

EXPERIMENTAL PROGRAM TO STIMULATE COMPETITIVE RESEARCH





2008-2013



EXPERIMENTAL PROGRAM TO STIMULATE COMPETITIVE RESEARCH Research Infrastructure Improvement Grant 2008–2013

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ON THE COVER: Delaware State University faculty member Clytrice Watson; a closeup of a "sensor on a chip," which will be incorporated into portable environmental sensors; environmental scientist Dave Carter speaks to participants in EPSCoR's undergraduate summer research program; environmental studies students from Wesley College evaluate a Delaware watershed.







Director's Message

Building the research capacity of the state of Delaware to enhance workforce and economic development and increasing our competitiveness at the national level are the key goals of the Delaware EPSCoR program.

This report highlights how we have invested \$15 million from the National Science Foundation and \$5 million from the state of Delaware over the past five years. The focus of our EPSCoR Research Infrastructure Improvement (RII) grant was captured in its title: "Building Research and Education Infrastructure to Enhance Environmental Science and Its Application in Delaware."

We have built on our strengths in environmental sciences and engineering within the state and contributed to a robust research community, a strong and diverse STEM educational pipeline, and a growing economic sector committed to environmental sustainability.

From almost any angle, the return on the federal and state investments in Delaware EPSCoR has been considerable. Since our designation as an EPSCoR jurisdiction in 2003, the NSF EPSCoR program has resulted in \$46 million in direct EPSCoR funding to the state (including our most recent RII award of \$20 million, which will go forward until 2018). Those funds have been leveraged to generate an additional \$68 million in research funding for Delaware so far. More than 450 journal articles have been published as a result of research directly or indirectly funded by EPSCoR and more than 250 graduate and undergraduate students have been supported.

We have launched five new academic research and service centers during the past five years, including the Delaware Environmental Institute, the Center for Integrated Biological and Environmental Research, the Center for Science, Ethics and Public Policy, the Office of Economic Innovation and Partnerships, and the Center for Industry Research and Workforce Alignment. These centers serve as hubs of interdisciplinary and inter-institutional activity in research, education, and outreach. Highlights of the activities of each of these centers can be found in this report.

As we now begin a new five-year RII grant, the four partners in Delaware's EPSCoR enterprise—the University of Delaware (UD), Delaware State University (DSU), Wesley College, and Delaware Technical Community College (DTCC)—are working together in new ways and reaching out to new partners to ensure the continued success of the programs catalyzed by EPSCoR thus far and to explore exciting new avenues for both environmental and economic health in Delaware and beyond.

Donald L. Sparks Director, Delaware EPSCoR S. Hallock du Pont Chair of Soil and Environmental Chemistry University of Delaware





Research

Monitoring and Restoring Ecosystem Health

Delaware EPSCoR features a globally competitive environmental research portfolio that addresses biogeochemical processes of Earth's near-surface environment, referred to as the Critical Zone, with special focus on topics relevant to the state.

The overarching goal of the research is to contribute new knowledge of how to observe, measure, evaluate, forecast, protect, and restore the health of complex ecosystems. Our research efforts fall into six interrelated and interdisciplinary thrusts, which fully integrate the capabilities of our partner institutions.

Phosphorus in the Chesapeake Bay

An overabundance of nutrients—primarily phosphorus—fosters the formation of an oxygenstarved "dead zone" in the Chesapeake Bay every summer. Phosphorus in the bay comes from three primary sources: the land, the ocean, and buried sediments. Each phosphorus source, including fertilizers used on land, wastewater effluents, seafloor sediments, and the ocean, usually has a distinctive isotope composition or "signature." By comparing data from sediment cores, scientists can identify the contributions of different phosphorus sources over time, which could have significant implications for future efforts to manage nutrient pollution in the Chesapeake Bay region.

UD faculty member Deb Jaisi investigates the sources of phosphorus responsible for the Chesapeake Bay's annual dead zone.

Interactions at Environmental Interfaces

Interactions among microorganisms, organic matter, and minerals play important roles in the cycling of nutrients such as carbon, nitrogen, and phosphorus and toxic metals such as arsenic and chromium. This is a frontier in environmental science that will enable us to improve and refine our predictions of global environmental and climate change. The work has benefited from synergistic research collaborations with the NSF-supported Christina River Basin Critical Zone Observatory, managed through the Delaware Environmental Institute.

Soil Toxicity and Remediation Strategies

Certain soil properties such as pH can make toxic metals like nickel, cobalt, and zinc less available for uptake by humans and other organisms. EPSCoR research strives to better understand the chemical processes involved. Scientists have developed an innovative technique that employs intense X-rays to track the processes and rates at which metal ions attach to soil particles and form products that result in less metal leaching into water and reduced bioavailability. This research has involved extensive collaboration with scientists at several national laboratories where such high-powered synchrotron-based radiation sources are available. The resulting information can be applied by resource managers and others dealing with contaminated soils to protect human health and make recommendations about soil remediation that are economically sound.



LEFT: UD graduate student Shannon Carter tests air samples taken from poultry houses for the presence of particulates containing arsenic.

RIGHT: A receiving station on a UD rooftop feeds environmental data from Earth-observing satellites to researchers who can apply the information in EPSCoRsponsored projects.

