executive Associate Dean Frederick J. Meyers and Vice Chancellor and SOM Dean Claire Pomeroy report on the need for biomedical researchers that focus on multidisciplinary collaboration and address health benefits to shorten the time from discovery to application at the bedside. "Biomedical research should have the goal of producing sustainable improvements in health and include the full range of early translational research efforts," said Claire Pomeroy, UC Davis vice chancellor for human health sciences and dean of the School of Medicine and co-author of the article. She states, "True health gains will occur only if we move beyond the current paradigm and embrace real-life assessment of innovations."⁴ "Biomedical research workforce development, the authors wrote, requires new approaches because of today's increasingly complex scientific and technically sophisti-

cated knowledge base, which includes the fields of bioinformatics, statistics, genomics, nanotechnology and regenerative biology.” The biomedical research workforce must evolve with our rapidly changing scientific development,” said Pomeroy. “Biomedical science trainees require a new set of core knowledge competencies in addition to the traditional scientific disciplines so that they can optimize their potential to make important and relevant discoveries.” One approach is to foster the clinical relevance of biomedical research by promoting partnerships between academia and industry, a relationship that has traditionally been considered suspect in academic institutions.⁴

“Industry has resources and expertise that academic institutions should utilize,” said Meyers. “New partnerships between the private and public sectors will create an environment that judges the value of novel research and technology according to their contributions to solving health issues as well as to economic vitality.”⁴

Dean Pomeroy is the principal investigator for a NSF Partnerships for Innovation (PFI) Grant to create a prototyping center so that new medical technology start-ups may secure investment capital. The Medical Technology Commercialization Clinic (MTCC) brings together multidisciplinary teams that include faculty, physicians, STEM students and postdoctoral fellows, MBA and law school students, and Entrepreneurs-in-Readiness (EIRs), to take medical technologies closer to market. The teams develop commercialization strategies for technologies of interest, under the leadership of EIRs and with mentorship from our project partners. Four PFI MTCC Forums were scheduled for 2011. The forums engage, educate, and challenge the region’s creative minds interested in medical technology innovation, via networking, invited talks on medical technology commercialization and presentations on unmet medical needs. Speakers include clinicians, medical technology inventors, entrepreneurs, engineers, and investors.⁵

NOVEL EDUCATION AND TRAINING PROGRAMS

UC DAVIS BIOTECHNOLOGY PROGRAM

In 1986, the UC Davis Biotechnology Program (<http://www.biotech.ucdavis.edu>) was founded to assist in the organization of university activities related to biotechnology and to coordinate such activities with other efforts on the campus. Base funding for the Biotechnology Program comes from the Office of Research. The Program’s mission include: 1) Promoting and coordinating the development of biotechnology and biotechnology-related research on the campus; 2) Assisting with devel-

opment of new and improved facilities for biotechnology research; 3) Promoting research interactions between faculty and private industry and public agencies; 4) Recommending and implementing curriculum development and training in biotechnology; and 5) Serving as an information and education resource on biotechnology for the campus and the public. Currently, UC Davis is the only UC campus with a stand-alone Biotechnology Program. The Program serves a critical role in bridging academia with private industry and government to foster critical partnerships to enhance the education and training of students and researchers as well as support early stage biotech companies in the region. Director Kjellstrom serves as technology brokering in helping to move ideas from the bench to the market. The motivation for the creation of the projects within the Biotechnology Program is to address critical needs in biotechnology research, education and training. Communication with industry is a critical element. The Biotechnology Program has an entrepreneurial spirit and develops programs involving multiple partners. Operational funds are generated through grants, sponsorships and registration fees.⁶

One of the key programs administered by the Biotechnology Program is the Designated Emphasis in Biotechnology (DEB) graduate program (www.deb.ucdavis.edu). It was officially established in 1997 as an outgrowth of the first NIH-NIGMS Training Grant in Biotechnology (funded since 1991). The DEB program supplements a student’s Ph.D. curriculum with interdisciplinary skill sets and those completing the program obtain an official designation on their diploma & transcript indicating a qualification in biotechnology (Example: Doctoral Degree in Microbiology with a Designated Emphasis in Biotechnology).