Poultry Particulates

Poultry production is a major industry on the Delmarva Peninsula. Some associated activities disperse small airborne particles that could have harmful contaminants such as arsenic and copper attached to them, posing a potential health hazard to workers or possibly surrounding communities. EPSCoR researchers are working to determine the form and distribution of metals and other contaminants associated with particulate matter emitted from poultry houses—information that is essential for establishing proper health and safety precautions.

Small Particles, Big Roles

The exact mechanisms by which small clusters of particles form and grow in the atmosphere are poorly understood, but this process may significantly impact cloud condensation and global climate. EPSCoR scientists are working to better understand the sources and transformations of small particles (called nanoparticles) in air and wastewater.

Environmental Monitoring

Satellites, buoys, and other monitoring equipment provide EPSCoR scientists with valuable data about environmental conditions. With data generated by one of the densest environmental monitoring networks in the country, researchers at the Delaware Environmental Observing System, or DEOS, can supply important information in usable formats to environmental regulators, farmers, and emergency management personnel, saving tax dollars and even lives. Two new satellite receiving stations installed on the UD campus in 2010 support a wide range of research, including projects that monitor coastal flooding, observe coastal waters for harmful algal blooms, and track changes in ocean circulation.





Juejun Hu works in his materials science and engineering lab at UD to perfect smallscale environmental sensors.

Reaping What We Sow: Planting Seeds for Future Research Growth

S ince 2008, EPSCoR has awarded 43 seed grants to researchers throughout Delaware, benefiting some 80 faculty and students. Seed grants, averaging \$30,000-\$50,000 apiece, stimulate new research and help investigators set the stage for applications to larger federal funding programs. Seed grant proposals are solicited annually, and final selections are made by a committee of senior faculty affiliated with Delaware EPSCoR and external reviewers, including scientists at the Delaware Department of Natural Resources and Environmental Control.

Awardees are chosen based on the quality of the science being proposed, the applicability of the research to state environmental issues and EPSCoR



DSU environmental chemist Qiquan Wang studies the possible human health effects of indoor air contaminants such as phthalates.

themes, the strength of the collaborations, and whether the grantee is a first-time recipient of EPSCoR funding. Selected projects typically feature multidisciplinary collaboration and/or inter-institutional partnerships. Since 2008, more than \$1.4 million in seed grant support has been awarded. The following are highlights of a few of the projects supported:

Indoor Air Quality

Phthalates are chemicals used in cosmetics, personal care products, and flexible plastic and vinyl consumer products such as toys, shower curtains, and food packaging. The human health effects of phthalates are not yet fully known, but since they are not chemically bound to the plastics to which they are added, phthalates can be released into the environment and appear in foods, indoor and ambient air, indoor dust, water sources, and sediments.

In an example of multi-institutional collaboration, EPSCoR researchers at DSU and Wesley are



UD graduate student Jacob Fooks interviews a tourist on the Rehoboth Beach boardwalk about how offshore wind farms might affect her vacation plans.

investigating phthalate occurrence in dust samples from various indoor environments and exploring their possible effects on humans. Their findings will add valuable insights to an important public health question.

Offshore Wind and Tourism

With significant interest in increasing the nation's alternative energy production, coastal states want to know how offshore energy development could affect other economic drivers, such as tourism. To help answer that question, EPSCoR researchers surveyed Delaware beachgoers to see how open they were to the idea of offshore energy, specifically wind turbines and oil drilling platforms.

The researchers wanted to determine how close the turbines and platforms could come to shore before people would no longer want to visit. Would such structures negatively impact visitors' experiences to the point where they would not return to the area again?



UD plant and soil scientists Janine Sherrier and Harsh Bais are studying how a common soil microbe can slow arsenic uptake by rice plant roots.

The group's findings indicated that people would be more open to viewing wind turbines off the coast than oil platforms, and that people were generally very open to the idea of having wind turbines visible from the beach if it resulted in lower energy costs. In fact, only about 30 percent of participants indicated that the presence of wind turbines would detract from their beach experience, while 60 percent indicated the same for oil platforms. Such feedback can be used to inform decisions about the placement of energy development facilities.

Sensor on a Chip

EPSCoR researchers are developing sensors that they hope will allow real-time, in situ detection of water and air pollutants in an inexpensive and environmentally friendly manner. They are creating small, highly sensitive devices that will detect various chemicals, even at low levels in the environment. With further research and development, the devices could be integrated into portable, battery-powered sensor packages—replacing more traditional molecular detectors, which require bulky and expensive equipment.

Deployed in a network in the field, an array of the small sensors could detect contamination in air, water, and soil in real time and relay that information wirelessly to a computer. A major obstacle preventing small sensors from becoming practical replacements for bulky machines is that the new technology is still less sensitive and specific in its detection than the instruments currently in use. The project aims to create sensors that overcome these obstacles.

Reducing Arsenic in the Food Chain

Rice is a staple in diets across the globe, but it can be contaminated by arsenic in the soil, thereby posing a health risk to millions of people. To help solve this problem, EPSCoR scientists are studying whether a naturally occurring soil bacterium can create an iron barrier in rice roots that reduces arsenic uptake.

Their preliminary research has shown that the bacterium can indeed mobilize iron from the soil and slow arsenic uptake in rice roots, but the scientists have not yet determined exactly how this process works and whether it will lead to reduced levels of arsenic in rice grains—the edible portion of the plant. If successful, the project could lead to easy, low-cost strategies in the form of soil amendments that reduce arsenic in the human food chain.