The DEB is an inter-graduate group program that allows Ph.D. students to receive and be credited for training in the area of biotechnology. The DEB encourages predoctoral scholars to take an interdisciplinary approach to research, maintaining excellence in the deep, narrow focus of the doctoral discipline while adding professional skill sets that allow communication and problem-solving across many groups of stakeholders, including scientists from other disciplines, but also members of the wider community. DEB coursework is designed to educate students through an interdisciplinary lens that includes entrepreneurial, intellectual property, industry and global policy perspectives. For example, all DEB students are required to gain “real world” experience via internships at biotechnology companies, institutes or national laboratories. The DEB graduate program offers courses, special seminars and mentoring that facilitate student development as leaders, visionaries, entrepreneurs, researchers and teachers in the broad area of biomolecular technology in academia, industry or government.

The DEB graduate program stresses academic expertise as well as “social awareness” and entrepreneurship. Deep, narrow expertise, gained through doctoral research, must be balanced with broad, global perspectives to be an effective leader in the 21st century. To create effective cross-disciplinary teams, students must value the so-called “soft skills” of business. Reference books for students are listed on the DEB website under Entrepreneurship: 1) *Emotional Intelligence and Social Intelligence: The New Science of Human Relationships* by Daniel Goleman; 2) *How Breakthroughs Happen* by Andrew Hargadon; 3) *The Speed of Trust* by Steven M.R. Covey; 4) *Good to Great* by Jim Collins; 5) *A Whole New Mind* by Daniel Pink; 6) *Building Biotechnology* by Yali Friedman; 7) *The Business of Bioscience* by Craig Shimasaki, PhD; 8) *Peak* by Chip Conley; 9) *The Five Dysfunctions of a Team* by Patrick Lencioni, etc.

It is widely recognized that new PhD recipients must have the ability to interact with individuals outside of their narrowly focused discipline and forge working relationships across public and private sectors to meet global challenges in health, agriculture and the environment. In fact, a recent NRC Report of the National Academy entitled “A New Biology for the 21st Century”, describes “the essence of the New Biology is integration—re-integration of the many sub-disciplines of biology, and the integration into biology of physicists, chemists, computer scientists, engineers, and mathematicians to create a research community with the capacity to tackle a broad range of scientific and societal problems.”⁷ The DEB graduate program addresses the four key pre-doctoral training challenges highlighted in the 2005 report by the Woodrow Wilson National Fellowship Foundation entitled “The Responsive PhD”. The four challenges are: 1. Increase diversity in graduate education; 2. Seek new ways to apply academic knowledge to social challenges; 3. Address globalization; 4. Improve professional development in a full range of careers.⁸ In a recent article in *Nature*, Mark Taylor discussed the crisis in PhD education in “Reform the PhD system or close it down”⁹. Taylor states that “There are too many doctoral programmes, producing too many PhDs for the job market. Shut some and change the rest.” He states, “If doctoral education is to remain viable in the twenty-first century, universities must tear down the walls that separate fields, and establish programmes that nourish cross-disciplinary investigation and communication. They must design curricula that focus on solving practical problems, such as providing clean water to a growing population. Unfortunately, significant change is unlikely to come from faculty members, who all too often remain committed to traditional approaches. Students, administrators, trustees and even people from the public and private sectors must create pressure for reform. He states, “It is important to realize

that problems will never be solved as long as each institution continues to act independently.”⁹ The DEB graduate program is in alignment with the recommendations proposed by Taylor and has achieved success. Additional references are listed in the references that address the need for reform in graduate programs.¹⁰⁻¹⁵