Core Strengthening

Modern scientific research often relies on sophisticated and expensive equipment, from electron microscopes to gene sequencers and mass spectrometers. When scientific instruments are too costly for an individual researcher to buy and maintain, shared core facilities allow multiple researchers access to the tools they need. Since 2008, EPSCoR has contributed significantly to the state's research infrastructure by purchasing \$1.7 million in research equipment for use by faculty and students in the statewide network and our partners in industry and government.

Housed in laboratories around the state and managed by qualified research professionals, the core facilities are operated on a fee-for-service basis. EPSCoR further assists members of the research community by offering fee waivers that offset the costs of using the equipment. Individual researchers may apply to the EPSCoR office to receive a fee waiver for research that is not already supported by other grants, enabling them to collect the preliminary data that aids them in the development of future research proposals. Fee waivers valued at \$176,000 were distributed to 23 faculty across the network during the five-year grant period.

Through EPSCoR funding, a new materials characterization laboratory in the Interdisciplinary Science and Engineering Laboratory on the UD campus was outfitted with state-of-the-art equipment to analyze properties of materials. Specifically, funds were used to support the purchase of an X-ray diffractometer to support research in the environmental sciences, including environmental mineralogy, biomineralogy, and soil biogeochemistry. The new XRD allows researchers to analyze very small samples, iron-rich minerals, and complex mixtures of environmental minerals.

The Right Stuff: New Faculty, New Expertise for Delaware

Delaware EPSCoR endeavors to develop a new and diverse generation of science, technology, and policy experts. To meet that goal, EPSCoR uses program funds to help hire new faculty and provide many of them with essential start-up funds to get their research underway. From 2008 to 2013, EPSCoR helped to bring in 15 new faculty with expertise in environmental disciplines such as microbiology, hydrology, geochemistry, and bioinformatics. The new faculty were hired strategically, to fill needs identified both internally and externally. Some were hired to fill gaps in expertise identified by our state committee and external advisory board. Others round out important areas of strength at Delaware institutions, boosting our already strong reputation in these fields. The result is an outstanding team of collaborators, whose work will not only provide answers to critical problems facing the state, but also influence future generations of scientists, engineers, and policy experts through their teaching. New faculty hired with EPSCoR assistance include the following:

- Cristina Archer, UD, atmospheric modeling, wind power
- Jennifer Biddle, UD, environmental microbiology
- Clara Chan, UD, geomicrobiology
- Luc Claessens, UD, hydrology
- Deb Jaisi, UD, mineral surface geochemistry
- Hong Li, UD, aerosol science
- Liang Liu, DSU, biostatistics
- Julie Maresca, UD, biogeochemistry
- Holly Michael, UD, hydrogeology
- John Newberg, UD, aerosol chemistry
- Andrea Sarzynski, UD, environmental policy
- Angelia Seyfferth, UD, soil and environmental biogeochemistry
- Tomasz Smolinski, DSU, bioinformatics
- Rodrigo Vargas, UD, soil-plant-atmosphere interactions
- Cathy Wu, UD, bioinformatics





Holly Michael works withWstudents to measure coastalasgroundwater quality.b

To further support faculty, EPSCoR provides assistance to those who wish to apply for the National Science Foundation's Faculty Early Career Development (CAREER) awards. The awards are made "in support of junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research within the context of the mission of their organizations," according to NSF's website. In particular, Delaware EPSCoR helps applicants plan the education and outreach projects required in their proposals. Twelve Delaware faculty have received CAREER awards since 2008 with co-funding from the national EPSCoR program-two of them are highlighted here.

"With sea level rise, groundwater salinization could become more of an issue."

— UD hydrogeologist Holly Michael

The most widespread contaminant of groundwater is not a microbe or industrial chemical, according to UD hydrogeologist Holly Michael. It's seawater. "Salt is everywhere along the coast," Michael said. "With sea level rise, groundwater salinization could become more of an issue."

Michael is using her CAREER award to study large-scale movement of water between land and sea. She aims to better understand coastal



water flow and salt transport, which can help shed light on the potential consequences of sea level rise. The research has implications for water resource management, from protecting coastal ecosystems to informing where to install offshore wind farms.

Beyond research, Michael is dedicated to improving education in the geological sciences. Her grant is enabling her to create workshops for high school students at the DuPont Environmental Education Center in Wilmington, Delaware. Students will collect and analyze data from wells in the marsh along the Christina River to learn about tide-driven water exchange.

"Microbial iron cycling is important to understanding the chemistry of our waters."

— UD geomicrobiologist Clara Chan

Patches of orange slime with an oily sheen are not uncommon to see along stream banks, often mistaken for pollution or decomposing leaves. In fact, the substance is made by metal-eating bacteria



that create oxidized iron, or rust, naturally in the environment.

UD geomicrobiologist Clara Chan studies the role of these rust-producing bacteria in water flowing both above and below ground, and her CAREER award allows her to expand her research. "Microbial iron cycling is important to understanding the chemistry of our waters," said Chan.

Chan is using her CAREER award to study iron-oxidizing microbes that live in areas where iron-rich water underground meets surface water. The goal is to better understand the conditions in which the bacteria thrive in these groundwater-surface water transition areas—and how they affect water chemistry and movement. Clara Chan studies the role microbes play in the cycling of iron and the movement and chemistry of groundwater.



DENIN hosts an annual symposium that highlights research by Delaware faculty and students and our regional partners.

Launching Sustainable Centers for a Sustainable Delaware

elaware faces significant environmental challenges, including climate change and sea level rise, soil contamination, nutrient management, and water quality. Addressing these challenges demands innovative applications of science, engineering, and public policy.

To meet such critical needs, EPSCoR played an instrumental role in forming the Delaware Environmental Institute (DENIN) at UD and the Center for Integrated Biological and Environmental Research (CIBER) at DSU. They serve as a hub for scholars in environmental fields across various departments and colleges to form a focal point for collaboration, partnership, and joint research. Assisting these key components of research infrastructure to become self-sustaining is a primary goal of EPSCoR.

Delaware Environmental Institute www.denin.udel.edu

Launched at the University of Delaware in 2009 under the direction of Donald L. Sparks, DENIN has quickly become a catalyst for collaboration. DENIN seeks to add value to environmental programs statewide by initiating large, interdisciplinary research projects; facilitating and supporting the development of interdisciplinary academic programs; forging partnerships to address environmental concerns and to provide solutions; and sponsoring events and programs that provide interaction and public engagement. Many of these activities are designed to help sustain the state's economic pillars in agriculture, industry, and tourism. More than 120 faculty from UD, DSU, and Wesley College are affiliated with DENIN.

"Delaware is in an ideal position to pilot research strategies to address critical environmental issues," according to Sparks. "The First State has a track record of effectively identifying, prioritizing, and acting on difficult issues and valuable opportunities. DENIN strives to facilitate informative research, effective communication, and issue resolution among key stakeholders."

In a short time, DENIN has forged a strong and cohesive network of distinguished scientists, engineers, policy makers, and educators committed to world-class science and education. Below is a sampling of recent accomplishments and activities.



Research

- Facilitated faculty working groups in core research areas, including processes at air/land/ water interfaces and environmental monitoring and remediation
- Managed major research grants totaling about \$26 million focused on environmental science and policy
- Sponsored exploratory research to enhance competitiveness for major grants

Education

- · Provided fellowships and research internships for more than 250 graduate and undergraduate students
- Established new interdisciplinary graduate program in water science and policy
- Provided professional development programming for K-12 teachers in partnership with scientists

Outreach

- Sponsored public lectures, films, field trips, and appearances at educational fairs
- Developed workshops on communicating science effectively for faculty and students





Center for Integrated Biological and Environmental Research ciber.desu.edu

CIBER is a regional faculty network hub in environmental and life sciences based at DSU. Faculty and students from DSU, Wesley, DTCC, and UD participate in the CIBER network. According to CIBER's director Venu Kalavacharla, "With the launch of CIBER in 2009, DSU has taken major steps to institutionalize support for growing collaborative, interdisciplinary research capacity."

Kalavacharla leads the center's core implementation team, which includes faculty from DSU, Wesley, and DTCC. The center's major functions include identifying funding opportunities and gathering groups of researchers to secure grants; providing opportunities for undergraduate and graduate students to pursue hands-on research; coordinating the user training, maintenance, and use of shared research facilities and instrumentation at DSU; and integrating research and outreach activities for partner institutions. CIBER manages EPSCoR seed grant funds that are awarded to faculty from the College of Agriculture and Related Sciences and the College of Mathematics, Natural Science, and Technology at DSU. In addition, CIBER works closely with the Ethics Resources Site at DSU to provide training and consultation in research ethics for its participants and partners.

CIBER serves as an important gateway to research experiences for students in Delaware and beyond. As the home of an NSF Research Experiences for Undergraduates (REU) program, the center trains approximately 10 students from around the country in molecular genetics and genomics each summer. Several places in the program are reserved for students from the partner institutions.

Recent accomplishments are highlighted below:

Research

- Secured more than \$3 million in additional federal funding including grants from NASA, USDA, and NSF
- Involved more than 12 faculty in CIBERfacilitated research



Center for Integrated Biological & Environmental Research

Education

- Managed summer research internship programs in molecular genetics and genomics, bioenergy, and agricultural farm experiences
- Launched DSU's summer research symposium for students
- Helped train more than 80 undergraduate students

Outreach

- Organized and managed agriscience and technology camps for elementary school students
- Provided training opportunities and exposure to STEM careers to middle and high school students

FROM LEFT: The molecular genetics and genomics lab at DSU; Mingxin Guo conducts biofuel research at DSU; CIBER director Venu Kalavacharla leads students in a discussion. BELOW: DSU researchers are developing drought and salt-tolerant plant varieties.



Connectivity + Collaboration = Cyberinfrastructure

Delaware EPSCoR strives to improve regional internet connectivity to national high-speed networks, facilitate research collaborations, provide training and education for scientists and educators, strengthen inter-institutional partnerships, and enable access to distributed research resources.

Bioinformatics

Increasing statewide access to bioinformatics is a priority, achieved through four initiatives:

- The Center for Bioinformatics and Computational Biology (CBCB) now includes more than 60 faculty across five UD colleges. Another faculty hire brought new bioinformatics-related research and education expertise to DSU.
- New academic programs have been established. UD now offers three bioinformatics and computational biology graduate programs and an interdisciplinary Ph.D. program in bioinformatics and systems biology. At DSU, a computer science master's program with an option for thesis and course work in biological informatics was introduced.
- The Delaware Biotechnology Institute (DBI), CBCB, and DTCC have built an educational platform allowing biology undergraduates to sequence marker genes from soil microbes and build a Delaware Soil Microbe Database.
- Wesley College faculty and undergraduates worked with CBCB to design and develop an online Cancer Drug Database which details pharmacokinetic properties of 85 FDA cancer

drugs and enables users to evaluate Structure Activity Relationships (SARs) among those drugs.