The DEB program is well ahead of the learning curve, instituting just this type of training nearly twenty years ago. Through training grant awards, the DEB has been recognized by federal funding agencies as a model for 21st century pre-doctoral training across disciplines in the life sciences, physical sciences and engineering. Currently, over 210 PhD students are enrolled in the DEB graduate program. They come from 28 different graduate programs such as biochemistry, chemistry, microbiology, biomedical engineering, chemical engineering, molecular biology, genetics, statistics, etc. The DEB students are required to complete coursework in team science, bioethics, business and legal aspects of biotechnology, as well as a 3-6 month internship in a company or research laboratory in another college or national laboratory. Public service and mentoring of other junior level students are encouraged. The program has provided an effective cross disciplinary immersion for over 105 UC Davis graduates with 50% of them working in industry. A few have even started their own technology companies. DEB graduates have become senior scientists, vice presidents of biomanufacturing, business development and regulatory affairs professionals, venture capitalists, biotechnology patent attorneys, founders of technology companies, science policy analysts, as well as entrepreneurial academics. One example of a success story is Dr. Sunny Shah, who earned his PhD in Biomedical Engineering with a DEB last spring. Sunny was also one of our NIH Biotechnology Fellows. He was offered a senior scientist position with the Advanced Diagnostics and Therapeutics Initiative (AD&T) at the University Notre Dame to develop biosensor technologies for technology transfer. The goal of this position is to test these biosensors on tuberculosis biomarker and dengue fever virus RNA. He recently contacted the Biotechnology Program to personally thank the DEB graduate program for the mentorship, chalk talks and exposure to technology transfer and interactions with industry. He stated that the DEB chalk talks and the retreat presentations were extremely helpful as he prepares presentations for business audiences. He said that the most exciting part of his new job is the work outside of research. His team is in negotiations with a biotechnology company to license the technology. At the same time, he is submitting proposals to build prototypes of his device to attract venture capitalists and other industries. Without the Designated Emphasis in Biotechnology as well as the Big Bang! Business Plan Competition, Sunny would not have the required

skills for this position (Sunny Shah, 2011, personal communication).

As stated previously, the DEB is the formal academic training program for two prestigious pre-doctoral training grants. The strong interdisciplinary focus and success, as measured by program growth of the DEB program has been key in securing continued funding of the NIH-NIGMS Training Grant in Biomolecular Technology (T32-GM08799) and initial funding of the NSF CREATE (Collaborative Research and Education in Agricultural Technologies and Engineering) IGERT (Integrative Graduate Education and Research Traineeship) Training Grant (DUE #065984). The current iteration of the NIH-NIGMS Training Grant in Biomolecular Technology is supplemented by generous matches from campus and industry. Dr. Kjelstrom serves as program coordinator of the Biotechnology Training Grant. The NSF CREATE - IGERT Graduate Training Program is a multidisciplinary research partnership of biologists and engineers focuses on genetic engineering of plant biosynthesis to permit efficient production of products that include enzymes, biodiesel, and vaccines. Industry internships take place in both the United States and Ireland. The program is directed by Prof. Karen McDonald (Associate Dean of Research and Graduate Studies, College of Engineering) and is coordinated by the Biotechnology Program associate director, Dr. Denneal Jamison-McClung. Entrepreneurship is encouraged in both training programs. NIH Biotech fellow, Alan Szmodis and CREATE IGERT trainee Luca Arzola were winners of the Big Bang Business Plan competition. Dr. Szmodis is a cofounder of a tech start-up called *NanoOasis* in Richmond, CA (www.nanoasisinc.com). Lucas Arzola will graduate in 2012 and is in the process of securing funding for *Inserogen* (vaccine production in tobacco).

In addition to the formally associated training grants mentioned above, DEB students are actively encouraged to pursue related biotechnology training opportunities here on campus. In 2006, Dr. Kjelstrom co-directs the Howard Hughes Medical Institute's Integrating Medicine into Basic Science (HHMI-IMBS) graduate training program (directed by School of Medicine Executive Associate Dean Frederick Meyers), which builds "bench-to-bedside" translational research skills. Although the HHMI-IMBS Training grant is not formally linked to DEB curriculum, close to half of the eight scholars per year are DEB members. Dr. Kjelstrom oversees recruitment and retention activities and DEB students are a good fit for this cross-disciplinary training program. Students who complete this program may earn a Certificate or a Designated Emphasis in Translational Research. The ability to provide fellowship and traineeship support for many of the DEB students is a critical element due to the rapid growth of the graduate program and the recruitment of

high quality students from diverse backgrounds. The DEB graduate program is very proud of the fact that 25% of its students from under-represented minorities and many of these students have been funded on the training grants.

DEB CURRICULUM

(see www.deb.ucdavis.edu for more detailed information)

The keystone course is Biotechnology Fundamentals and Application (MCB 263). It is team taught by molecular biology and engineering faculty. A team project is required and the team must include both biologists and engineers. Working in interdisciplinary teams is very challenging, but is a key element of the graduate program. Students learn the fundamentals of molecular biology and chemical engineering as they relate to recombinant DNA technology. For the team project, the class is divided into teams of approx. 5 students. Based on the concepts, methodologies and strategies discussed in class (or found in the literature), the teams will propose, describe and analyze a biotechnological approach for producing a specific product(s) in a biological host. Each team will make an oral presentation on their project to the class and instructors near the end of the quarter.

Three quarters of the industry-related seminar Current Progress in Biotechnology (MCB 294/ECH294). Speakers come from industry as well as academia. This eclectic seminar series covers a wide range of biotech-related topics as well as the business of biotech (venture capital investment, IP and patents, regulatory affairs, developing a GMP facility, etc.). Lunch is hosted after the seminar, which enables faculty and students to meet the speaker and develop collaborations or internships.

Scientific Professionalism & Integrity (GGG296) or equivalent course is required for all DEB students, since bioethics is a critical component of the biotechnology industry. The students become familiar with their roles and responsibilities as professional scientists or engineers. While some standards of acceptable scientific behavior will be presented in class, most of the time will be spent discussing various "gray zone" scenarios, in which proper conduct is unclear.

MCB 282 (Internship) is the most popular course in the DEB program. This 3-6 month experience allows students to experience hands on training in industry. The internship exposes DEB graduate students to: 1) research activities in a biotechnology company; 2) company culture; 3) legal and business aspects of industry and 4) career options. Performance (student report) will be evaluated by the professor in charge and in consultation with the company trainer. In 2011, 30 students were placed in paid, off campus internships. Examples of internship sites include: Genentech; Amgen; Monsanto;

Novozymes; Novartis; OncoMed; Celgene; Takeda SF; Pfizer; California Healthcare Institute (CHI); etc.

Electives:

MIC 292 - From Discovery to Product: An Introduction to Industrial Biotechnology seminar (offered every other year) consists of a series of seminars from scientists and engineers from Novozymes, Inc. as well as a tour of the facility. This seminar gives the students a good overview of the operations of a biotechnology company as well as what skills are required. MIC 292 may substitute for one quarter of MCB 294.

ECH 198 - Principles of Biomanufacturing. This course covers principles of large scale bioreactor production of metabolites, enzymes and recombinant proteins (human therapeutics, antibodies, vaccines, etc) including the development of strains/cell lines, fermenter/bioreactor design, monitoring and operation, product recovery and purification, and biomanufacturing economics. The goal is provide students with fundamental and practical knowledge of large scale manufacturing in the biotechnology and related industries. Course is intended for students outside of the biochemical engineering major.

PLS 298 - Transgenic Plant and *In vitro* Plant-Based Expression Systems. Course is designed to train graduate students interested in new developments in the fundamental understanding and applications of plant biotechnology, with particular emphasis on the use of plant-based systems for the production of recombinant protein products. It will cover scientific principles, methods and protocols, challenges, and case studies associated with the generation and use of transgenic plants and plant cell cultures for recombinant protein production and metabolic engineering; practical issues and limitations; recovery and purification of plant products; and related regulatory, environmental, health and safety, and intellectual property topics. This course will provide background to prepare students for the CREATE-IGERT summer short courses and emphasizes the complexity and integrative perspectives that are needed to fully analyze these types of systems. For example, students work in teams to review and evaluate a recent USDA/APHIS regulatory case.

OTHER DEB OPPORTUNITIES:

In addition to offering academic courses, the DEB graduate program provides guidance and assistance in: 1) Locating internships; 2) Strategic Career Explorations; 3) Creation of oral presentations; 4) Composing a cover letter and curriculum vitae, especially for non-academic positions; and 5) Networking with industry & government scientists as well as business leaders.

There are numerous informal mentoring sessions, networking at the luncheons after the MCB 294 semi-

nars and at the annual Biotechnology Retreat and public communication on science at the Pizza Chalk Talks, K-12 outreach on Picnic Day and the Teen Biotech Challenge, volunteer opportunities at SARTA events, the Big Bang Business Plan competition, business development bootcamps and the certificate program.