Multi-state Networks

Improved connectivity not only benefits educational and research priorities throughout Delaware, but regionally as well. NSF EPSCoR and NIH IDeA support has been used to improve networking capabilities among the northeast regional IDeA and EPSCoR states—Delaware, Maine, New Hampshire, Rhode Island, and Vermont.

Two pilot projects enabled collaborators to conduct meaningful research while also building the information highway and assessing its effectiveness. One project determined the metagenomes of cyanobacterial blooms in lakes in the Northeast; the other sequenced and annotated the complete genome of the little skate, a fish of increasing commercial relevance commonly found in New England.

Desktop Research Collaborations

Delaware EPSCoR partner institutions have significantly upgraded their cyberinfrastructure and centralized informatics capabilities. The improved system closed gaps in intra- and intercampus cybernetworks and supports leading-edge research, education, and outreach in the EPSCoR focus area of environmental science and biotechnology. Further, the



Cathy Wu, Unidel Edward G. Jefferson Chair and director of the Center for Bioinformatics and Computation Biology, participates in a meeting of the North East Cyberinfrastructure Consortium held at UD.

system serves as the video bridge for multi-site collaborations.

Environmental Sensing

Delaware EPSCoR's focus on environmental science has led to a need for large-scale data collection and analyses. Increased capacity was necessary to integrate information from diverse data streams and to store, process, organize, analyze, and share the data. EPSCoR support led to the launch of the Delaware Environmental Monitoring and Analysis Center (DEMAC), which integrates a large set of statewide environmental sensing systems and enables researchers to model and analyze environmental trends and patterns.

Ethics

Fair and Equitable: Ethics for Research and Policy

The ethical challenges posed by technological innovation, the use of natural resources, and environmental protection or degradation frequently make headlines. But while the headlines appear in black and white, the issues involved are rarely so simple. Human relationships with our natural and built environments are complex and interrelated.

Delaware EPSCoR emphasizes the integration of ethics, policy, economics, sociology, and the humanities into discovery research. To help meet that objective, EPSCoR catalyzed the creation of two programs at UD and DSU.

UD Center for Science, Ethics and Public Policy www.sepp.udel.edu



Center for Science, Ethics & Public Policy

The purpose of SEPP is to integrate ethics and public policy inquiry with scientific research, the university curricula, private sector innovation, and government policy making. SEPP activities cover three main areas:

• Lectures and discussions around ethical issues of high social interest and educational events for undergraduate and graduate students on research integrity

- Interdisciplinary collaboration and publication on ethical and public policy issues that emerge from science and technology
- Supporting clear scientific input in debates on issues of social concern and engaging the private sector and public interest groups, in partnership with academic researchers, to address those concerns.

The Ethics Resource Site at DSU www.desu.edu/research/ ethics-resource-site

The Ethics Resource Site serves as a repository of expertise in ethical theory and in applied ethics in areas that include environmental ethics, bioethics, ethics in technology, and business ethics. The program sponsors public lectures, forums, and panel discussions to raise community awareness of social issues that impact our daily lives and the ethical concerns and concepts that are inherent in such issues.

The Ethics Resource Site also offers seminars and courses on ethical issues relevant to faculty and students from EPSCoR partner institutions. In addition, training and educational opportunities are offered for employees of governmental agencies and business enterprises and members of professional associations.



Stephen Taylor, director of The Ethics Resource Site at DSU, organizes the annual Q.E.D. Natural Science Symposia. Along with the Science Café series hosted by SEPP, these informal public discussions with scientists and engineers about topics with ethical implications help improve public understanding of and engagement in science.

Ethics in the Classroom

In 2008, SEPP launched RAISE (Research and Integrity in Science and Engineering), a novel ethics education project for graduate students in science and engineering. RAISE is designed to increase student awareness of research ethics through small-group discussions on a range of issues, including the falsification of experimental results, plagiarism, conflicts of interest in industryfunded research, improper attribution of authorship, and the vulnerability of junior researchers in reporting misconduct.

Economic Development

Turning Discovery into Opportunity

UD marine scientist Adam Marsh launched the company Evozym, focused on protein identification. A major goal of the Delaware EPSCoR program A is to contribute to the state's economy by attracting a broad range of students to science and technology careers and by catalyzing the development of advanced technology-based businesses and new jobs. EPSCoR's emphasis on forging collaborations with government agencies, industry, and nonprofit organizations is one way the program makes an impact on the state's economy.





Office of Economic Innovation and Partnerships www.udel.edu/oeip

Since its formation in 2008, OEIP has established an "entrepreneurial ecosystem" at UD that serves as a support system for students, faculty, and researchers and encourages interdisciplinary collaboration to grow new business ideas.

OEIP works with the university community to turn research discoveries into meaningful inventions. Its Technology Transfer Center helps protect intellectual property and assists with licensing, commercialization, and growth of new enterprises.

OEIP has worked with the state, Delaware Technology Park, numerous researchers, and companies in creating a culture where innovation and entrepreneurship can thrive in Delaware. With part of its focus on discovering inventions, OEIP helps EPSCoR researchers and others develop and market intellectual property and build those assets into businesses.