DEB students receive discounted registration for The Biotechnology Program's Summer Technical Short Courses. These successful cutting-edge summer courses enable campus researchers and students, government and industry scientists to keep up with the latest technologies. Course offerings have included: Flow Cytometry, Proteomics, Bioinformatics –Next Generation DNA Sequencing, DNA Microarrays, Confocal Microscopy and Advanced PCR Techniques.

Associate director, Dr. Denneal Jamison-McClung has developed a formal mentoring program for the CREATE-IGERT trainees (who are all members of the DEB). The mentoring program was piloted in the fall 2010 and included career topics: CV preparation; interviewing skills; related career tracks; professional networking via social media; understanding the culture of peer review; grant preparation strategies; ethical and intellectual property issues and scientific communication for non-specialist audiences. There are plans to expand the formal mentoring program to address the needs of all of the DEB graduates as additional funds become available.

STUDENT TRACKING/NETWORKING

The Biotechnology Program maintains extensive databases on Industry partners as well as DEB students. The DEB student database is used to follow academic progress as well as employment history after graduation. The website for the Designated Emphasis in Biotechnology was created in 2002 to market the program and associated training grants. The website also includes an entrepreneurship resources page for those students wishing to learn more about what is involved in starting and managing a company. In 2008, a DEB LinkedIn group was created to connect program alumni with campus and maintain professional ties that may be leveraged into internship and other professional development opportunities for current DEB students. In 2010, she also created a Facebook site and Dr. Jamison-McClung launched a Twitter feed. Both social media outlets facilitate networking with DEB colleagues, students and alumni, and enhance sharing of biotech-related research news.

COLLABORATIVE EFFORTS IN EDUCATION AND TRAINING:

COLLEGE OF ENGINEERING

The Biotechnology Program has had a long relationship with the College of Engineering. Prof. Karen McDonald in the Department of Chemical Engineering and Materials Science is the chair of the Biotechnology Program Executive Committee in addition to serving as Director or Co-Director on the two graduate training grants and as a member of the DEB executive committee. AS stated previously, the NSF CREATE IGERT graduate training program is focused on translational research in the area of plant-based biomanufacturing. Although plant biotechnology has been deployed commercially for decades for improved agronomic traits of crops, primarily by large multinational corporations, a nascent industry dominated by small start-up firms is developing in which plants are being used in very different ways to solve some of our most important societal problems in health, energy and the environment. These companies are focusing on using plant biotechnology for manufacturing of plant-made pharmaceuticals (PMP) or plant-made industrial proteins (PMIP), referred to collectively as PM(I)P. One of the goals of the IGERT training program is help graduate students identify potential commercial applications of their research, and provide them with tools and training to help them become entrepreneurs and leaders in this emerging industry. For example, through workshops and lectures offered by PIPRA (Public Intellectual Property Resource for Agriculture, <http://www.pipra.org/>), a global consortium of universities, public agencies and nonprofit research institutions headquartered at UC Davis that helps public sector organizations get their research out of the lab and into use, students learn how to navigate the complex intellectual property landscape in the plant biotechnology field, identify intellectual property obstacles in their own research, and think strategically about a commercialization path as they embark on their research.

As part of one of the required CREATE-IGERT courses, Dr. Alan Bennett (PIPRA Executive Director) and Dr. Cecelia Chi-Ham (PIPRA Director of Science and Technology) present tutorials and lectures on patents, the intellectual property landscape in plant biotechnology, freedom to operate analyses¹⁶, and enabling plant transformation technologies developed by PIPRA members that maximize freedom to operate. Students learn early on in their research program how intellectual property can support innovation if it is understood and used strategically but also how it can block innovation and potential commercialization if it is ignored, and they can use this knowledge to plan their research in a way

that may allow for an easier path for commercialization. CREATE-IGERT students and/or other DEB students have also participated in the:

- Big Bang! Business Plan Competition (<http://bigbang.gsm.ucdavis.edu/>),
- Entrepreneurship Academies (<http://entrepreneurship.ucdavis.edu/program.php>),
- Business Development Certificate Program (<http://entrepreneurship.ucdavis.edu/fellows.php>)
- Angels on Campus program (<http://entrepreneurship.ucdavis.edu/angels.php>)

In addition to entrepreneurship opportunities at UC Davis, CREATE-IGERT students have participated in workshops offered by the National Collegiate Inventors and Innovators Alliance (NCIIA) such as the Invention to Venture workshop on technology entrepreneurship held at the NSF IGERT Annual Meeting, the UC Berkeley Business Plan Competition, and the UCSF Idea to IPO course.

Professor McDonald is very entrepreneurial and encourages her students to pursue their entrepreneurship interests. One of her CREATE-IGERT predoctoral students, Lucas Arzola, was the leader of the *Inserogen* team and won the UC Davis 2010 Big Bang! Business Plan competition. Two of her CREATE-IGERT trainees were recipients of recent National Collegiate Inventors & Innovators Alliance (NCIIA) Advanced E-Team awards and she and her graduate student, Lucas Arzola, participated in an NCIIA Sustainable Vision Venture Lab (<http://nciia.org/taxonomy/term/1388>) to further develop their business model. Lucas Arzola and team's business plan was for Green Technology for Sustainable Poultry Vaccine Manufacturing (<http://nciia.org/node/1605>). They received a grant that will help develop a proof-of-concept that will bring SwiftVax-produced vaccines closer to market. The team's initial target product is an animal vaccine for Newcastle Disease, a devastating and highly pathogenic disease in poultry. The other IGERT trainee, Mark Lemos and his team are focused on biofuels. Helios (<http://nciia.org/node/1708>) is researching the viability of duckweed, a tiny, stem-less monocot plant that grows on the surface of ponds, as a cellulosic biofuel. Duckweed has a 2-3 day doubling time, utilizes non-arable land, can grow all year round and does not require extensive biomass pretreatment for biofuel production."

ENGINEERING TRANSLATIONAL TECHNOLOGY CENTER (ETTC)

The College of Engineering at UC Davis has recently established an incubator facility for faculty startups. The ETTC is a technology incubator designed to speed the transfer of high-impact, innovative ideas to the marketplace to meet society's needs. Funding for ETTC is provided by private donations. Typically, government grants support the early stage of discovery, while fewer funds are available for the vital developmental period that precedes demonstrating proof of concept or financial viability to investors. For more information about ETTC, contact Executive Associate Dean, Bruce White.

GRADUATE SCHOOL OF MANAGEMENT

The Child Family Institute for Innovation and Entrepreneurship [formerly the UC Davis Center for Entrepreneurship (C4E), <http://entrepreneurship.ucdavis.edu>] is led by Prof. Hargadon and Wilton Agatstein. The Institute will expand on the multitude of workshops and programs for entrepreneurial scientists and engineers that many of the DEB graduate students participate.

Current offerings:

1. **Big Bang! Business Plan Competition**
The Big Bang! is the annual UC Davis Business Plan Competition organized by MBA students of the Graduate School of Management. The goal of the contest is to promote entrepreneurship at UC Davis and the region supported by the University. Big Bang! provides a year round forum in which UC Davis students, alumni, staff and faculty can collaborate to develop and test their business vision and plans. The competition provides a network of resources for mentorship, team creation, education, networking and financing for these aspiring entrepreneurs. Many groups and constituencies benefit from the competition, including students, faculty, staff, alumni, venture capitalists, business professionals and local entrepreneurs. The competition is generously sponsored by local corporations and the venture capital community so the participants can participate for free.
2. **Business Development Fellows Certificate Program**
The Business Development Fellows program provides UC Davis science and engineering graduate and postdoctoral

students hands-on experience in growing new skills for a career in industry, and the opportunity to develop new business ventures. Fellows in the one-year program study technology management, innovation and entrepreneurship and participate in interdisciplinary practicums alongside MBA students and under the guidance of Graduate School of Management faculty, investors and entrepreneurs. Networking events and visits to regional start-ups round out the immersive experience. Fellows take five (5) Graduate School of Management courses during the year. They also participate in the Big Bang Business Plan Competition.