During the five-year grant period, EPSCoR researchers were awarded six patents, and 35 others are pending. OEIP also assisted DSU with its firstever licensing of technology, in the area of fiber optics.

By empowering small business owners and assisting researchers in creating their own start-up companies, OEIP is helping to put people to work in Delaware. Three companies, launched through OEIP with EPSCoR's start-up assistance since 2008, are now thriving.



Discoveries in Biofuels, Drug Development

One of those companies is Evozym Biologics Inc., the brainchild of Adam Marsh, associate professor of marine biosciences at UD, and Joseph Grzymski, assistant research professor at the Desert Research Institute in Reno, Nevada.

The two first met in Antarctica while researching organisms that thrive in harsh environments. Both scientists were fascinated by how organismal genomes become adapted to life in such difficult, stressful conditions. A key to the process, Marsh said, is understanding how specific proteins are shaped by evolution, by how well they fit into their environment. With their computational platform of highthroughput computers and patented algorithms and databases, Evozym Biologics can quickly zero in on genes that code for specific proteins of interest to scientists. For example, in the biofuels realm, a company might spend a million dollars or more on a more shot-in-the-dark research approach to identify proteins that help catalyze certain biochemical reactions, such as breaking down the cellulose in plant material more easily. Evozym technology allows researchers to quickly focus their search on a suite of genes that contains the most likely candidates.

In the drug development arena, the company's role is to pinpoint a pathogen's most critical, sensitive genes—so that pharmaceutical companies can create drugs to knock them out. LEFT: The team that launched PAIR Technologies includes (left to right) Dan Frost, Scott Jones, Bruce Chase, and John Rabolt.

"Multi-drug-resistant pathogens are a serious issue, causing staph infections, skin infections, and other problems in hospitals and nursing homes," Marsh noted. "While one drug can target a single protein, a gene often can mutate and bypass that drug's effect. But if you could target three to four protein interactions with one drug, you could build a whole new class of antibiotics."

Revolutionary Technology Has Environmental, Military Applications

PAIR Technologies, a start-up company established by UD researchers and a former DuPont scientist, has commercialized a high-precision detector that can identify biological and chemical agents in solids, liquids, and gases, present at low levels, and in less than a second.

The revolutionary technology—a planar array infrared spectrograph—holds promise in multiple applications, ranging from the early detection of diseases, to monitoring for chemical weapons and environmental pollutants, to enhancing qualitycontrol efforts in manufacturing processes.

"Most technology has about a 30-year cycle. Then something comes along to disrupt it, change it," said company co-founder John Rabolt, the Karl W. and Renate Böer Professor of Materials Science and Engineering at UD. "We think we have that nextgeneration technology."

The company has been steadily developing with federal, state, and university support. For example, OEIP and its Small Business Development Center have provided the company with a variety of help and services, from intellectual property protection to marketing assistance.

Driving Workforce Development

Delaware Tech received a grant from the U.S. Department of Labor in 2012 to establish the Center for Industry Research and Workforce Alignment (CIRWA). In close partnership with local businesses, government, and academia, CIRWA delivers future-focused labor market data. The information enables educational institutions to make proactive and flexible decisions in response to the workforce needs of Delaware's competitive industries.

CIRWA aims to identify change within an industry and assess the impact on educational programs and the available workforce within the region. CIRWA will expand the state's capacity to foresee labor market changes and niche opportunities, enabling it to make strategic decisions in economic development and workforce education, ahead of the curve.

Delaware's traditional industries are changing dramatically due to improved technological advancements, new policies and mandates, and consumer demand for products that provide greater reliability and efficiency at more affordable prices. Through research and analysis of real-time industry trends and labor market data, CIRWA will enable education and training providers to

Veronica Buckwalter (center), director of CIRWA, and Steve Borleske, project consultant to CIRWA, meet with Carolyn Snyder, former director of the Division of Energy and Climate at DNREC, to discuss changes and emerging needs within Delaware's energy-related job market. quickly and effectively respond to the changing needs of Delaware's most competitive and highpriority industries. The results of CIRWA's research efforts will be used to drive educational programming, inform academia and government leaders of real-time developments within an industry, and ensure business leaders that Delaware is ready, willing, and able to produce a highlyskilled workforce to meet their changing needs.

Based on the successful California Centers of Excellence model, Delaware's CIRWA will have

the ability to bring to light new and emerging technologies, trends, and occupations not captured in traditional workforce research and data. CIRWA will capture regional nuances, supply and demand projections, barriers to hiring and employment, and skills gaps that training and work readiness programs should address.

CIRWA's website (www.dtcc.edu/cirwa) provides ongoing, public access to all of the center's labor market publications, events, and news updates as they become available.



14 Economic Development

The People Pipeline

Ust as laboratories need pipelines for water and natural gas, they also need a "pipeline" that provides a continuous supply of people able to conduct research there.

Making sure the people pipeline is full of well-trained individuals from its source in the elementary grades to its outlet in the academic and commercial laboratories of the world is one of the most important goals of Delaware EPSCoR. "Expanding the pool of students pursuing science, technology, engineering, and mathematics or STEM fields—is a matter of national importance," says Jeanette Miller, director of education, outreach, and diversity for Delaware EPSCoR. "The cornerstone of EPSCoR is building research capacity through infrastructure improvements, and that includes developing people as well as building facilities and buying equipment." By linking the four institutions of higher education in Delaware that offer science degrees, increasing student and instructor awareness of scholarship and internship opportunities, facilitating research collaborations across institutions, and funding research that supports student development, EPSCoR plays an important role in stimulating students to pursue degrees and careers in STEM fields.

"Thanks to EPSCoR, we all have much better knowledge about what opportunities exist at each of our institutions and can direct students accordingly," said Venu Kalavacharla, associate professor of plant molecular genetics and genomics at DSU and a member of the Delaware EPSCoR leadership team. "We can provide both the financial and personal support that aspiring scientists often need to persevere."

Mollee Crampton, a native of Kent County, Delaware, has traveled EPSCoR's people pipeline in pursuit of a career in science. She began her higher education journey at DTCC, where she completed an associate degree in biotechnology. She continued on to DSU, where she participated in a summer internship program and EPSCoR-sponsored undergraduate research on her way to a bachelor's degree in biology. She has now completed her master's degree in molecular biology and genetics at UD.



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Education & Outreach

Partnering for Policy

During the five-year grant period, Delaware EPSCoR developed close ties with Delaware's Department of Natural Resources and Environmental Control (DNREC). This effort has resulted in multiple mutually beneficial partnerships and programs that have enhanced the effectiveness of both organizations.

DNREC Secretary Collin O'Mara serves as chair of the state EPSCoR steering committee, while deputy secretary David Small is a member of DENIN's external advisory board. EPSCoR education director Jeanette Miller serves on DNREC's Climate Change Vulnerability Assessment Steering Committee. These appointments help ensure that Delaware EPSCoR activities are serving state needs, while increasing policy makers' knowledge of resources available at Delaware's institutions of higher education.

In 2010, Delaware EPSCoR initiated the EcoCafé program, designed to bring DNREC personnel and EPSCoR researchers together in an informal setting for breakfast, networking, and a presentation on a topic of common interest.

The following year, EPSCoR and DNREC launched a joint internship program, designed to provide real-world policy-making experience to advanced undergraduate and graduate students with environmental interests. DNREC staff identified projects and mentors for the interns, while DENIN staff recruited qualified students, and the Delaware EPSCoR program provided funding. At the end of their internships, interns present written and oral reports of their work to DNREC's senior managers, including Secretary O'Mara.

Tom Battagliese was one of the first two interns in the joint program. His work analyzing Delaware's outdated oil spill liability policies was the catalyst for new legislation that passed both houses of the Delaware General Assembly and was signed into law by Governor Jack Markell during the spring of 2013. House Bill 32, as it was known, eliminated oil spill liability limits that were inadequate to cover the potential costs of cleaning up catastrophic spills in the Delaware River and Bay, one of the busiest petroleum shipping routes in the nation, thus protecting both Delaware's taxpayers and our fragile coastal ecosystem.

EPSCoR research continues to address state needs, providing the data and tools policy makers need to make sound environmental decisions. Prime examples of this applied research include the development of a web-based coastal flood monitoring and warning system and research on the potential impact of offshore wind turbines and oil drilling platforms on Delaware beach tourism.



Delaware's biosolid waste management policies.

RIGHT: DNREC intern

Sarah Taylor worked

Churchill to evaluate

with mentor Brian

Delaware EPSCoR reaches out to work with other agencies, businesses, and organizations across the state and in the nearby region. Here is a sampling of our regional research and education partners during the past five years:

- Brandywine Conservancy
- Brookhaven National Laboratory
- Canadian Light Source
- Chesapeake Bay Foundation
- China Agricultural University
- Christina Conservancy
- City of Dover
- Delaware Bar Association
- Delaware Emergency Management Agency
- Delaware First Media
- Delaware Humanities Forum
- Delaware National Estuarine Research Reserve
- Delaware Nature Conservancy
- Delaware Nature Society
- Delaware Sustainable Chemistry Association
- Delaware Wild Lands
- DuPont Company
- Institute for Urban Environment, Chinese Academy of Sciences
- Institute of Soil Science, Chinese Academy of Sciences
- Johns Hopkins Bloomberg School of Public Health
- Sassafrass River Association
- Stanford Synchrotron Radiation Light Source
- Stroud Water Research Center







The Delaware Environmental Institute (DENIN) has hosted a series of joint workshops with DNREC, known as EcoCafés. Here DNREC Secretary Collin O'Mara explains his priorities for protecting Delaware's environment.



Learning by Doing

ectures, textbooks, and laboratory exercises are all important parts of a scientist's education. But a research internship, in which a student fully experiences the process of scientific inquiry under the guidance of a faculty mentor, is often the deciding factor in whether or not a student will pursue an advanced degree or a career in research. Delaware EPSCoR is instrumental in giving undergraduates valuable experience and opportunities to explore potential career tracks.

Each summer, Delaware EPSCoR sponsors 30–40 undergraduate interns from UD, DSU, DTCC, and Wesley in a 10-week program of supervised, environmentally focused research. Thirty percent of these students are from groups typically underrepresented in science and engineering. Interns work on a specific research problem while developing the skills they need to work individually and as part of a team. With help from their faculty mentors, many of whom are engaged in EPSCoR-sponsored research, interns learn to apply the scientific method to their problem or question—designing an experiment, gathering and analyzing data, and drawing conclusions.