3. **The Entrepreneurship Academies**
The Entrepreneurship Academies are the Center's flagship programs. The Entrepreneurship Academy is an innovative, one-week intensive designed for science and engineering senior undergraduates, graduate students, postdocs and research faculty who want to learn to commercialize their research, prepare for a career in industry, or take the first steps toward launching a new venture. Academies are taught by university faculty, venture capitalists and industry experts and attract participants from universities around the globe to UC Davis. The Entrepreneurship Academy provides a framework for the university to build a network between its research and the investment community. It combines a comprehensive curriculum based on building a business with hands-on exercises for science and engineering graduate and post-graduate researchers to learn technology commercialization and new business development, the navigation of intellectual property and technology transfer, the development and validation of potential opportunities for commercialization, and integration of scientific research and entrepreneurship. Currently there are three one week intensive academies offered: 1) Food and Health; 2) Green Technology and 3) Biomed Engineering. These are intensive business development academies for science and engineering graduate students, postdocs and faculty working on research in the related technology. They are held

annually at UC Davis for approximately 50 researchers from around the globe but priority given to UC Davis students. Investors, industry executives and entrepreneurs in the tech space participate as mentors and speakers.

4. **UC Entrepreneurship Academy**
It is a general one-week intensive business development academy for science and engineering senior undergraduates, graduate students, postdocs and faculty. It is held annually at UC Davis, priority given to UC Davis and UC students. Investors, industry executives and entrepreneurs from regional and Bay Area engineering and science fields participate as mentors and speakers.
5. **Angels on Campus**
The Angels on Campus is a mentoring program for students and faculty to meet with angel investors on campus and explore commercial opportunities surrounding their ideas. Once a month, 3-4 individuals/teams present their ideas and gather feedback from a panel of three to four angel investors. Each team has 40 minutes to present and receive feedback. This unique opportunity provides researchers with a risk-free environment to gather commercialization feedback and to build their network with the investment and business community. It also allows angel investors the opportunity to foster their network on campus and see first-hand potential technologies coming out of the campus.
6. **Chairperson on Campus**
The Chairperson on Campus program provides students in the Business Development Clinics the opportunity to interact with experienced industry executives and angel investors. Selected industry execs and angels investors participate for a quarter as chief business advisors and mentors for student teams in the Graduate School of Management's Business Development Clinics. The chairperson assists each student team as an advisor, guiding the teams as they identify the uncertainties surrounding their idea, developing team deliverable, and analyzing their venture for market opportunities.

The mission of the new Child Family Institute for Innovation and Entrepreneurship is to: 1) Integrate innovation and entrepreneurship courses alongside and within existing academic degree programs; 2) Promote the study of innovation and entrepreneurship by management, social science, humanities, and legal researchers across the university; 3) Support the MBA-student run Big Bang! Business Plan Competitions; 4) Expand the pioneering and nationally-recognized business development certificate programs and entrepreneurship academies for faculty, doctoral students and post-doctoral researchers in the life sciences and engineering and for graduate students in business designed to help move ideas from lab to market; 5) Develop opportunities for innovation and entrepreneurship for undergraduate students across the university, including those in social sciences and humanities; 6) Further programs to build networks that connect campus entrepreneurs with mentors and investors to accelerate commercialization and 7) Reach out to business and government to inform the adoption of innovative technologies.²

SACRAMENTO AREA TECHNOLOGY ALLIANCE (WWW.SARTA.ORG)

SARTA is an important member of this translational team for launching start-up tech companies coming out of UC Davis. SARTA is directed by a board of 30+ regional leaders of academic institutions, investment groups, business associations and technology corporations that seek to foster technology innovation and growth in the nine county greater Sacramento region. UC Davis was one of the three founders in 2000, along with Golden Capital Network and the Sacramento Metro Chamber. Currently there are four UC Davis members on the Board. Dr. Kjelstrom has been on the board since 2001. The Dean of the GSM, Steven Currall is also an active board member. Meg Arnold, the CEO, was previously the associate director of UC Davis CONNECT, so she is well aware of the needs of fledging startup companies emerging from campus research.

SARTA is accelerating the growth and development of the technology sector in the Sacramento region. It is the nexus that links technology leaders, entrepreneurs, investors, service providers, community organizations, and educational institutions. It is a not-for-profit 501(c)3 corporation founded in 2001, and focused on a nine-county region of Butte, El Dorado, Nevada, Placer, Sacramento, Solano, Sutter, Yolo and Yuba counties. SARTA's vision is to develop the Sacramento region into a nationally recognized center of technology and technological innovation, as evidenced by a significant number of technology companies growing, developing and prospering

in the region. In support of its mission, and across all of its programs and services, SARTA's work has three main areas of emphasis: 1) Build community within and among the technology sector in the region. We connect technology entrepreneurs and executives to each other, as well as to the resources they need to be successful. 2) Raise the profile of the technology sector in the region, among those who are not engaged with it. We highlight, emphasize, collect, and publish information about the technology sector overall, as well as the accomplishments and milestones of specific companies. 3) Provide learning and educational opportunities to entrepreneurs and executives with regional technology companies. They support their efforts to learn best practices from subject-matter experts and technology leaders.

SARTA oversees a number of programs for early stage entrepreneurs in a number of technology sectors:

1. CleanStart is an initiative of McClellan Technology Incubator (MTI) and Sacramento Area Regional Technology Alliance (SARTA) designed to accelerate the development of clean energy technology ventures within the Greater Sacramento Region. CleanStart was born out of an innovative needs assessment study that was jointly funded and managed by the California Energy Commission, the Sacramento Municipal Utility District, and the McClellan Technology Incubator.
2. MedStart is a new initiative in medical technology. MedStart will help build and strengthen a healthy medical technology industry in the Greater Sacramento Region and strive to be a repository of information and expertise for our vital medical technology sector. Claire Pomeroy, CEO, UC Davis health System, Vice Chancellor of UC Davis Human Health Sciences and Dean of the School of Medicine, kicked off the Lead Sponsor campaign. In 2010, she established The Claire Pomeroy Awards for Innovation in Medical Technology to recognize and celebrate outstanding achievement within our region for innovation in medical technology. Networking mixers, CEO Roundtables, the Telemedicine Task Force, Inventors Forums, the Med Tech track in the Leadership Series etc. are key elements of the MedStart initiative.
3. VentureStart prepares high growth/high technology entrepreneurs and early stage companies in the Sacramento region to be investor-ready for Angel and VC financing by providing free, comprehensive, and expert mentorship.
4. Leadership Series - SARTA is committed to engaging members and the regional tech community in quality educational programming. This annual series of seminars is designed to help local technology companies participate to provide high return activities that promote the success of growing regional technology companies. Each session runs 1.5 -2.5 hours in length and will be attended in person. All seminars occur on the third Wednesday of the month at McClellan Technology Incubator and partner locations.
5. Sacramento Venture Lab is SARTA's newest initiative, Sacramento Venture Lab, is a unique university-private industry technology development center that serves as a catalyst to accelerate the growth of companies based on innovative technologies. The lab, located at 3801 Power Inn Road, Sacramento, CA 95826, brings together business incubation services and linkage to resources of Sacramento State University and University of California, Davis. The lab focuses particular emphasis on growing clean technology and medical technology firms and related jobs in the Sacramento region.
6. Executive Roundtables - SARTA offers by-invitation peer-to-peer networking groups. These successful forums allow CEOs to interact with other CEOs to provide support and advice in a collaborative manner. This year we plan to add two new CEO forums as a service to the medical technology and clean energy industry sectors as well as a new networking forum for engineers. Their discussions are kept confidential in order to facilitate an open exchange.

SUMMARY

UC Davis and its community partners have addressed the need for innovation in graduate education and training for close to twenty years. This paper has showcased how graduate education programs, new centers and in-

stitutes, cross-disciplinary academic-private partnerships and technology brokering can bring diverse groups of individuals together to translate ideas into real world applications. The creation of intellectual and human capital at universities must be linked to financial capital and social capital via dense social networks. PhD programs in science and engineering must continue to address the needs of the 21st century to stay relevant. UC Davis has been assembling this dense network for over fifteen years and is now seeing results. As more start-up companies emerge from campus research, they will lead to the development of technology clusters and employment opportunities for new graduates.

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