DSU also hosts a nine-week summer Research Experience for Undergraduates (REU) program supported by NSF that introduces students to state-of-the-art techniques in molecular biology and genomics. REU participants work closely with other students and research mentors from DSU, DTCC, Wesley, and the Delaware Biotechnology Institute. They also have opportunities to interact with researchers in government and industry.

Participants in both of these programs take part in skill-building seminars on such topics as graduate school, research ethics, and how to make a research presentation. All interns are required to present their work at student research symposia sponsored by UD and DSU at the end of the summer. Some have become authors of published scientific papers.

"For most students, a summer research internship is an exploratory experience. It's a chance to think about whether research is something they want to pursue in the future and how their own skills and interests might fit into that arena," said EPSCoR education director Jeanette Miller. "We are proud of the academic success of our students. They are tenacious! More than half go on to advanced degree programs."



LEFT AND ABOVE RIGHT: Each year, EPSCoR's summer research interns gather at the Delaware Nature Society's DuPont Environmental Education Center in Wilmington for a daylong retreat. Fun, community-building activities are included along with sessions on career and graduate school planning, communication, and other topics.

Public Engagement

Delaware EPSCoR recognizes the vital importance of a scientifically engaged and literate citizenry. To this end, we sponsor numerous public events throughout the year designed to involve the public in learning and discussion related to science, engineering, policy, and the environment.

Our highest profile event is the DENIN Dialogue Lecture Series, which has featured internationally renowned speakers such as Rajendra Pachauri, head of the Intergovernmental Panel on Climate Change; Daniel Hillel, winner of the 2012 World Food Prize; and Terry Tempest Williams, environmental author and activist.

Other events include seminars, research symposia, panel discussions, film screenings, field trips, Science Cafés, and appearances at educational fairs around the state that reach thousands of citizens each year.

Educating the Educators

Each summer, Delaware EPSCoR hosted Delaware secondary teachers for a multiday training workshop designed to introduce handson classroom activities and bring teachers the latest scientific information in fields related to EPSCoR's mission, including biotechnology, environmental and climate science, and renewable energy.



Rajendra Pachauri, head of the IPCC, lectures on climate change as part of the DENIN Dialogue Series.

"It was a refreshing and informative workshop filled with content that I will be able to use in my classroom and share with colleagues."

- Quote from teacher evaluation form

Over the course of these workshops, the participants hear directly from EPSCoR researchers and representatives of government and industry, who present their work and provide resources for teachers to use to introduce concepts in the classroom.



McKay Jenkins, Cornelius Tilghman Professor of English and co-director of UD's environmental humanities program, interviews environmental writer Terry Tempest Williams on stage at Mitchell Hall as part of the DENIN Dialogue Series. Her appearance was supported in part by the Delaware Humanities Forum.



K-12 teachers from around the state of Delaware participate in a summer teacher training program led by EPSCoR's Bill Hall



Water Science and Policy Graduate Program www.udel.edu/watersciencepolicy

The world's human population surpassed 7 billion in 2012 and is expected to top 9 billion before 2050. Of all the burdens this growing population places on the planet's resources, none is more critical than the pressure on the world's fresh water supplies.

Meeting the need for clean water requires solutions that are socially acceptable, economically viable, and environmentally sustainable. Developing those solutions is the focus of a new interdisciplinary graduate program in water science and policy at UD.

Delaware EPSCoR, through the Delaware Environmental Institute (DENIN), was instrumental in the program's development. DENIN staff helped to coordinate the diverse group of interested faculty and navigate the approval process for the program.

Launched in 2011, the program offers a master of science degree and doctoral degrees with either a water science or a water policy concentration. It involves more than 30 faculty members in four of UD's seven colleges. The program is housed in

Students in the interdisciplinary water science and policy graduate program engage in a combination of field, laboratory, and policy research focused on maintaining the quality and quantity of water resources around the world. UD's College of Agriculture and Natural Resources and directed by Shreeram Inamdar, professor of watershed hydrology. Beginning in fall 2013, DENIN will also support two students in the program with two-year fellowships.

"We have a top-notch cadre of faculty representing many disciplines, including hydrology, geology, geography, ecology, climatology, microbiology, plant and soil sciences, environmental chemistry, engineering, resource economics, and public policy," Inamdar said. "We may approach the problem of water from different perspectives, but we share a common goal of understanding, protecting, and managing our precious water resources. The beauty of this program is it provides students greater flexibility in shaping their curriculum and greater opportunities to collaborate with faculty from diverse disciplines and departments."

Program leaders expect great demand for clean water in the coming century. Accordingly, they also expect strong demand for the program's graduates, who will be prepared for careers in academia, government, and nongovernmental agencies.



S ince Delaware's designation as an EPSCoR jurisdiction in 2003, the NSF EPSCoR program has resulted in \$46 million in direct EPSCoR funding to the state—including our most recent RII award of \$20 million, which will continue until 2018. These funds have been leveraged to generate an additional \$68 million and 129 additional research awards to EPSCoR faculty as of August 31, 2013. The additional awards include \$4.3 million for an NSF Critical Zone Observatory and \$5.2 million for 12 faculty CAREER awards co-funded by NSF EPSCoR. Other federal EPSCoR agencies (NASA, DOE, DOD, EPA) have awarded \$10 million to Delaware. The state of Delaware has also contributed \$8.8 million, and has commited another \$3.2 million over the next four years to the program. Delaware EPSCoR has awarded 43 seed grants to its participants and supported six core instrumentation centers through equipment purchases, fee waivers, maintenance, and staffing.



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